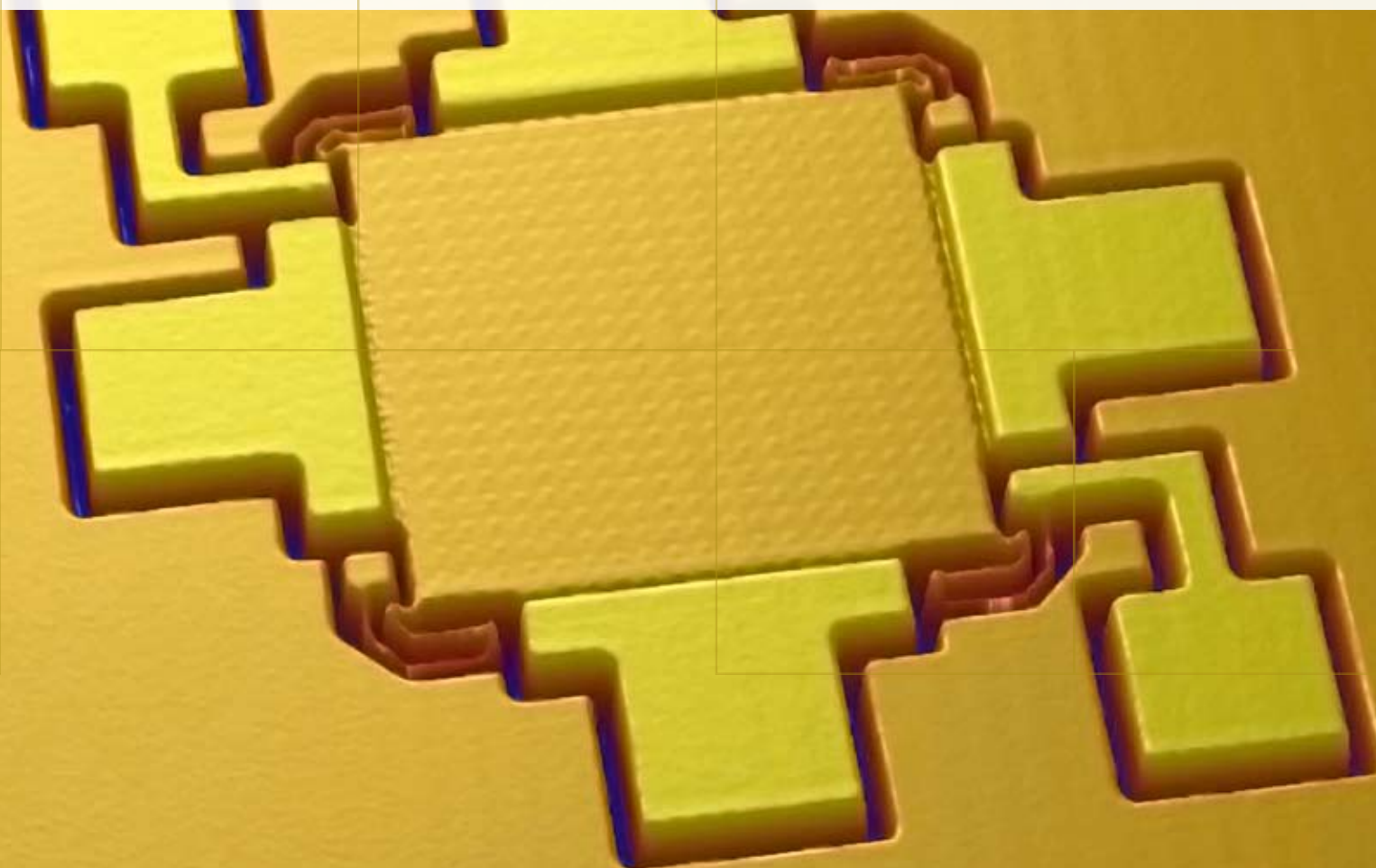


December 2005

MINUT – Microsystems for Industrial Nordic economic growth

Nordic innovation based on Microsystems

- **Breakthrough technology: Numerous possible applications for Microsystems**
- **Easy access between research centres, technology suppliers and companies = Large potential for synergy and strong industrial acceleration**
- **Nordic MEMS – status and possibilities – Update 2005**



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Title: Nordic innovation based on Microsystems		
Project name and number: 03101 MINUT – Microsystems for Industrial Nordic economic growth		
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Abstract: Microsystems, or small, functional components, will be the key components in systems realizing “the instrumentation society” we are entering during the next 5-10 years. There are numerous possible applications for microsystems. As a breakthrough technology, allowing unparalleled synergy between previously unrelated fields such as biology and microelectronics, many new microsystems applications will emerge, expanding beyond those that are currently identified or known. A Nordic project, MINUT, has been carried out in 2004 and 2005 to demonstrate the innovation potential for the Nordic industry and create better synergy between national actors within all Nordic countries. The project goals have been to stimulate collaboration, create synergies among Nordic microsystem technology (MST) performers, and accelerate the industrial take-up of MST in the Nordic countries. The basic idea is that there is large potential and strong industrial acceleration when ease of access is established among research centres, technology suppliers, and companies across the borders of the Nordic countries. Establishment of a common Nordic competence area within MST therefore is vital for future innovation. From the Awareness phase up to the Feasibility projects run within this project it is shown that this type of initiative is really needed at the Nordic level and has to be further sustained.		
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Executive summary

Main objectives

Main objectives for the project have been to:

- 1. Demonstrate the innovation potential of microsystem technology (MST) by showing how the technology creates business opportunities for companies and identify the radical impact MST has for the Nordic society in the future.**

Output: The 16 turbo-projects completed demonstrate the innovation potential for microsystems. The companies behind these cases prove that business opportunities exist. Some of the cases illustrate the radical impact MST will have for the society in the future.

- 2. Create synergy between national MST research organisations including the national micro- and nano- laboratories.**

Output: The project partners have demonstrated their capabilities by including each other in the ‘turbo’ and ‘feasibility’ projects. The effect of the work carried out in these projects clearly shows the added value effect of combining a broader knowledge base to the cases. As a result of this, the cooperation between the partners are much closer at the end of the project than before.

- 3. Build and strengthen the common Nordic knowledge market & network**

Output: 7 companies or institutes outside the core project have been involved in either the ‘turbo’ or the ‘feasibility’ projects at their own cost and resources. Around 230 people from more than 100 companies and organisations¹ have been present at the six awareness seminars set up by MINUT. This includes both potential users of MST and people representing the Nordic knowledge base within the field. An important development for the project is the new Nordic initiative on commercialising micro- and nanotechnology launched by NICe in December 2005². This call is very much in line with the experiences and recommendations from MINUT.

Success criteria’s for the project were established. 20 Nordic companies should run a ‘turbo’ project and 4 of them continue with a ‘feasibility’ study as the second step towards a final product development. At the end 16 companies have completed a ‘turbo’ and 5 of these cases have gone further with a ‘feasibility’ project. The missing 4 ‘turbo’ projects are explained by difficulties to be attractive for Finnish companies due to more attractive national funding.

Overall, the project has turned out to be a success. All objectives are met and the success criteria’s are fulfilled.

¹ Research institutes, Universities, organisations, etc.

² <http://www.nordicinnovation.net/mint>

Method/implementation

The project has been implemented through three different phases; awareness, turbo and feasibility, ending up with a basis for new and innovative products based on MST.

The work carried out in all ‘turbo’ and ‘feasibility’ projects has been based on existing competence and sensor solutions looking at the possibilities of implementing the technology into new products or process. One intention with MINUT has been to create an application pull complementing the technology push within the field.

The three phases in the “MINUT-funnel” have been:

1. Awareness

Nordic industry and organisations have been stimulated to look at implementations of and business opportunities for MST in their new or existing products or services. Through this awareness, a Nordic knowledge network also is established

2. ‘Turbo’ projects

Companies made curious about MST and the business opportunities enter into the second phase by conducting a ‘turbo’ project clarifying the new possibilities with MST for their products.

3. ‘Feasibility’ studies

The most promising ‘turbo’s have been brought one step further to a final product implementation by answering key questions about technology, manufacturing, possibilities, patents, demonstrators, etc.

The first two phases have been run in parallel focusing most on the awareness in the beginning and closing the ‘turbo’s in the end. Phase 3, ‘feasibility’, has been run in parallel with phase 2 during the last period of the project, and all cases have been a further development of the initial ‘turbo’.

The method has proven its capability by being an efficient way to take-up a new technology in potential new or existing products.

Results and conclusions

Important results and conclusions from the project are:

- The project has proved that microsystems, or small, functional components, will be key components in future products and add value both to the products and services offered by Nordic companies.
- There are numerous possible applications for microsystems within the Nordic industry. As a breakthrough technology, allowing unparalleled synergy between

previously unrelated fields such as biology and microelectronics, many new microsystems applications will emerge, expanding beyond those that are currently identified or known.

- MINUT has been the first step towards a common Nordic competence platform of microsystem technologies and has proven that this platform will give Nordic companies access to design and production competence at a leading international level.
- There is large potential for synergy and strong industrial acceleration when easy access is established between research centres, technology suppliers and companies across the borders of the Nordic countries. Existing companies need a push to get into this new technology and discover the innovation potential it represents for their future products.
- An important task will be to facilitate and support the industrialization of MST within new innovative companies. For start-up companies, it is crucial to get access to highly qualified technology support without adding too much cost to the start-up phase. The MINUT methodology has proven its capability for such companies, clearly seen in many of the ‘turbo’ projects performed.

Recommendations

The MINUT project method has proven itself an efficient way to take-up a new technology in new or existing products. This approach could be used in other projects where the potential of new technologies in future new Nordic products should be investigated.

The MINUT project method implies:

- o Efficient pooling of the knowledge from Nordic institutes
- o Appointing potential projects by awareness and direct contacts
- o Performing an overall qualification of the project idea and its fit to microsystem technologies (‘turbo’ projects)
- o Performing a predevelopment and proof-of-concept study (‘feasibility’ studies)

The MINUT partners welcome the new initiative taken by the Nordic Innovation Centre that attacks the problematic of commercialising micro- and nanotechnologies. New projects should build upon the established Nordic competence platform on microsystem technologies and focus on its use in specific applications fields where Nordic countries have strong business environments. Such applications fields could be:

- o Biomedical and other applications within the health sector
- o Instrumentation applications within the process industry (paper, oil & gas, pharmacy, ...)
- o Automobile and aerospace

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1 Summary

This report presents the results for the project period 2004-01-01 to 2005-12-31.

1.1 Background and problem description

Microsystems, or small, functional components, will be the key components in systems realizing “the instrumentation society” we are entering during the next 5-10 years.

There are numerous possible applications for microsystems. As a breakthrough technology, allowing unparalleled synergy between previously unrelated fields such as biology and microelectronics, many new microsystem applications will emerge, expanding beyond those that are currently identified or known.

Microsystems will have a value adding effect for most industries, and have influence on many industry processes and services.

There is large potential for synergy and strong industrial acceleration when easy access is established between research centres, technology suppliers and companies across the borders of the Nordic countries.

In all Nordic countries large investments in laboratories for microsystem technologies have been made during the last 5 years. It is a common Nordic challenge to take advantage of these investments in other industry sectors than the electronics industry.

Background information is provided in the updated report “Nordic MEMS – status and possibilities – Update 2005”. This report is available as Appendix 1, but will also be available at www.ittf.no/annet/minut.

1.2 Main project objectives

Main objectives in the project have been to:

- a. Demonstrate the innovation potential of microtechnology (MST) by showing how the technology creates business opportunities for companies and identify the radical impact MST has for the Nordic society in the future.
- b. Create synergy between national MST research organisations including the national micro- and nano- laboratories.
- c. Build and strengthen the common Nordic knowledge market & network

Two success criteria for the project were established:

1. 20 Nordic companies should run a ‘turbo’ project within the project framework
2. 4 of these should go one step further by carrying out a ‘feasibility’ project as the second step towards a final product development.

1.3 Methodology

The project has been implemented through three different phases; awareness, turbo and feasibility, ending up with a basis for new and innovative products based on MST.

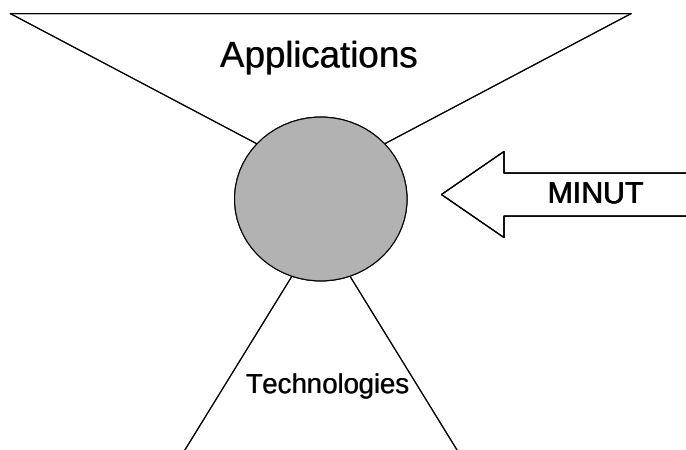


Figure 1 The MINUT project has focused on the point of intersection between technology and applications. The case studies have identified technologies and existing micro-sensors based on specifications for an application area.

The work carried out in all ‘turbo’ and ‘feasibility’ projects has been based on existing competence and sensor solutions looking at the possibilities of implementing the technology into new products or processes. One intention with MINUT has been to create an application pull complementing the technology push within the field.

The three phases in the “MINUT-funnel” have been:

1. Awareness

Nordic industry and organisations have been stimulated to look at implementations of and business opportunities for MST in their new or existing products or services. Through this awareness, a Nordic knowledge network also is established

2. ‘Turbo’ projects

Companies made curious about MST and the business opportunities enter into the second phase by conducting a ‘turbo’ project clarifying the new possibilities with MST for their products.

3. ‘Feasibility’ studies

The most promising ‘turbo’s have been brought one step further to a final product implementation by answering key questions about technology, manufacturing, possibilities, patents, demonstrators, etc.

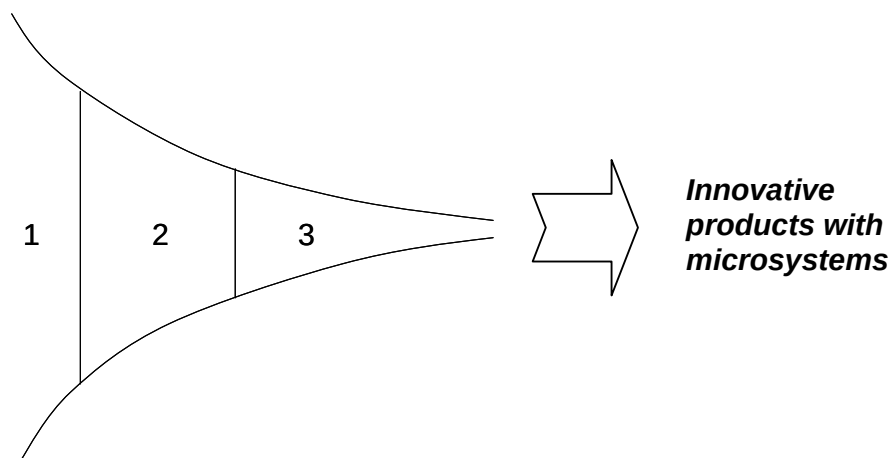


Figure 2 MINUT Methodology: Innovation based on MST using the "funnel". Phase 1: **Awareness**, phase 2: **Turbo** and phase 3: **Feasibility**

The first two phases have been run in parallel focusing most on the awareness in the beginning and closing the ‘turbo’s in the end. Phase 3, ‘feasibility’, has been run in parallel with phase 2 during the last period of the project, and all cases have been a further development of the initial ‘turbo’.

To succeed with the company cases, it is important that the companies have expectations for the outcome. By paying cash for the work done, and not only giving support by own man-hours, the companies get expectations for the outcome of the case and the relevance for their products. This mechanism has been proven with success in MINUT.

1.4 Conclusions

The project has:

1. Demonstrated the innovation potential of microsystems by showing how the technology creates business opportunities for 18 Nordic companies. New business opportunities are also identified for 2 Nordic MST-suppliers.
2. Created synergy effects between the partners as national research organisations within microsystem technologies. Through some of the MINUT-cases, the partners involved have carried out projects together demonstrating that the cases turned out more successfully by combining competence from the MINUT-partners. The national micro- and nano- laboratories are working more closely together as a result of the project, and all partners are aware of the strengths and capabilities in the “Nordic micro/nano laboratory”.
3. Build and strengthen the common Nordic knowledge market & network, by including more than 10 companies and research organisations in the turbo- and feasibility projects. The business opportunities for a possible application have been discussed with around 100 small and medium sized Nordic companies. Over 300 people from at least 150 companies and organisations have taken part in the awareness seminars.

The success criteria for the project are fulfilled through completing 16 turbo projects and 5 feasibility studies as the second step towards a final product development.

The method has proven its capability by being an efficient way to take-up a new technology in potential new or existing products.

The project has been a success, at least seen from the project partners.

Other reflections:

- Through the different cases the partners got a ‘real feeling’ of how a relative new technology is received by conventional / traditional industry
- The cases performed have identified some integration / perception issues and problems for MST as industrial technology
- Through the awareness some new sectors in business life where MST can add value and/or create new value have been identified
- The competence within MST and its potential in traditional industry is low

2 WP 1 – Awareness

The objective of this work package has been to establish the Nordic knowledge market in the microsystem technology field and to launch / market its potential. Further the project has spread knowledge to selected partners from Nordic industry. Industrial potential and Nordic industry niche set the basis for company selection.

Some of the activities carried out in this work package have been:

- Established contact with a large number of Nordic companies which can be interested in using microsystems in new or existing products.
- Carried out informative meetings for “technology providers” and researchers in order to create / establish synergy between ventures / organisations / support projects within the fields and lay the background for a unified Nordic knowledge market.
- Updated the report on the Nordic microsystem knowledge-market
- Strengthen the co-operation between members/participants by starting activities that connect them together.

The following sub-chapters present a status of this work. The activities in this work package are closely linked to the information strategy and activities in the project.

2.1 Awareness seminars

Seven successful seminars have been organised in all Nordic countries by the project partners (see Table 1), three in Finland, two in Sweden and one each in Denmark and Norway. More than 300 people from at least 100 different Nordic companies have taken part at the seminars.

The main objective with the seminars has been to distribute information about microsystems and their applications in general and about the MINUT project and the possibilities for Nordic companies within this project. The target group has been selected to be small and medium-sized enterprises, especially those with little prior background in practical microsystems. The companies invited were also based on a selection (mainly at Delta seminar) to increase the chance of a possible project opportunity. It was emphasized by the speakers that microsystems will emerge in a great variety of fields and into our everyday life. Almost any company can renew their product portfolio using miniaturized high-end systems by making use of existing microsystems networks, including MINUT. All seminars had fruitful discussions in the breaks and at the end. In addition to project partner presentations, practical industrial cases were introduced. Most of the seminars have been carried out in cooperation with other actors within microsystems in the Nordic countries. Examples

of such partners are the Finnish MicroNano Technology network³ and the Swedish project minST⁴.

Table 1 Awareness seminars carried out as part of the MINUT project.

Date	Location	Organiser	Statistics				
			# Industry	# University	# Research	# Others ⁵	# Participants
2004-06-08	Espoo (FIN)	VTT & FMNT	24	6	11	18	59
2004-06-16	Kongsberg (NO)	SINTEF & Kongsberg Innovasjon AS	18	1	2	4	25
2004-09-16	Göteborg (SE)	Imego AB	21	4	1	1	27
2004-09-21	Hørsholm (DK)	Delta	18	3	1	7	29
2004-10-11	Kuopio (FIN)	VTT & FMNT	15	13	5	21	51
2005-03-16	Vaasa (FIN)	VTT & FMNT	16	18	1	3	38
Total			112	45	21	54	229

A set of presentations used at the awareness-seminars (ppt-files)⁶ have been made. These presentations were combined with presentations from regional industry and university actors within MST at the seminars.

2.2 Other activities

2.2.1 SenseFood 2004

At 19 March 2004 an original, unique seminar covering micro technology's unprecedented opportunities within the food production & packaging industries and entire food chain were held at DTU, the Technical University of Denmark, outside Copenhagen. The seminar addressed the advantages and opportunities with micro technology in food packaging and processing, from concepts to good business.

The seminar presented and discussed a new platform for the future in these fields:

³ <http://www.fmnt.fi>

⁴ <http://www.minst.nu>

⁵ Consulting, Patenting, Innovation, Media, etc.

⁶ [http://www.ittf.no/annet/minut/awareness/1133968453/SINTEF Microsystems - from oil wells to in-vivo devices.pdf](http://www.ittf.no/annet/minut/awareness/1133968453/SINTEF_Microsystems_-_from_oil_wells_to_in-vivo_devices.pdf);
[http://www.ittf.no/annet/minut/awareness/1133968835/IMEGO From idea to product.pdf](http://www.ittf.no/annet/minut/awareness/1133968835/IMEGO_From_idea_to_product.pdf);
[http://www.ittf.no/annet/minut/awareness/1133968977/DELTA Microsensor product - from chip to manufacturing of medium volumes.pdf](http://www.ittf.no/annet/minut/awareness/1133968977/DELTA_Microsensor_product_-_from_chip_to_manufacturing_of_medium_volumes.pdf);
[http://www.ittf.no/annet/minut/awareness/1133969308/VTT What is a microsystem.pdf](http://www.ittf.no/annet/minut/awareness/1133969308/VTT_What_is_a_microsystem.pdf)

- Industrial food production
 - fresh packaged meat, poultry, fish
 - dairy products
 - juices, beverages
 - fresh fruits and vegetables
 - bakery products
 - dry packaged products
- Food processing, cooking and preparation
- Functional and speciality foods
- Frozen packaged foods
- Food packaging & bottling
- Transportation, distribution, retail
- Food inspection and quality control
- Allergy, infection & dietary health

Background and motivation

Substantial rewards are earned by developing new and challenging ideas into mature solutions and being first on the market. Right now, discovering which technologies will shape our future sustainable society in 5-10 years, or longer into the future, can generate wealth by delivering practical benefits.

It's vital to monitor the taste and quality of foods from production, handling, transportation, storage and retail sales through to the point of consumption to guarantee product safety. Recognized threats caused by any specific article must be thwarted by rapid tracking that will enable quick removal from the market and the distribution chain.

Soon, products will need to communicate better with consumers. Companies who want to keep their market shares and gain new territory can unleash fresh opportunities for growth and prosperity by researching, developing and rapidly implementing innovations. When micro sensor solutions are integrated into food packaging, tomorrow's consumer will feel safe and secure. These are feasible improvements that will enable firms to conquer monitoring challenges while adding value to their brand names and strengthening their trademark.

The seminar was organized by IMEGO, SIK⁷ and ØFN⁸. A Swedish national research institute, IMEGO works with innovations in micro and nano technology. SIK has amassed extensive experience in food research. In agriculture and the food industry, ØFN steers and promotes dynamic development, research and education among the universities, industrial sectors and individual businesses in the region.

The attendees at the seminar were given an introduction to micro technology and micro sensors. Further challenges that the food production and packaging industries can overcome by developing intelligent solutions for handling increased safety and

⁷ SIK, the Swedish Institute for Food and Biotechnology, www.sik.se

⁸ ØFN, the Øresund Food Network, www.oresundfood.org

quality were highlighted. The seminar constituted a platform for innovation and development of concepts that can be expected, quite soon, to become applied commercial procedures.

Micro sensors for food quality

At present, there is a growing demand to control different aspects of the food quality both from the consumer's side as well as from the aspect of legislative and political authorities. This demand advances the necessity to trace and sense the quality of the entire food production chain starting from the agricultural product, continuing through the process of food production and packaging and ending at the consumer's table. By applying recent technological achievements, it may be possible to satisfy safety requirements, decrease food waste and introduce new products on the market. The presentation at this topic gave a brief and broad outline of the possibilities that new advancements in micro technologies and (micro) sensing open up with regard to food quality through process control and food packaging. A few technological challenges that need to be overcome in commercial applications of a food quality control system were discussed and possible solutions were presented.

Example

Control of the temperature of chilled or frozen products are of great interest for all involved in the distribution chain. The Swedish company Bioett AB⁹ has developed a transparent control system to be used from production site to retailer. The system consists of self adhesive RF-tags, which are attached to the master carton. The tags are scanned by a detector at critical sites along the cold chain and the information obtained reveals breaks in the cold chain. The system has been developed and tested during 2003 in close cooperation with customers, and is launched in commercial flows in 2004.

The system enables an operator to conduct live checks on the integrity of a temperature controlled supply chain from source to each critical point along the way to the end destination. The information confirms how well the supply chain is operating and brings the management onto a new level of expertise that will benefit the whole chain, from brand owner through to the consumer.

The time temperature biosensor (TTB) is activated at source and is printed with a unique barcode for traceability. The label will also alert operator staff that the case is monitored to ensure extra attention in the handling process. A handheld scanner that reads both the signal value of the TTB and the ID in the barcode, inform the operator of the status of the product. The information is stored in a memory and can later be sent to the database via the Internet.

⁹ www.bioett.com

2.2.2 Microsystems in Sweden – status and possibilities

minST, expert competence small functional components, is a Swedish initiative by KK-stiftelsen to promote MST to Swedish SME's and transfer competence from the institutes and Universities to the companies. Imego is together with Acrea the institute partners in the project.

On January 26, 2005, Uppsala University put together a workshop presenting the initiative and the technology and its applications. Both Imego and SINTEF contributed to the agenda, presenting examples from their activities and the possibilities within MINUT. More than 80 people took part at the seminar, around 40 of them representing Swedish companies.

More information: <http://www.minst.nu/>

2.2.3 ‘Small detectives’ – Danish conference

Both Delta and Imego were involved in a conference including an exhibition in Århus, Denmark, June 9 2005. The one day conference was organised by Innovation Lab and was an introduction into the field of MEMS and particularly sensor technology in Denmark. The participants were meant to be mainly decision makers from Danish companies, minor and major. The point was to educate the market and explain to these budget holders the perspectives of MEMS/sensor technology; in order to help disseminate the rich perspectives of microtechnology and the very idea of adding value to producers by adding features and “senses” to products.

More information: <http://www.innovationlab.net/sw6938.asp>

2.2.4 Workshop Bio MEMS (FIN)

VTT contributed to a regional seminar on BioMEMS in Kuopio, Finland, November 22, 2005. The seminar was organised by Savonia and the FMNT-network.

2.2.5 Foresight Biomedical Sensors - FOBIS

MINUT initiated a proposal to NICE for a foresight study in November 2004. The proposal was accepted and the FOBIS project was started during the spring 2005. A Nordic consortium headed by SINTEF (Norway) and with the participants VTT (Finland), FOI (Sweden), S-SENCE (Sweden), STC (Denmark) and MedCoast-Scandinavia is conducting a foresight study on Biomedical Sensors.

Questions the groups try to answer are:

- How will biomedical sensors shape the healthcare systems of the future?
- How can they impact the quality and cost of healthcare?
- What are the business opportunities in the Nordic region?

The project revolves around a series of workshops, the first was held in Copenhagen 6-7th October, the second in Oslo, 2nd November. More information is found on the web-site: www.nordic-fobis.net.

2.3 Marketing and publications

As part of the information strategy, some general marketing material is published from the project and used for marketing of the project activities at meetings, visits to companies, at seminar and workshops, and other related events.

This is the material developed:

- MINUT web ¹⁰
- MINUT press release ¹¹ (February 2004 / December 2005)
- MINUT presentation ¹²
- MINUT handout (in Norwegian) ¹³
- MINUT brochure ¹⁴ (also made in a Finnish version)
- MINUT paper ¹⁵ (given at the Micro Structure Workshop 2004 in Ystad¹⁶)

In addition to this, a lot of publications have been made directly or indirectly as a result of the project. The most relevant publications are listed in Appendix 3 Marketing and publications in the categories paper, presentation, article and “in the news” (written by others).

¹⁰ Project web: www.ittf.no/annet/minut

¹¹ Available at http://www.ittf.no/annet/minut/1103111148/MINUT_Press_release_UK_and_NO_.pdf

¹² Available at http://www.ittf.no/annet/minut/1103108686/MINUT_presentation.pdf

¹³ Available at http://www.ittf.no/annet/minut/Turbo/1087567488/MINUT_-_handouts.pdf

¹⁴ Available at http://www.ittf.no/annet/minut/1098962563/Minut_brochure.pdf

¹⁵ Available at http://www.ittf.no/annet/minut/1103109195/MINUT_paper_MSW04_Ystad.pdf

¹⁶ Micro Structure Workshop 2004, <http://www.elmat.lth.se/msw04/>

Examples of articles and “in the news” publications is shown below.



Figure 3 Article and front cover in the Danish magazine “Elektronik & Data” nr. 9/2004 (left). Segments of an article in the Norwegian magazine “Elektronikk” 2/2004 (right)

RF MEMS – Neste generasjons teknologi for elektroniske systemer

Prosessering og pakking

Framstilling av MEMS benytter seg av de velkjente og modne teknologiene som brukes i mikroelektronikkindustrien, med tillegg av spesialprosesser innen mikromaskinering. RF MEMS har potensial til å revolusjonere de elektromagnetiske egenskapene til høyfrekvente elektroniske kretser.

Av Anton M. Bøffot,
Geir Ulf Jansen og Ulfrik Hanka
SINTEF IKT

MEMS er et akronym for Micro-ElectroMechanical Systems, men det har blitt vanlig å bruke begrepet om alle typer komponenter og systemer som baserer seg på mikromaskinering, også når helt andre prinsipper for energiomvandling enn det elektro-mekaniske benyttes. Andre betegnelser på det samme er mikrosystemer med tilhørende mikrosystemteknologi. De siste 10-15 år har MEMS gjennomgått en rivende

utvikling og teknologisk modning. MEMS er tatt i bruk i en rekke anvendelsesområder, som telekommunikasjon, bilindustri, medisin, bioteknologi, industriproduksjon, luftfart og astronomi. Fordelene ved å bruke MEMS varierer fra en applikasjon til den neste, og inkluderer ny funksjonalitet, bedre ytelse, miniaturisering, masseproduksjon, lav produksjonskost og bedre integrasjonsmuligheter med elektronikk. Kommerielle komponenter for RF- (Radio Frequency) og mikrobølge-/millimeterbølge-systemer har imidlertid latt vente på seg;

først i løpet av 2003/2004 har kommersielle RF MEMS sistjer sett dagens lys. RF MEMS åpner for helt andre dimensjoner når det gjelder elektromagnetiske egenskaper til RF-, mikrobølge- og millimeterbølgekreter.

FoU-miljøet ved SINTEF IKT følger RF MEMS utviklingen tett, bl.a. gjennom et fireåring prosjekt støttet av NFR og norske industriaktører. Prosjektet har tittelen «Integreert rekonfigurerbar radio front-end teknologi», og involverer SINTEFs mikrobølge- og MEMS-miljøer. SINTEFs nybygg i Gaustadbekkdalen i Oslo,

Vi starter nå opp en artikkelserie om RF MEMS. RF MEMS er komponenter som framstilles v.h.a. MEMS-teknologi og benyttes i frekvensområdene RF, mikrobølge og millimeterbølge. Først skal vi se på grunnleggende teknologiske aspekter som prosessering og pakking. Deretter følger vi opp med artikler om design og framstilling av enkeltkomponenter og bruk av dem i kretser og systemer.

MiNaLab, inneholder det ypperste av MEMS prosesseringsutstyr og vil benyttes i prosjektet til å utvikle RF MEMS komponenter som gjør det mulig for →

Figure 4 Segments of an article in the Norwegian magazine "Elektronikk" 1/2005

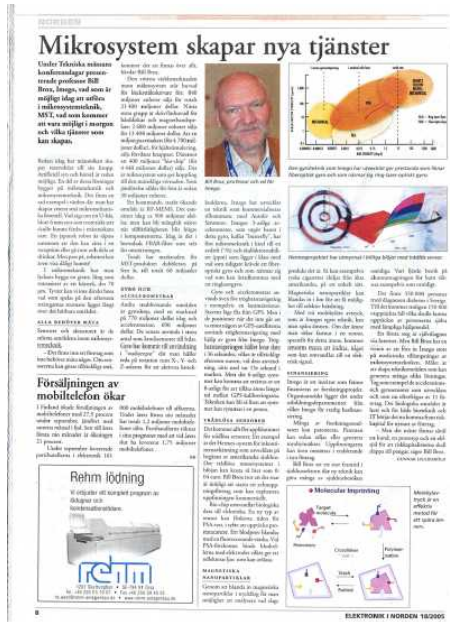


Figure 5 Article in “Elektronik i Norden” magazine nr. 18/2005

Robot's new arm

Being a Norwegian company that export robots to Japan, ABB as Robotics are quite extraordinary. Based in Norway, they are the world's leading manufacturer of painting robots for the car industry. This summer they have conducted a feasibility study on the use of micro sensors in their robots, through their participation in the MINUT-project. Celebrating their 40th anniversary this year, they keep up their lead in the technological forefront.

The ABB painting robot is primarily used in industries with high quality demands. Typical use is the application of two-component paint, and clear-coat, on automobile bodies. This requires a fast and accurate robot motion, and accurate control of the robot's spraying fan, both concerning its shape, amount of paint and accuracy in switching the spraying fan "on" and "off".

"Our challenge, and interest in joining the MINUT-project, was with flow and pressure sensors for robotics", Ole Kristian Brekken says. "These components are normally mounted on the robot's arms. These we wanted to improve." Brekken is head of the department for development at ABB as Robotics.

Size matters
"MINUT put us in contact with the Norwegian company MEMSCAP. They had developed a micro sensor for use in autopilots in airplanes. We made a few adjustments, and tested the concept in the feasibility studies, the results were promising", says Brekken. This is still an ongoing project, more work needs to be done before any predictions can be made about the possible potential in the market. Another issue is official approvals and bureaucracy; to introduce a new robot in a highly flammable industry environment is not done in a day. But

Brekken is positive about the initial test results. "Integrating a micro sensor in the robot means that we can reduce the weight of the robot's arms. This makes the robot faster, and more accurate. The whole robot can be scaled down."

"The cooperation with MINUT has been excellent all the way. This meant we could focus on development. By solving robotic tasks more cost efficient, we can potentially position ourselves better, and maybe take some more market shares", says Brekken. Their Norwegian contact SINTEF carried out an extensive pre-study, outlined possibilities and solutions for the robot system, and accommodated an easy trial of the technology involved.

Now ABB as Robotics need to work out a business case, and see if the project will be developed further. The next big thing might be a MEMS-robot. Coming to the car driving past you.



ABB, leading manufacturer of painting robots

Contact:
Ole Kristian Brekken
ole.brekken@abb.com

Figure 6 Article in NICE magazine INNOVATE 3-2005 describing the case for ABB AS Robotics, Bryne, Norway

3 WP 2 – Turbo

The objectives of this work package have been to demonstrate and clarify how microsystems can open new possibilities for the Nordic companies. This has been done by carrying out pre-projects, or ‘turbo’ projects, for Nordic companies.

The success criterion for this WP has been to carry out 20 ‘turbo’ projects during the project period.

The ‘turbo’ projects in fact are the first step of traditional feasibility studies to evaluate for the companies the use of microsystems in their existing and future products / services. The ‘turbo’ projects have maximum been financed 50% by MINUT, the size have been around 10-30 k€ and about 1-2 month of duration. The projects have been carried out in close co-operation with a project team within the companies.

The work carried out in each ‘turbo’ project has mainly been done by the institute responsible for this sub-project. The project outline was spread to the other partners and they have been asked to present their competence within the field addressed in the turbo and comment on the work to be done. The project leader for the turbo has then contacted each institute and asked for more details and discussed synergies. One of the chapters in the confidential report to the company presents the Nordic competence and summarizes the input from the other institutes. Some of the ‘turbo’ projects have also been presented and discussed at project meetings.

MINUT has in total been running 16 different ‘turbo’ projects within the project framework. The same amount of other potential cases has been discussed with other companies, but of different reasons, these concepts have not been brought into a ‘turbo’ under the MINUT umbrella. Especial, it has been difficult to get response from Finnish companies on ‘turbo’ projects within MINUT framework. The most probable explanation to this is the fact that Finnish companies have good access to national funding from TEKES¹⁷. This is the main reason for why the project has not met the success criterion of 20 ‘turbo’ project at the end. But the outcome of the studies carried out well describes the potential within different application areas.

3.1 Overview Turbo-projects

An overview of the 16 ‘turbo’ projects carried out in MINUT is listed in the table below.

¹⁷ Typical project support in Finland: TEKES (60%), VTT (20%), Industry (20%)

Table 2 Overview of ‘turbo’ projects in MINUT initiated in the first period of the project

No.	Company	Contact person	Other participants	Responsible partner	Project period
1	Eagle Ultrasound AS	Bjørn Angelsen	NTNU, dep. of Circulation and Medical Imaging	SINTEF	01.05. – 01.10.2004
2	ABB AS, Robotics	Jone Gjerde	Memscap AS	SINTEF	24.05. – 15.11.2004
3	Nera Research AS	Karl Martin Gjertsen		SINTEF	1.10.04 – 30.11.2005
4	Samba Sensors AB	Svante Höjer		Imego	01.05.04 – 31.01.2005
5	Flexit AB	Claes Ericsson		Imego	01.05. – 30.12.2004
6	Atlas Copco AB	Johan Wallgren		Imego	01.07. – 30.12.2004
7	Nammo Raufoss AS	Christian Johansen	FFI - the Norwegian Defence Research Establishment	SINTEF	01.09. – 15.12.2004
8	SNIPOS AS	Arve Gustavsen		SINTEF	01.09.04 – 1.10.05
9	Laerdal Medical AS	Jon Nysæther	Hök Instruments AB	SINTEF	01.11.04 – 30.11.05
10	Scana Steel Björneborg AB	Håkan Lundbäck	MEFOS Metallurgical Research AB	Imego	01.09.– 31.12.2004
11	Statchip ApS	Reza Sharifpour		Delta	01.03.05-15.08.05
12	Certo ApS	Rune Wetlesen		Delta	01.12.04 – 01.03.05
13	CM Hammar AB	Tor Christiansson		Imego	01.12.04 – 01.03.05
14	Norrøna AS	Anders Wien	SINTEF Health	SINTEF	1.9. – 1.12.2005
15	Electronic Board A/S	Liselotte Blaklev		Delta	01.06-01.09.05
16	Ortopediteknikk AS	Bjørn Sværen	SINTEF Health	SINTEF	1.11. – 30.11.2005

Each turbo-project has been set up with its own economy and deliverables, both to the company involved and to the MINUT project. Deliverables to the companies have mainly been a confidential report describing the potential with MST within the arena addressed by the company in the turbo. As deliverable to the MINUT-project, each turbo has written a public abstract to let others get an impression of the technology and possible application. The Nordic perspective is also addressed in each turbo, both by describing relevant competence within the MINUT partners and by addressing other Nordic actors with technology of relevance for the turbo. For some turbo's these actors have been directly involved in the work performed also.

To give other companies ideas for how MST could be used, the summary in the next chapter has been presented on the project web and in project presentations. The turbo's will be used as examples to stimulate the take-up of MST in the Nordic industry.

3.1.1 Summary of turbo-projects

Eagle Ultrasound AS develops technology for medical ultrasound imaging in the 10 - 100 MHz frequency range. Such imaging has several applications for studying the micro structure of tissue in tumors and vessel walls, and also for guidance of minimally invasive treatment. The turbo-project evaluates a transducer design for such applications.

The turbo project for ABB AS, Robotics evaluates the integration of MEMS based pressure and flow sensors in industrial robots. Such sensors are typically used for maintaining overpressure in hazardous environments and in flow measurements of both air and paint. Current solutions are based on conventional mechanical systems manufactured in-house.

Nera ASA develops and manufacture products based on microwave communication technologies. Such systems expand rapidly and RF-MEMS offers possibilities for better performance and reduced prize. Wideband radio links are suitable for inter satellite and personal communication systems. The turbo-project looks at different designs for RF-MEMS components for microwave-based systems.

Samba's optical pressure sensor is currently used for medical applications. New application areas, such as harsh environments (high temperature/pressure etc), are looked for in this turbo-project.

Flexit AB is a Swedish manufacturer and developer of advanced equipment for measuring all types of drill holes. Flexit needs an investigation on the possibilities of using MEMS based inertial sensors for accurate coordinate determination of drill holes.

Atlas Copco Tools AB has a large production of, for example, industrial screw drivers, which are used to mount together machine equipment. ACT has a need to increase their knowledge on the use of small and cheap inertial sensor systems through a turbo-project in MINUT.

To avoid accidents, ammunition should be equipped with a mechanism that prevents it from detonating before it is launched. The project will conceive and evaluate concepts for integration of an acceleration switch in ammunition for Nammo Raufoss AS. Researchers from FFI are also part of this turbo-project.

High end microphones have difficult to record and survive extreme sound pressure levels. An application niche for such microphones is chock wave and blasting/explosion recording with a need for a robust and repeatable microphone. The turbo project for SNIPOS AS aim at defining specifications and finding the design principles for such a microphone.

CO2 sensing in demanding applications, such as air quality control and medical diagnostics, remains a technological challenge. Existing solutions based on infrared spectroscopy have proven concept viability, but large scale industrial exploitation is hampered by problems related to reliability and cost. The turbo-project for Laerdal

Medical AS studies a medical application of such CO₂ sensors for non-invasive respiratory monitoring.

The turbo-project for Scana Steel AB evaluates possible physical principles and new non-contact measurement techniques in order to enhance measurement of shape and dimensions during production of large steel products.

The turbo project for the Danish start-up company Statchip ApS have been looking at the possibilities to develop a multi microsensor device (MMS) shaped as a cylindrical mouthpiece, which is the most important part of IPSM apparatus. The IPSM, Intelligent Personal SpiroMeter, is a handheld apparatus which should measure accurately (equal to or less than 3 %) the lung volume and function.

CERTO ApS, Denmark wishes to develop a miniaturised system based on an idea of being able to stimulate sacred nerves wirelessly by the means of one or more implanted transponders in combination with an external pulse generator placed on the patient.

The business concept for CM Hammar AB is to design, manufacture and market components for lifesaving at sea, lakes and other waters. Sensor systems to measure relative water pressure with the resolution of 10mm on a range of 10m have been studied.

The Introduction of Microsystems in clothing products is presently in an initial phase. Such products are often termed *SmartWear*. There are considerable research activity and novel commercial solutions, yet the clothing manufacturers have been reluctant to introduce *SmartWear* products in their assortment. For Norrøna AS, Norway, it is crucial that new technology is proven before it is introduced to their high end customers expecting top quality and reliability. The turbo-project has search for and identified technologies relevant for the *SmartWear* concept at Norrøna.

A Danish company Electronic Boards A/S has patented the idea of making an electronic Bingo-board. The function of the board should contain 3 x 27 windows, each containing a touch switch and a mechanism in witch the optical “look” of the window can be changed electronically. A foil containing the numbers of the 3 bingo-plates will be laminated on top of the electronic board. This turbo-project has studied possible optical and touch sensors for the application.

The last turbo carried out in MINUT, has been looking at technologies for development of an objective system for measuring how shoes fit the foot. Ortopediteknikk AS in Norway is the partner for this turbo-project.

3.2 Reports from the Turbo-projects

The reports from the turbo-project by the MINUT-partners to the participating companies are confidential due to market situation. Each turbo-project has described either the technology or application or both. This is presented as an abstract for each turbo. The Nordic dimension is also addressed for most of the cases. This reflects relevant competence at the other partners and within other Nordic MST actors. It has been important to identify complementary competence both within the partners and at other Nordic MST actors. By doing this, easy access to the best technology for the specific application is gained. This approach also addresses existing technology and solutions relevant for the application. The purpose with MINUT has been to use existing MST components and solutions at new application areas, not to develop new sensors.

3.2.1 Ultrasound Imaging for Guidance of Minimally Invasive Treatment

Project formalities

Participating company: Eagle Ultrasound AS, Trondheim, Norway

Responsible partner: SINTEF

Project deliverable: SINTEF Report STF90 F04608-Confidential

Abstract

By professor Bjørn Angelsen, Eagle Ultrasound AS

Minimally invasive treatment or intervention is done by inserting small tools for remote operation inside the body through small openings in the body surface. Such tools can be stiff for surgery in the abdominal cavity or the thorax, or can be flexible catheters that are inserted into vessels even towards the heart cavities and coronary arteries. Typical treatments are placement of stents to expand arterial stenosis and ablation of electrical conduction tissue in the heart to prevent re-entry arrhythmia of the heart. Coronary by-pass surgery is done on the beating heart, and developments are even in process for minimally invasive placement of aortic valve prosthesis.



Figure 7 High resolution 3D image of 7 weeks 5 days human embryo (14mm from top to bottom) with Eagle Ultrasound equipment.

With all these developments for simpler and better treatment, there is an increasing demand for better imaging both for accurate diagnosis of the condition, and for better visual guidance when carrying through the procedure. For example, with new developments in Drug Eluting Stents where the drug inhibits the growth of vessel wall atheroma, it becomes feasible to treat early vessel wall disease to inhibit the growth into a blood flow limiting stenosis. This provides a need for high resolution imaging of the coronary artery wall, that can be achieved with ~ 100 MHz ultrasound transducer arrays at the tip of a catheter that is inserted into the coronary artery. Due to the high frequency, preamplifiers and initial signal conditioning must be integrated in a chip to be located at the catheter tip near to the ultrasound transducer.

Another example is guidance of minimally invasive placement of aortic valve prostheses, where one wants accurate imaging of the aortic valve area for selection of prosthesis size and moving the valve prosthesis into position. However, for adequate operation some beam forming electronics must be placed close to the array.

Hence, there is a large opportunity to develop ultrasound transducer arrays with frequency in the 10 – 100 MHz range. To reduce transmission losses at these high frequencies, one must place preamplifiers and some signal processing electronics together with the transducer arrays at the tip of the probes. As one wants to avoid re-sterilization of complex probes, there is a need for low cost manufacturing to allow probes that are used only one time.

Eagle Ultrasound AS in Trondheim is a start-up company that focuses on high resolution 3-dimensional imaging in the 10 – 100 MHz frequency range. The company has developed prototype instrumentation for high resolution 3D imaging of the fetus, where an example is shown in Figure 7. The company is further developing 10 – 100 MHz ultrasound transducer arrays and low cost manufacturing processes that allow one time use of pre-sterilized probes for guidance surgical and interventional procedures.

Nordic perspective

cMUT technology

At VTT in Finland, they have developed a surface micromachining technology to make capacitive micromachined ultrasonic transducers (cMUT) in the frequency range of interest. This may be considered as an alternative technology to the one studied in this turbo-project.

Imego AB has a strong experience in the area of silicon micromechanics and front-end electronics for high frequencies. Another important competence is thick-film technology, where Imego has worked for a long time. Nordic companies have to some degree production facilities for thick-film substrates, and may be involved as partners.

Other Nordic institutes and industry

The Danish company Ferroperm Piezoceramics A/S is a very strong candidate for supplying the piezoelectric material and serve as a subcontractor for the future production. It's likely to see them as a project partner if the work is continued. Their main focus is to:

- Provide high quality piezoceramic components for the professional user
- Assist our customers at the designing stage with a choice of the best material for the application
- Guide our customers through the definition phase in order to obtain the best quality vs. price ratio.

3.2.2 Pressure and flow sensors for robotics

Project formalities

Participating company: ABB AS, Robotics, Bryne, Norway

Responsible partner: SINTEF

Project deliverable: SINTEF Report STF90 F04617-Confidential

Abstract

By Ole Kristian Brekken, ABB AS, Robotics

The ABB painting robot is primarily used in industries with high demands concerning the quality of the surface finishing of their products. Typical use is application of two component paint and clear-coat on automobile bodies. This requires a fast and accurate robot motion and no less accurate control of the robot's spraying fan, both concerning its shape, amount of paint and accuracy in switching the spraying fan 'on' and 'off'.

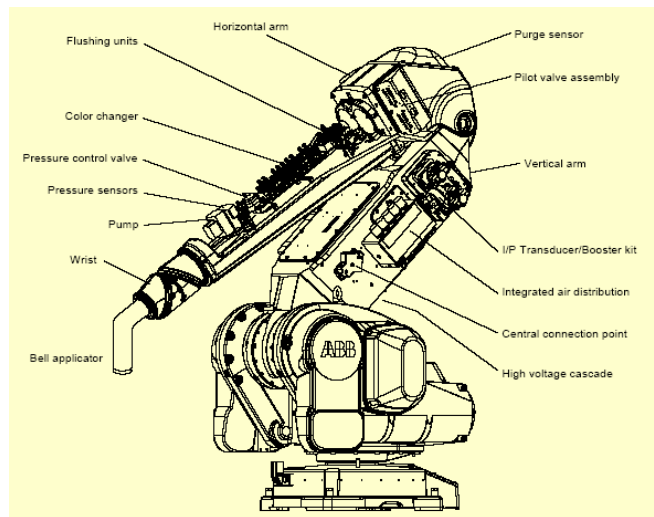


Figure 8 Robot system

The paint control is performed by advanced electronic and software control systems which is designed in such a manner that it 'learns by experience' from previous performed operations so that it can improve response times for changing the shape of the spraying fan and triggering points. In addition to this, functions such as rapid and frequent colour change are required.

The paint can be applied with conventional automatic spray-guns or advanced rotating bell applicators, often combined with high voltage for electrostatic charging of the sprayed material.

To achieve these functions, various types of regulators and sensors are included in the control system. These components are normally mounted on the robot vertical- and horizontal arm. An essential point in the paint control system is rapid response both for regulators and functions such as color changers and it is therefore preferable to have the system performance critical components placed as close to the applicator as possible.

We see advantages by having the opportunity to obtain small flow sensors and pressure sensors which can either be used separately or even possibly be integrated in the regulators. We may thereby have the possibility to reduce the weight of the robot arm and also be able to place the regulator even further up front, closer to the wrist and the applicator.

This would mean that the weight of the robot arm, especially the front end of the horizontal arm, can be reduced which in turn would enable us to make a faster and more accurate robot. Further, as the new sensors are small or can possibly be included in the regulators, this may enable us to make a slimmer horizontal arm design which is important as the robot also needs to be moved into small spaces such as inside and automobile body for coating of the interior surfaces.



Figure 9 Painting robots in operation. The product is sold world wide to leading car manufactures.

Nordic perspective

VTT has been actively involved in the project and has specifically contributed to two paragraphs in the report. VTT is interested in further development of their capacitive sensor technology with the aim of producing sensors for the purge sensor system in the short term. This could either be realized through a continuation of the project under the MINUT program or through alternative funding provided continued interest from ABB exists.

DELTA has developed a wafer level testing facility for pressure sensors. The system would allow for the early screening of sensors and can thereby reduce component cost, and may be of interest for the continuation of the projects. DELTA's competence and facilities within environmental testing of microsystems is also relevant.

3.2.3 Micromachined microwave filters

Project formalities

Participating company: Nera Networks AS, Bergen, Norway
Responsible partner: SINTEF
Project deliverable: SINTEF Report - Confidential

Abstract

By Kjetil Folgerø, Nera Networks

Nera develops and manufactures telecommunication products based on microwave technologies. Due to their excellent electromagnetic properties, RF MEMS components have several potential applications both in existing and future telecommunication products. For instance, RF MEMS switches may become essential

components in reconfigurable systems. High Q inductors, resonators, and varactors are other promising components. The research within RF MEMS around the world is extensive, but there are few components available commercially. Static (i.e., working principle does not depend on physical movement) components like filters and resonators seem to be the most mature and reliable devices, and this project was therefore initiated to explore the challenges associated with design and processing of such RF MEMS components.

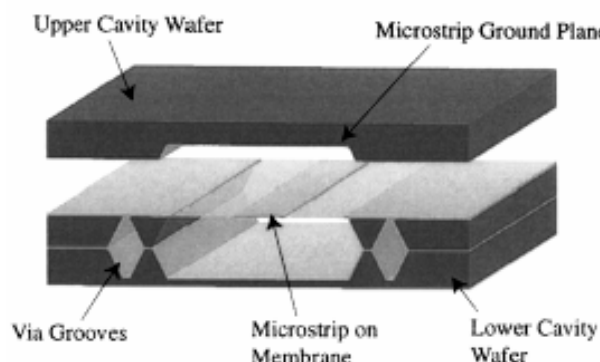


Figure 10 Schematic of cross-section of a possible filter structure. After Brown et.al , IEEE Trans MTT. Vol.47 (8), pp. 1477-1481 (1999)

Objective

The main objective of this project is to investigate how micromachining processes can be used to fabricate production friendly microwave filters exhibiting low loss and acceptable cost in the 10 GHz – 60 GHz frequency range.

Project work and output

Based on an extensive literature review, potential microwave filters topologies suitable for fabrication with micromachining were found. Nera came up with relevant filtering specifications. Based on these specifications, mechanical dimensions for some potential topologies were calculated. SINTEF evaluated the manufacturability of the example cases and provided feedback to Nera's engineers. By considering the interaction between process possibilities and electromagnetic implications closely, conclusions regarding possible fabrication methods were found. Possible production routes were described, followed by a rough estimation of design and manufacturing cost.

Nordic perspective

VTT has considerable experience with RF MEMS processes and devices and exploitation of RF MEMS in microwave/millimeterwave circuits. In this turbo-project, the intention has been to evaluate a range of technologies and candidate suppliers, and VTT has been included as one of such suppliers..

DELTA's facilities for wafer level testing, including environmental testing, are seen as interesting for a concept development phase as well as for screening of components at an early production phase for reduction of component cost. In addition, DELTA is a candidate for mounting and packaging of components.

3.2.4 Sensor Packaging for harsh environments

Project formalities

Participating company: Samba Sensors AB, Göteborg, Sweden
Responsible partner: Imego
Project deliverable: Imego Report 110040 – Confidential

Abstract

By Cristina Rusu, Imego

Samba AB investigated the use of fibre optic technology and micro mechanics for pressure measurement and developed an optical pressure sensor for medical applications. The Micro Pressure Transducer is miniaturized, versatile and intended for use in demanding medical applications. It is highly stable, with high accuracy and low temperature drift. Innovative technology offers a possibility to increase measurement quality in many different medical fields, e.g. MRI applications.

They would like to locate new application areas for their sensor. In this "Turbo project", we recognized the main requirements needed for the sensor system to be used in the harsh environment applications.

Nordic perspective

MINUT-partners

SINTEF has key competence in the field "packaging for harsh environments" and has been working with customers for such applications in many years. Examples of "harsh" environments are oil-wells with temperatures up to 200C, high pressure and demanding "chemistry". Another example is packaging of a MEMS-based system intended for temperatures in the range of 350-500 C and medium pressure (100 bar). Radiation hard systems have also been studied.

DELTA has competence and services within the field of fibre pressure sensor packaging for harsh environments.

3.2.5 MEMS based inertial sensors for accurate coordinate determination of drill holes via inertial navigation

Project formalities

Participating company: Flexit AB, Vallentuna, Sweden
Responsible partner: Imego
Project deliverable: Imego report 110047-rap-R4 - Confidential.

Abstract

By Dag Billger, Imego

Flexit is a Swedish manufacturer and developer of advanced equipment for measuring all types of drill holes. Flexit needs an investigation on the possibilities of using MEMS based inertial sensors for accurate coordinate determination of drill holes. The solution is already covered by Imegos in-house gyro and inertial navigation knowledge.

During the last years Imego has developed a unique inertial navigation system with total weight less than 80 gram. The system is the most precise on the market in this size category. This advanced stand alone sensor system measure all motion parameters; acceleration, speed, position and angles in all direction with high precision. The system is now being implemented in applications for a broad range of customers.

Nordic perspective

SINTEF has the expertise for sonar based system and high temperature electronics, but for this project the customer in the end only needs a gyro based system for attitude navigation. Delta has expertise on packaging / mounting of the components/system that can be eventually used in the future.

3.2.6 Small and cheap inertial sensor systems for accurate navigation

Project formalities

Participating company: Atlas Copco Tools AB, Nacka, Sweden
Responsible partner: Imego
Project deliverable: Imego report 110045-rap-ACT-R1 - Confidential

Abstract

By Dag Billger, Imego

Atlas Copco Tools (ACT) has a large production of, for example, industrial screw drivers, which are used to mount together machine equipment. ACT has a need to increase their knowledge on the use of small and cheap inertial sensor systems.

Imego has developed a micro-sized system for inertial navigation (INS) and motion tracking, based on micro mechanical sensors. Now the system technology is moving towards a complete stand-alone real-time INS. It has a modular build-up and can be configured to fit a multitude of different applications, where size and performance are key parameters among others.

Nordic perspective

It was strongly suggested to combine INS technology with the technology of another reference system. The customer thus received a proposal for combining Imegos INS with a sonar based system developed by SINTEF for Sonitor. However it became apparent that the customer had already developed a sonar based prototype system on its own. Furthermore, it was said to be too early in the R&D planning of the customer for them to make a decision on building a prototype based on these two navigation systems. There might be an interest in the near future but this is yet unclear.

3.2.7 Acceleration switch

Project formalities

Participating company: Nammo Raufoss AS, Raufoss, Norway

Responsible partner: SINTEF

Project deliverable: SINTEF Report STF90 F04603 – Confidential

Abstract

By Christian Johnsen, Nammo Raufoss AS

The safety regarding manufacturing, handling and use of ammunition is of great importance. An important part of the safety in the ammunition is the Safe & Arm Unit (SAU). This unit shall prevent the main charge to detonate if the detonator unexpectedly should be ignited. Traditionally the SAU is mechanical clockworks that are expensive to produce and the arming distance (the distance from the muzzle where the ammunition is safe)



Figure 11 MEMS as a key component in the Safe and Arm Unit for ammunition.

could vary a lot depending of the temperature. The mechanical clockworks are normally not very flexible.

Nammo wants to develop a SAU using MEMS switches. This SAU is meant to be used in Programmable Ammunition. Compared to the traditional mechanical clockwork, the MEMS SAU will reduce the need of space, the SAU will be more flexible and the large-scale production costs will probably decrease.

In medium calibre ammunition, the space available for the SAU is limited, so it is important to keep the SAU unit as small as possible. The function of a MEMS SAU will not be that temperature dependent as the traditional mechanical clockwork. A more accurate arming distance will increase the flexibility of the ammunition. The possibility to be able to vary the arming distance makes the SAU more flexible for different ammunition products. The projectile is exposed for high G-forces during firing (up to 70 000G). Because of the small physical dimensions, the MEMS construction could be more reliable to high G-forces than the traditional mechanical clockwork.

The production costs for the traditional mechanical SAU is normally a significant cost of the total projectile. To make Nammo competitive of delivering programmable ammunition in the future, it is important to reduce the costs for the SAU. That's why Nammo wants to replace the mechanical clockwork used in the ammunition of today.

A reliable SAU is vital to make it possible to produce, handle and use the ammunition safely. If Nammo succeeds the development of the MEMS SAU, this will increase the need of employees in Norway and the Nordic countries. Traditionally the SAUs for the European market are produced in Switzerland. A MEMS SAU developed by Nammo could be produced in Norway or other Nordic countries. This will contribute to sustain or increase the need of employees for decades. It is very expensive to develop new ammunition. This means that when an ammunition type is qualified and is ready for a customer, the ammunition will be in the market for decades.

Nordic and European perspective

The competency and infrastructure for packaging and testing of Microsystems at Delta will be valuable for the realization of this product. Especially the "design for testability" competence at Delta will be an important knowledge to implement in the design phase.

For the fabrication of test-structures proposed in the turbo-project, both the VTT and SINTEF lab facilities are capable of development and manufacturing of such systems. The initial costs for the prototypes needed in the first round are high, so the turbo-project recommends taking advantage of manufacturing services within Europractice¹⁸. Both Tronics and Qinetiq have built good manufacturing services supported by the Europractice initiative. Utilizing these services provide the fastest and cheapest way to a testable device.

¹⁸ <http://www.europractice.com/>

3.2.8 Microphone for measurements and survival at extreme sound pressure levels as well as harsh environmental conditions

Project formalities

Participating company: SNIPOS AS, Re, Norway
Responsible partner: SINTEF
Project deliverable: SINTEF Memo – Confidential

Abstract

By Odd Løvhaugen, SINTEF

SNIPOS AS has developed a system for detecting the originating coordinates of the weapon and the type of projectile that are being fired by snipers. The acoustic detection system is liable to experience extreme sound pressure levels and dynamics from the chock wave created by the passing projectile as well as the muzzle sound from weapons at close range.

There exist no commercial products that comply fully with the desired technical and environmental specifications combined with a competitive price. SINTEF has investigated different designs for micro machined membranes that may fulfil the wanted specifications. A design and product development path has been proposed.



Nordic perspective

Figure 12 Acoustic sensor system

Delta and VTT have participated in discussion regarding survivability and suitability of present microphone designs for this application. Further cooperation might be foreseen when a design is finalized.

3.2.9 CO₂ sensor for Respiratory Monitoring

Project formalities

Participating company: Laerdal Medical AS, Norway
Responsible partner: SINTEF
Project deliverable: Q-breath sensors including instrumentation
SINTEF Memo – Confidential

Abstract

By Jon Nysæther, Laerdal Medical, and Bertil Høk, Høk Instrument AB

CO₂ sensing in demanding applications, such as air quality control and medical diagnostics, remains a technological challenge. Existing solutions based on infrared spectroscopy have proven concept viability, but large scale industrial exploitation is hampered by problems primarily related to size and cost.

The turbo project has assessed the viability of employing an existing CO₂-sensor, Q-BREATH from Høk Instruments AB, for non-invasive respiratory monitoring, and compared its merits against the specifications required.

The Q-BREATH sensor measures variations of CO₂ concentration in expired air, providing information on the quality of each breath, i.e. the degree of gas exchange taking place. It represents the first industrial effort of exploiting an electro-acoustic measuring principle for this purpose. The effort has been preceded by considerable research and development, in which the principle has been subjected to both theoretical and experimental analysis. The conclusion of this research is that the principle offers a number of properties that may be taken advantage of. These properties are in short:

- 1) Small physical size. The basic sensor element may be highly miniaturised which allows measurements and recordings in areas which are difficult to access, e.g. the respiratory tract. For example, Q-BREATH may be applied directly into the respiratory airflow – mainstream application – which obviates the need for pumps and anti-clogging devices necessary in standard sidestream equipment.
- 2) Low power consumption. The sensor principle requires only very small amount of power to be energised. This allows battery operation and wireless transmission.
- 3) Low cost materials and components. Q-BREATH is built up by standard materials and components produced in high volume.
- 4) User-friendly. The sensor is ready to use with a minimum of preparations. In many applications no calibration is necessary by the user.
- 5) High reliability. The device is based on well-known physical properties which are highly reproducible and stable.



Figure 13 Q-BREATH sensor from Høk Instruments AB

Potential applications within non-invasive respiratory monitoring are:

- a. Apnea alarm devices for newborn babies, post-anaesthesia patients, emergency care units, home care (persons suffering from upper airway obstruction, leading to episodes of sleep apnea)
- b. Devices for securing proper function of tracheal tubes, mouthpieces, face masks, respiratory assist devices, diving equipment etc
- c. Diagnostic devices for measuring end tidal CO₂ in athletics, patients with lung disease etc

Other application areas of CO₂-sensors are within indoor air quality monitoring and control. Main challenges to overcome for a successful implementation of such sensors are to improve reliability and user-friendliness compared to the state of the art – at significantly lower cost.

Nordic perspective

A European project “Micro-Acoustic Sensors for CO₂ Tracking”, acronym MASCOT, terminated successfully in February 2005, gives the basis for this Turbo-project. The project proved the feasibility of employing a MEMS-based technology platform for acoustic gas sensors. Nordic partners were Høk Instrument AB, SensoNor AS and SINTEF.

A Nordic network project, MONTIE, has been established to enlarge a strong Nordic knowledge base and discussion forum to address the current – and future uses - of advanced multi-sensors to provide key information about indoor air quality (IAQ). More information about this project is available at www.teknologisk.dk/montie.

The Finnish company Vaisala Oy has a patented CO₂-sensor for indoor air quality control (CARBOCAP[®]) based on MEMS technology. This sensor is state-of-the-art within this application area. The technology platform is developed together with VTT.

3.2.10 Non-contact measurement of shape and dimension on steel products during production

Project formalities

Participating company: MEFOS & Scana Steel Björneborg AB, Björneborg, Sweden

Responsible partner: Imego

Project deliverable: Imego report 110054 - Confidential

Abstract

By Håkan Lundbäck, MEFOS

State of the art

Open die forging is a forming method to produce large steel products, often in small numbers compared to products from rolling mills. The total production volume in Scandinavia is about 200 kton/year. Open die forging is also used in cases when customer demands on material properties are high and when the geometry of the final product is complex. Typical steel weights are 5-50 tons, sometimes even larger. The product shape is cylindrical for rings, axes and shafts, rectangular for large flats. The initial temperature for forming is typical 1250°C and the forming operation continues to 900 °C. After hot forming the products normally are heat treated and finally machined to final shape. During the hot forming it is important to control the intermediate dimensions. This is done partly by measurement devices in the forging press and partly with manual methods. The forging companies are interested to find new and better methods to perform measurement. The potential is to increase the accuracy and to minimize the hazardous manual work in the hot environment close to the work piece.

Objective

The objective is to evaluate possible physical principles and new non-contact measurement techniques in order to enhance measurement of shape and dimensions during production of large steel products.

Project work and output

A literature survey will be made and evaluate available and possible new principles and methods for non contact measurement. Existing methods will be evaluated as a reference. A report with the suggested method and equipment will be produced. Scana Steel Björneborg and MEFOS Metallurgical Research AB will supply necessary information to specify the equipment. Visits will be made both to MEFOS and to Scana Björneborg AB in order to study the production environment and to discuss the demands. The pilot plant at MEFOS Metallurgical Research AB is available to evaluate sensors. The forging press in Björneborg is available to make full scale test.

Overview was done and the first optical measurements are in progress.

Nordic perspective

SINTEF was contacted and info was received which described their expertise in optical measurement in some similar applications. Their expertise is relevant for the project and will most probably be used.

3.2.11 *Measurement of lung volume and function*

Project formalities

Participating company: Statchip ApS, Lyngby, Denmark
Responsible partner: Delta
Project deliverable: Delta Report 101057 – Confidential

Abstract

By Andreas Duun Andersen, Delta

STATCHIP ApS (DK) is currently developing a handheld apparatus so called Intelligent Personal SpiroMeter (IPSM) which should measure accurately (equal to or less than 3 %) the lung volume and function.

The MINUT project has studied the possibilities to develop a multi microsensor device (MMS) shaped as a cylindrical mouthpiece, which is the most important part of IPSM apparatus.

Nordic perspective

MINUT-partners

SINTEF has worked with optical detection of NO-gasses. VTT has worked with microsystem for measuring gas flow by using ultra sound transducers, and has developed sensor chips for this purpose

Other Nordic institutes and industry

Measuring of asthmatics conditions is part of the product portfolio of several companies in the Nordic countries. The STATCHIP idea complements the existing product and the MINUT project could promote Nordic collaboration in this field

3.2.12 *Stimulation of the nerve path*

Project formalities

Participating company: Certo ApS, Denmark
Responsible partner: Delta
Project deliverable: Delta Report – Confidential

Abstract

By Andreas Duun Andersen, Delta

CERTO ApS, Denmark wishes to develop a miniaturised system based on an idea of being able to stimulate sacred nerves wirelessly by the means of one or more implanted transponders in combination with an external pulse generator placed on the patient.

During the initial phase (the MINUT Turbo phase) of the product development, the fundamental technological principles for power transfer to the transponder(s), communication frequency dependent on the tissue, power consumption of the chosen electronics, choice of active/passive transponder technology together with outlining of 2-3 transponder design proposals of the implant have been clarified. Clarification of an electrode on the implant and mechanical fixture possibilities has also been part of the initial phase.

Nordic perspective

MINUT-partners

SINTEF have worked on implants for measurement of pressure in the brain, and these competences could be used in a later product development phase.

Other Nordic institutes and industry

Medical devices to insure continence are produced by several Nordic companies. Especially Coloplast in Denmark is strong in this field and has its own products and research. Further research is performed at “Sansemotorisk” institute at Aalborg University.

3.2.13 Sensor System - Titanic

Project formalities

Participating company: CM Hammar AB
Responsible partner: Imego AB
Project deliverable: “Hammar-Slutrappport” – confidential
“SlutPresentation.ppt” – confidential

Abstract

By David Storek, Imego

The customer – Hammar- tasked Imego to explore as many technologies and principles as possible, in trying to find a replacement for their current sensor technology. Hammar’s basic function is to detect water and thereafter to penetrate a canister with compressed CO₂, which inflates a life jacket. During Imego’s research, VTT and DELTA were found to be able to deliver various key technologies. VTT could produce commercial MEMS sensor chips and DELTA is a world leader in packaging technology, particularly for harsh environments. Imego pursued a number

of technical principles but is soon became evident that a pressure sensor solution, using VTT's sensor chip and DELTA's packaging, would be the strongest candidate.

Nordic perspective

MINUT-partners

VTT contributed MEMS sensor chip expertise. They handled all issues concerning the "silicon" and how to produce it commercially.

DELTA contributed sensor packaging expertise, which turned out to be the key technology to make this work at a reasonable cost.

Imego contributed the customer, electronics, systems thinking, and management portions of the project. Imego also pursued the parallel "commercial sensor" path.

Other Nordic institutes and industry

CM Hammar, Sweden, has a lot of experience in mechanical design, manufacturing and commercialisation. Hammar will in the future take care of the overall system assembly.

3.2.14 Applications of Microsystems for Outdoor Clothing Products

Project formalities

Participating company: Norrøna
Responsible partner: SINTEF ICT
Project deliverable: SINTEF Health Research Report – Confidential

Abstract

By Frode Strisland, SINTEF ICT

The potential for using Microsystems technology in outdoor clothing products have been evaluated.

The Introduction of Microsystems in clothing products is presently in an initial phase. Such products are often termed *SmartWear*. There are considerable research activity and novel commercial solutions, yet the clothing manufacturers have been reluctant to introduce SmartWear products in their assortment. For Norrøna it is crucial that new technology is *proven* before it is introduced to their high end customers expecting top quality and reliability.

An established Microtechnology *infrastructure* that includes electrical conductors, connectors, circuit boards, packaging solutions, power sources and user interaction functionality (buttons, displays) is required before SmartWear technology reaches a

broad use in textile and clothing manufacturers. The purpose of the Minute project has therefore been to search for and find technology relevant for Norrøna.

Nordic perspective

MINUT-partners

VTT conducts research on wearable electronics.

Other Nordic institutes and industry

SINTEF is a member of the Nordic Centre of Excellence for Smart Textiles and Wearable Technology (NEST, <http://nest.hb.se/nest/>). This is a cooperation between Scandinavian research institutes and university institutions that focus on smart textile and clothing technology. The objective of NEST is to gather together and develop the resources that exist in the field of smart garments so that each institution specializes in certain subtopics and each can complement the others. The ultimate goal of NEST is to initiate RTD projects in collaboration with industry or other partners, and to attain a leading position in global RTD in the field of smart textiles and wearable technology. The work of the NEST project is supported by Nordic Innovation Centre. The NEST members are:

- SmartWearLab, Tampere University of Technology, Finland
- Institute of electronics, Tampere University of Technology, Finland
- Swedish School of Textiles Borås, Sweden
- IFP Research AB, Sweden
- Danish Technological Institute, Denmark
- Kaunas University of Technology, Faculty of Design and Technology, Lithuania
- SINTEF Health Research, Norway

3.2.15 *Electronic Bingo board*

Project formalities

Participating company: Electronic Board A/S
Responsible partner: Delta
Project deliverable: Delta Report m101115 – Confidential

Abstract

By Jens Branebjerg, Delta

A Danish company Electronic Boards A/S have patented the idea of making an electronic Bingo-board. The electronic bingo-board should contain 3 electronic bingo plates and be 15 X 20 cm. The function of the board should contain 3 X 27 windows, each containing a touch switch and a mechanism in which the optical “look” of the window can be changed electronically. A foil containing the numbers of the 3 bingo-plates will be laminated on top of the electronic board.

In the turbo project a technology evaluation has been made focusing on:

- Technologies for the optical mechanism
- Technologies for the touch switches
- Botch elements should be distributed over an area of 15X20cm and made on sheets/foils/plates
- Electronics for use in 800 hours on one battery

Nordic perspective

MINUT-partners

All MINUT partners have activities on mikrosensor and micro devices which could be use in the Electronic borad project.

Other Nordic institutes and industry

Production of The Electronic board fits very well with the Danish company GPV-industries and several meeting was held with GVP on design and production of the electronic-boards

3.2.16 Objective Evaluation Equipment for Fitting of Shoes

Project formalities

Participating company: Ortopediteknikk AS, Oslo, Norway

Responsible partner: SINTEF ICT

Project deliverable: SINTEF Report – Confidential

Abstract

By Frode Strisland, SINTEF ICT

The fitting of orthopaedic aids such as prosthesis, soles and shoes are mainly based on skilled craftsmen and subjective feedback from the patient. In some cases the patient suffers from reduced limb sensitivity or is unable to express him/herself. Evaluation of how well the orthopaedic aid fits is difficult in this case. It is also difficult to evaluate to what extent a shoe or a sole that is “*not good, but not bad either*” will cause ulceration or sore feet after use. Ortopediteknikk AS therefore has identified a need for an objective system for measuring how shoes fit.

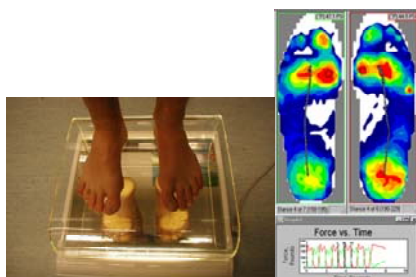


Figure 14 Qualitative (left) and quantitative (right) evaluation of the force/pressure on the feet from the ground.

SINTEF ICT and SINTEF Health Research have contributed to a study of available solutions and technologies. The requirements for such a system have been determined in collaboration with Ortopediteknikk AS. Technology searches for commercially available solutions or available technologies that might be developed into a useful tool for Ortopediteknikk AS have been carried out. The findings from these searches have been evaluated. Based on the evaluation, concepts suitable for Ortopediteknikk have been suggested.

Nordic perspective

MINUT-partners

Imego has projects on which pressure or force in small spaces has to be measured by using, for example, thin pressure-sensitive foils. These methods may be useful for sensing the pressure in a shoe for orthopaedics' applications.

Other Nordic institutes and industry

Acreo in Sweden has a research activity on printing electronics on paper. This activity is of interest for the current project, but development of integrated (pressure/force) sensor capabilities is needed.

4 WP 3 – Feasibility

The main objective of this work package has been to set foundation for novel product development based on the microtechnology knowledge base.

The tool for further handling of the ‘turbo’ projects (WP2) has been to push them into application driven ‘feasibility’-studies. The financing model for these studies has been 1/3 from MINUT and 2/3 from companies. The intention has been that the ‘feasibilities’ will be the first step in realization of a product based on microsystem(s) and microtechnology. The studies describe solutions for manufacturing, outline a prototype fabrication, prove the concepts by integrating prototypes in the potential application, choose a production technology, patent opinion, market condition, etc.

Five feasibility projects, one more than promised, have been carried out together with partners outside the project consortium. The output from each study is a short summary presented in chapter 5.1 to 5.5, a summary report made confidential for a period of two years and a full report to the company. All ‘feasibility’ studies describe confidential information relating future products and/or technologies. It is therefore important to keep most of the information confidential to protect the business opportunities. A summary report may be made non-confidential after two years.

Table 3 Overview of feasibility projects in MINUT

No.	Company	Contact person	Other participants	Participating partners	Project period
1	CM Hammar AB	Tor Christiansson		Imego, VTT, Delta	01.05. – 01.10.2005
2	ABB AS, Robotics	Jone Gjerde	Memscap AS	SINTEF, Imego, Delta	01.01. – 30.11.2005
3	Nammo Raufoss AS	Gard Ødegårdstuen	FFI - the Norwegian Defence Research Establishment	SINTEF, Delta	01.01. – 15.11.2005
4	Scana Steel AB, Uddeholm Tooling AB, Sandvik Materials Technology AB	Leif Näsman, Lars Westlund, Jonas Damberg	MEFOS – Metallurgical Research Institute AB	Imego, SINTEF	01.06. – 30.11.2005
5	Statchip Aps	Reza Sharifpour	USA company on NO-sensors	SINTEF, VTT	15.08. – 30.11.2005

4.1.1 Pressure Sensor System - Titanic

Project formalities

Participating company: CM Hammar AB
Responsible partner: Imego AB
Participating partners: VTT, Delta
Project deliverables: “Kostnadsuppskattning-Titanic” – confidential
“TitanicII-Slutrapport” – confidential

Abstract

By David Storek, Imego

From Phase I – Turbo- it was clear that a pressure sensor system was the customer’s preferred choice. Phase II- Feasibility- was then supposed to investigate start-up and manufacturing costs for a complete pressure sensor system, along the customer’s tight specifications. The project continued along two parallel paths: “evaluation of commercial pressure sensors for high-volume applications” and “evaluation of a tailored solution using VTI’s sensor chip, Imego’s electronics, and DELTA’s packaging technology.” The conclusions, which are confidential, revealed that both paths are currently too expensive to be commercially competitive. The tailored sensor system, however, turned out to yield a technically superior solution without adding extra cost, compared to the cheapest commercial alternatives. The customer is satisfied with the results and will activate the project again as soon as the “numbers” come out right in the future.

Nordic perspective

MINUT-partners

VTT contributed MEMS sensor chip expertise. They handled all issues concerning the “silicon” and how to produce it commercially.

DELTA contributed sensor packaging expertise, which turned out to be the key technology to make this work at a reasonable cost.

Imego contributed the customer, electronics, systems thinking, and management portions of the project. Imego also pursued the parallel “commercial sensor” path.

Other Nordic institutes and industry

No other companies or institutes have been involved in the feasibility project. The company has a lot of experience in mechanical design, manufacturing and commercialisation, and will in the future take care of the overall system assembly themselves. Nordic companies within microtechnology are potential sub-contractors.

4.1.2 Purge sensor system - demonstrator

Project formalities

Participating company: ABB AS, Robotics, Bryne, Norway
Responsible partner: SINTEF
Participating partners: VTT, Imego
Project deliverables: SINTEF Report STF90 F04617 – Confidential
2 purge sensors from MEMSCAP incl SW
SINTEF Memo – confidential

Abstract

By Wilfred Booij and Dag Ausen, SINTEF

In the ‘turbo’ project “Pressure and flow sensors for robotics” the realisation of a purge sensor system based on MEMS technology for ABB AS for use in a paint robot system was studied. The purge sensor system is a safety device that is located in the robot arm and is exposed to explosive gases. The recommendation from this phase was to go for a solution based on two differential pressure sensors. Suitable sensing elements for the system would be the MEMSCAP SP82 sensor. In the ‘feasibility’ phase of the project, two such sensors have been implemented and tested in a robot system at the ABB facility in Bryne. The tasks in the feasibility study have been chosen as to select the best possible compromise between costs and purge system performance. Two students worked all summer with implementation and evaluation of the sensors in the robot system. The results from these initial tests are very promising. The sensors may be used as they are. EXi og EXp qualifications must be made and the sensors must be given an interface to the robot system. Component price will be an important issue for product implementation.

The ‘feasibility’ was summarized and concluded with a workshop at ABB with participants from Delta, Imego and SINTEF. The purpose of this workshop was to identify and discuss possible implementations of microsystems in the robot system and set foundation for future implementations of new functionality.

Nordic perspective

MINUT-partners

DELTA and Imego took part at the concluding workshop and made valuable contributions to possible implementations of microsystems in the robot system.

4.1.3 Acceleration switch - demonstrators

Project formalities

Participating company: Nammo Raufoss AS, Raufoss, Norway
Responsible partner: SINTEF
Participating partner(s): Delta
Project deliverable: MEMS test report – confidential
MEMS design abstract – confidential
94 MEMS switches (devices)

Abstract

The main objective for this ‘feasibility’ has been to demonstrate a spin switch and a setback switch intended for ammunition. The main part of the work has been design and simulation of two MEMS sensors for 30 mm ammunition. The purposes for these sensors are to detect setback acceleration and rotation of the projectile. The sensors are designed in two SOI processes, the Tronics and Qinetiq processes respectively. Two series of prototypes have been processed. Different tests have been carried out on the switches.

During the design, it showed that it was extremely difficult to simulate the setback switch properly. This was mainly due to insufficient CAD tool and limited resources. Hence, there are uncertainties in this design such as threshold for latching and the dynamic behaviour during latching that can only be verified during testing. Common for all designs are that the contact resistance is very difficult to predict accurate. However, it needs only to be sufficiently low in order to fulfil the specifications. The sensors were prototyped and delivered to FFI from Tronics in June 05, and from Qinetiq in July 05. A broad series of tests have been performed on the switches during the autumn. Preliminary results were discussed and concluded at a workshop together with the MINUT-partners in November.

Nordic perspective

MINUT-partners

SINTEF has been involved in the design and simulation of the MEMS switches, and has also given advices in the fabrication and test phase. DELTA contributed with their key competence within testing of microsystems.

Other Nordic institutes and industry

FFI will be a partner for the continuation of the project. Nordic industry will be in a good position for realization of the acceleration switch in the future.

4.1.4 Non-contact measurements of open die forging

Project formalities

Participating companies: Scana Steel AB, Uddeholm Tooling AB, Sandvik Materials Technology AB
Responsible partner: Imego AB
Participating partner: SINTEF
Project deliverables: Imego report, 110065-rap-01 – confidential
Imego report, 110065-rap-02 – confidential
Demonstration set-up at Mefos facility 2005-29-11

Abstract

By Jan Wipenmyr, Imego

A feasibility study for a non-contact measurement system for measurement of dimensions of large forging has been performed by Imego, Göteborg, and SINTEF, Oslo. The demonstrator has been set-up at the experiment forging press at Mefos, Luleå. Tests and evaluations of the systems have also been done at Mefos and a demonstration of the system is planned 29th of November.

The measurement concept is based on two vision cameras and one blue line laser. One camera is used for triangulation measurement of the forgings profile and the other camera is used for longitudinal measurement of the forging. In laboratory environment accuracy better than the required one of 1 mm is achieved.

Software for collecting data, calculation of dimensions and presentation of the results has been developed together with graphical user interface (GUI) for easy control and presentation.

Nordic perspective

MINUT-partners

Imego and SINTEF have worked together on this feasibility study and contributed with key competence within optical measurement systems and laser technology.

Other Nordic institutes and industry

Mefos, the Industrial Research Institute for the Metallurgical and Metalworking Industry, based in Luleå, Sweden, has been a key partner in the work. They have contributed with own time, material and use of existing equipment in the demonstration carried out for the companies. The measurement system build in this project is set-up at Mefos' trial forging press. Tests, evaluations and demonstrations of the system have been done there.

4.1.5 Handheld Spirometer - Experimental demonstrator and feasibility of integration of an NO-measurement

Project formalities

Participating company: STATCHIP Aps, Lyngby, Denmark
Responsible partner: DELTA
Participating partners: VTT, SINTEF
Project deliverables: DELTA Report – Confidential
Prototyping set-up of Knowls silicon microphone and
DELTA developed interface circuit on PCB incl SW
DELTA Memo on NO-sensor concepts – confidential

Abstract

By Jens Branebjerg

From Phase I – Turbo it was concluded that a handheld spirometer might be constructed. In the feasibility study the focus was on:

- o Making a system design and a CAD-model,
- o Demonstrating the performance of a silicon microphone and interfacing electronics
- o Extended feasibility studies on two different sensor-systems for NO-measurements and their integrations in the handheld Spirometer.

The System design and the CAD model were developed. A silicon microphone from Knowls was purchased an interface circuit was made on a PCB and measurements was performed. Two different NO-sensor principles were identified.

Unfortunately this work was performed before the Costumer had signed the feasibility contract, and the negotiations on the further work are still going on.

Nordic perspective

MINUT-partners

SINTEF supported the feasibility project by background knowledge on spirometry and VTT supported the project by providing knowledge on silicon microphones

Other Nordic institutes and industry

Today a Swedish company is supporting PC-size systems for NO-analysis of excursion gasses. Data from this company has been analysed and evaluated for use. (The analysis is confidential)

5 Main conclusions

- The project has proved that microsystems, or small, functional components, will be key components in future products and add value both to the products and services offered by Nordic companies.
- There are numerous possible applications for microsystems within the Nordic industry. As a breakthrough technology, allowing unparalleled synergy between previously unrelated fields such as biology and microelectronics, many new microsystems applications will emerge, expanding beyond those that are currently identified or known.
- MINUT has been the first step towards a common Nordic competence platform of microsystem technologies and has proven that this platform will give Nordic companies access to design and production competence at a leading international level.
- There is large potential for synergy and strong industrial acceleration when easy access is established between research centres, technology suppliers and companies across the borders of the Nordic countries. Existing companies need a push to get into this new technology and discover the innovation potential it represents for their future products.
- An important task will be to facilitate and support the industrialization of MST within new innovative companies. For start-up companies, it is crucial to get access to highly qualified technology support without adding too much cost to the start-up phase. The MINUT methodology has proven its capability for such companies, clearly seen in many of the ‘turbo’ projects performed.
- The MINUT project method has proven itself an efficient way to take-up a new technology in new or existing products. This approach could be used in other projects where the potential of new technologies in future new Nordic products should be investigated.

The MINUT project method implies:

- Efficient pooling of the knowledge from Nordic institutes
- Appointing potential projects by awareness and direct contacts
- Performing an overall qualification of the project idea and its fit to microsystem technologies (‘turbo’ projects)
- Performing a predevelopment and proof-of-concept study (‘feasibility’ studies)

- The MINUT partners welcome the new initiative taken by the Nordic Innovation Centre that attacks the problematic of commercialising micro- and nanotechnologies. New projects should build upon the established Nordic competence platform on microsystem technologies and focus on its use in specific applications fields where Nordic countries have strong business environments. Such applications fields could be:
 - o Biomedical and other applications within the health sector
 - o Instrumentation applications within the process industry (paper, oil & gas, pharmacy, ...)
 - o Automobile and aerospace

5.1 Feedback from participating companies

“The cooperation with MINUT has been excellent all the way. This meant we could focus on development. By solving robotic tasks more cost efficient, we can potentially position ourselves better, and maybe take some more market shares.”

Ole Kristian Brekken, ABB AS Robotics

“The cooperation with MINUT has been very valuable for the MEMS project at FFI and Nammo. Our project has turned out successfully with excellent results for the prototypes processed. We will continue the work to integrate MEMS switches in ammunition. We hope to continue our good cooperation with SINTEF and Delta in design, manufacturing and test of the future MEMS devices.”

Hege Jødahl, FFI and Christian Johnsen, Nammo

“The cooperation within MINUT has made it possible for us start developing a novel non-contact measurement system for the forging industry. The two first steps have turned out successfully into a demonstrator system here at MEFOS in Luleå. We are now looking into the possibility to continue the development together with the participating forging companies and to continue the good cooperation between Imego, SINTEF and MEFOS.”

Håkan Lundbäck, Mefos

Appendix 1 Nordic synergy and network activities

NICE projects

Cooperation and synergy opportunities have been discussed with some of the other ongoing NICE projects.

Table 4 Synergy with other projects financed by NICE

Project	Contact person	Synergy
Nordic CoE for Smart Textiles and Wearable Technology (NEST)	Hilde Færevik, SINTEF Health, project member	General discussion. NEST focuses one of the possible application areas for micro technology. One 'turbo' project looks at "smart wear" technology.
System on Chip Technology for SMEs	Jan Zneider, ITEK, project leader	Project about to end. Possible synergy discussed, especially of open results from both projects. J.Z. took part at the MINUT awareness seminar in Denmark in September.
Scan-Balt in Biotechnology	Peter Frank, project leader MedCoast, project member	Contact established for cooperation for proposal "Foresight Biomedical sensors" delivered to NICE by November - 04. Some discussions initiated for biomedical applications of micro technology.
MONTIE, Multisensors and Other New Technology for Improved indoor Environment in buildings, network project www.teknologisk.dk/montie	Peter Østby, SINTEF ICT, project member Andy Drysdale, DTI, project leader	Application area of interest for micro technology. One of the MINUT turbo projects looks at another application area for CO2 sensors. The sensor principle/technology is the same.
FOBIS - Nordic Foresight project Biomedical Sensors, 2005-2006 www.nordic-fobis.net	Ingrid Svagård, SINTEF ICT, project leader	The biomedical sensors foresight project focus on three important aspects of health care – home based care, emergency medicine and chemical hazards. This foresight was initiated by the MINUT-project. All MINUT-partners take part in the foresight study, directly as project members or indirectly at the workshops.

Other Nordic projects / initiatives

Table 5 Synergies with other Nordic projects / initiatives

Project	Description	Synergy
minST, www.minst.nu (2005 – 2008)	”minST – expertkompetens små funktionella komponenter” fokuserar på kompetenshöjning inom mikro- och nanosystemteknik hos mindre och medelstora företag. Genom skräddarsydda utbildningar stödjer minST såväl teknisk som kommersiell idéutveckling hos dessa företag. Konsortiarer är Mälardalens högskola samt forskningsinstitutet Acreo och Imego. Mikro- och nanosystemteknik har en stor framtida potential för svenskt näringsliv, samtidigt som det finns en stark kunskapsbas vid svenska universitet och högskolor. Komponenter baserade på mikroteknik börjar finnas kommersiellt tillgängliga, men många mindre och medelstora företag har ännu inte fått upp ögonen för möjligheterna med den nya tekniken. I programmets målsättning ingår också att såväl befrämja kunskapsutveckling som att utveckla kunskapsutbytet mellan näringsliv och universitet, högskolor och forskningsinstitut.	Imego one of the partners in minST. Awareness seminar planned in collaboration. Held on 26 January 2005, Uppsala. Coordinated awareness activities in for 2005.
NORDITE (2006 – 2010)	Tekes, VINNOVA and the Research Council of Norway (RCN) are setting up a new Finnish, Swedish and Norwegian technology programme. This new programme is only open to research organisations in the above-mentioned countries (FIN, SWE, NOR). Tekes and VINNOVA have co-operated earlier in two technology programmes: INWITE in 1996-1999 and EXSITE in 2000-2003. It is now time to continue this co-operation and expand the number of countries taking part in the new technology programme.	The MINUT-partners have responded to the call in co-operation with other RTD actors in Finland, Sweden and Norway. One of the MINUT initiated projects, “RFID Platform for Ambient Intelligence” focusing wireless sensors & RFID technology, has been approved.
FMNT - Finnish MicroNano Technology network www.fmnt.fi	Finnish Micro- and Nanotechnology network • A Finnish cooperation network uniting companies and organisations who benefit from Micro- and Nanotechnologies and Adaptive/New Materials • An active player in developing a Nordic model for MNT-cooperation • Links the Finnish MNT-community to European level and Global MNT-networks • FMNT is continuously developing its methods and processes to serve the MNT-field in Finland	Partner in both awareness seminars in Finland. Partner also in the information activities in Finland.

Appendix 2 European dimension

Synergy with European projects

Table 6 European collaboration and synergy

Project	Description	Synergy
Eurimus II www.eurimus.com	EURIMUS II is a EUREKA programme focusing on commercialisation of microsystems technology (MST or MEMS).	MINUT partners gave presentations at Eurimus-seminars in Norway, Sweden and Finland in February 2004. SINTEF and VTT involved in Eurimus technical committee. Potential tool for continuation of turbo- or feasibility projects in MINUT.
MultiMEMS www.multimems.com Europractice - MPW-service within MEMS	MultiMEMS is a continuation of the services previously provided by NORMIC, but with enhancements towards new targeted application areas such as Bio- Opto- and RF- MEMS. The partners in this Europractice-supported Manufacturing Cluster are SensoNor, SINTEF, MicroComponent AS and Vestfold University College.	The project and service was presented at the awareness seminar at Kongberg (N).
CCMeSys Customer Support and Design Centre for Physical Measurement Systems http://www.isit.fhg.de/english/projects/ccmesys.html Europractice – project	The objective of CCMeSys is to stimulate the development, production and application of microsystems for physical measurement systems and provide access to expertise and technology for physical measurement systems.	MINUT Turbo 2 for ABB Robotics has taken advantages of the services offered in the project.
MINATUSE http://www.eureka.be/inaction/AcShowProject.do?id=3325 (2005-2011)	Euroeka project with The Main Objective To Provide Scientific And Technological Support, And General Technical Assistance To European SMEs Wishing To Integrate Micro And Nano Technology Into Their Products. Non-European Countries Will Also Be Made Aware Of Minatuse Activities.	Participation from MINUT-partners to be considered.
AMICOM	EC FP6 Network of Excellence (NE) within RF-MEMS	VTT partner in the NE. Potential co-operation identified between MINUT Turbo 3 Nera Research and the End user group” in AMICOM.

MASCOT Micro Acoustic Sensor System for CO2 Tracking EU RTD project no. IST- 2001-32411 (2001 – 2004)	EC FP5 RTD-project with Nordic partners (Hök Instruments AB and SINTEF). Development of CO2 MEMS-based sensor technology	Possible application studied in MINUT Turbo 9 Laerdal Medical.
4M Multi Material Micro Manufacture	EC FP6 NoE,	Imego is partner. Possible information for different MST projects.
MIMOSA Microsystems Platform for Mobile Services and Applications	EC FP6 IP	VTT partner
SpiroChip (www.spirochip.com)	EC FP STREP proposal	Outcome of Turbo 11. Initiated by Statchip ApS. VTT invited as partner. The project has not been funded. Other alternative funding mechanisms are searched.
Biodiagnostics	EC FP6 STREP	Imego is partner. Possible information for different MST projects.
IntelliSense	NORDITE program	SINTEF, Imego and VTT are partners. Possible information for different MST projects.

E-tranet – case study

Faugert & Co Utvärdering AB has studied the MINUT project with focus on cooperation across the Nordic countries. Main objective has been to identify cooperation mechanism and the effects of them.

The main conclusion from the study is that it is obvious an added value that four countries co-operates and learn and deriving advantage from each others' competence. The institutes together invites companies and develops feasibility studies for them. The rigging mechanism of several steps also gives possibilities in adjusting the project along the way.

Appendix 3 Marketing and publications

Project related publications

This table gives an overview of project relevant publications from the partners during the project period.

Table 7 Project papers, presentations, articles and “in the news” publications

Category	Title	Authors / responsible	Partner	Magazine	Issue / date
Paper	MINUT - Microsystems for Innovation in the Nordic region stimulating the Use of micro system Technologies	Cristina Rusu, Dag Ausen, Hannu Kattelus, Jens Branebjerg	All	Micro Structure Workshop 2004, MSW'04, Ystad	30-31.03.2004
Presentation	MINUT-project	Cristina Rusu	Imego	Eurimus seminar/Nordic roadshow 2004 Stockholm	12.02.2004
Presentation	MINUT-project	Hannu Kattelus	VTT	Eurimus seminar/Nordic roadshow 2004 Helsinki	Feb. 04
Presentation	MINUT-project	Dag Ausen, Fritz Bekkadal	SINTEF	Eurimus seminar/Nordic roadshow 2004 Oslo	Feb. 04
Presentation	Microtechnology for Innovative Nordic Products	Dag Ausen	SINTEF	NICE Forum, Iceland	2004-09-10
Presentation	Mikrosystemer - fra ide til produkt	Dag Ausen	SINTEF	DAK-forum -04, Trondheim	2004-10-20
Presentation	How research institutes and university centers cooperate with companies for commercialization of MEMS	Ilkka Suni	VTT	Visit of a Finnish technology delegation in AIST, Tsukuba, Japan	2004-04-02
Presentation	MINUT – possibilities for Nordic companies	Dag Ausen	SINTEF	minST seminar, Uppsala	2005-01-26
Presentation	From University to Market	Cristina Rusu	Imego	minST seminar, Uppsala	2005-01-26
Presentation	Amorphous Metals for RF-MEMS	Hannu Kattelus	VTT	URSI / IEEE XXIX Convention on Radio Science, Espoo	Nov 1-2 2004
Presentation	Micro and Nanotechnologies for Photonic and Electronic Applications	H.Kopola, H.Kattelus	VTT	International Workshop on Micromechatronics and Micro and Nano Fabrication	Oct 5-6 2004

Presentation	Intelligence and Sensors – Value-added via MEMS	Jens Branebjerg	DELTA	Conference: Small Detectives, Århus,	June 9 2005
Presentation	Microsystems at Imego - from idea to prototype	Cristina Rusu	Imego	Conference: Small Detectives, Århus,	June 9 2005
Article	RF MEMS – Bruk i RF-, mikrobølge og antennesystemer	A.Bøifot, U.Hanke, Kjetil Folgerø	SINTEF Nera Research	Elektronikk	3/2005
Article	RF MEMS – Integrasjon i RF og mikrobølgekretser	A.Bøifot, U.Hanke, Kjetil Folgerø	SINTEF Nera Research	Elektronikk	2/2005
Article	RF MEMS basiskomponenter	A.Bøifot, U.Hanke, G.U.Jensen	SINTEF	Elektronikk	1/2005
Article	RF MEMS – Neste generasjons teknologi for elektroniske systemer – Prosessering og pakking	A.Bøifot, U.Hanke, G.U.Jensen	SINTEF	Elektronikk	12/2004
Article	Mikrosystem skapar nye tjenester	Bill Brox	Imego	Elektronik i Norden	18/2005
Article	Rollover-sensor kanner av jordens rotationshastighet	Gert Andersson	Imego	Elektronik i Norden	Dec 8, 2004
Article	Byggsatt for 60 GHz	Leif Bergstedt	Imego	Elektronik i Norden	March 5, 2004
Article	MEMS Costs under Control	K.Henttinen, H.Kattelus	VTT	Prosessori	2/2005
Article	Mikroteknologilaboratoriet har "falt til ro"	Anders Hanneborg	SINTEF	Elektronikk	01 - 2004
Article	Små brikker forteller hvor tingene er	Wilfred Booij	SINTEF	Gemini	Nr. 1 Feb 2004
Article	Mikrosystemer - komponenter i kontakt med virkeligheten	Frode Strisland	SINTEF	Elektronikk	02/2004
Article	Lysende framtid	Jan Helstad / Odd Løvhaugen	SINTEF	Gemini	Nr. 2 April 2004
Article	Trådløs teknologi gjør innovation nemmere	Jens Branebjerg	Delta	EMC avisen	Nr. 32 (2004)
Article	"Mikroteknologi for krevende miljø"	Frøydis Oldervoll	SINTEF	Elektronikk	Mai -04, nr. 5
Article	Mikroteknologi skal ind i produkterne	Jens Branebjerg	Delta	Elektronik & Data	Nr. 9, Sep. 2004
Article	To skritt foran - Antenne og mikrobølgekretser for neste generasjon	Ulrik Hanke	SINTEF	Teleavisen	09/2004
In the news	Vasasensor: Pressen på pappret måts i full rulle	Christer Johansson, Brodde Wetter	Imego	Ny Teknik	24 Aug 05
In the news	Nordisk MEMS-projekt	Dag Ausen	SINTEF	Elektronik i Norden	1/2004 - 23.1.2004
In the news	Misjonærer for MEMS	Dag Ausen	SINTEF	Teknisk Ukeblad	2/04 - 30.01.2004

In the news	Smarte småting - noe for din bedrift?	Dag Ausen	SINTEF	Elektronikk	01 - 2004
In the news	Smarte småting - noe for din bedrift?	Dag Ausen	SINTEF	Gemini	Nr. 1 - Februar 2004
In the news	MINUT - Micro systems for Industrial Nordic economic growth	Cristina Rusu, Dag Ausen	Imego and SINTEF	NEXUS Newsletter	No. 02/2004, 4.3.2004
In the news	Calling all microtechies!	Dag Ausen	SINTEF	Innovate - NiCe newsletter	1/2004
In the news	Nytt laboratorium endelig klart!	Anders Hanneborg	SINTEF	Dagens næringsliv	21/4-2004
In the news	Gigantsatsing på mikro	Anders Hanneborg	SINTEF	Adresseavisen	21/4-2004
In the news	Storbygg for småting	Anders Hanneborg	SINTEF	TU-nettutgave / Teknisk Ukeblad	2004-04-02 / 11/04
In the news	Helle åpnet MiNaLab med Hammer	Anders Hanneborg	SINTEF	TU-nettutgave	2004-04-21
In the news	Samnordisk satsning på mikrosystem	Cristina Rusu, Dag Ausen	Imego and SINTEF	Elektroniktidning en	NR 7 / 23 April 2004
In the news	Mörkt för sensorn som varnar för sol	Jan Wipenmyr	Imego	NyTeknik	2 Febr 2004
In the news	Millicore byter bobblor mot tryckmätare	Peter Björkholm	Imego	NyTeknik	21 Apr 04
In the news	Pinnen som mäter trots gps-skugga	David Storek, Dag Billger	Imego	Ny Teknik	12 Oct 04
In the news	Millicores mikrosensor ska ut på marknaden		Imego	Ny Teknik	11 Nov 04
In the news	Instrumenteringssamfunnet tar over (for side TU)	Ralph Bernstein / TU	SINTEF	Teknisk Ukeblad	Nr 27 / okt 2005
In the news	Nå kommer instrumenteringssamfunnet (reportasje)	Ralph Bernstein / TU	SINTEF	Teknisk Ukeblad	Nr 27 / okt 2005
In the news	Time to think small	NiCe / Dag Ausen	SINTEF	Innovate	Nr 3 / 2005
Others	Calling all microtechies / Smarte småting – noe for din bedrift?	Dag Ausen	SINTEF	Pressemelding	Februar 2004
Others	MiNaLab åpnet	Anders Hanneborg	SINTEF	Pressemelding SINTEF, www.sintef.no	2004-04-21
Others	SenseFood	Manoo Eibpoosh	Imego	Seminar	16 March 2004

Appendix 4 Nordic MEMS – Status and possibilities

SINTEF report no: STF90 A05410

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Authors: Dan Larsson and Cristina Rusu, Imego, Andreas Andersen and Jens Branebjerg, Delta, Hannu Kattelus, VTT Information Technology, Dag Ausen and Ole Chr. Bendixen, SINTEF

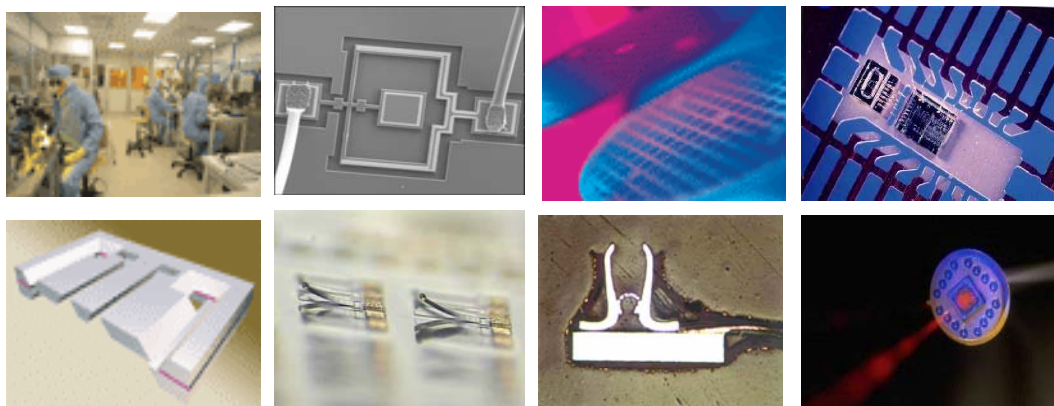
Pages: 34

Date: November 2005

Abstract: The report briefly describes the status of microsystems and related activities in the Nordic countries by the end of 2005 and lists the main actors within industry, research and education. Possibilities with microsystem applications for Nordic companies and the influence this technology will have on the society in the future are also discussed.

**MINUT – Microsystems for industrial Nordic economic growth
Nordic project**

**Nordic MEMS – Status and possibilities
Update 2005**



Dan Larsson and Cristina Rusu, Imego
Andreas Andersen and Jens Branebjerg, Delta
Hannu Kattelus, VTT Information Technology
Dag Ausen and Ole Chr. Bendixen, SINTEF

November 2005

Preface

This report briefly describes the status of microsystems and related activities in the Nordic countries by the end of 2005. Possibilities with microsystem applications for Nordic companies and the influence this technology will have on the society in the future are also discussed.

This report is an update of the report written in November 2003 as part of a pre-project Nordic MEMS¹⁹. The update has been done as one deliverable from the follow-up project MINUT²⁰ closing in November 2005.

The report lists the major actors within microsystem technology (MST) in the Nordic region. The MINUT project has been the first initiative to build a common Nordic knowledge market based on these actors.

Oslo, November 2005



Dag Aasen, SINTEF
Project Manager

¹⁹ Nordic Industrial Fund project 03042, 2003

²⁰ Microsystems for Industrial Nordic economic growth, NICe project 03101, 2004-2005,
www.ittf.no/annet/minut

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1 **Summary**

Microsystems, or small, functional components, will be the key components in systems realizing “the instrumentation society” we are entering during the next 5-10 years.

There are numerous possible applications for microsystems. As a breakthrough technology, allowing unparalleled synergy between previously unrelated fields such as biology and microelectronics, many new microsystems applications will emerge, expanding beyond those that are currently identified or known.

Microsystems will have a value adding effect for most industries, and have influence on many industry processes and services.

There is large potential for synergy and strong industrial acceleration when easy access is established between research centres, technology suppliers and companies across the borders of the Nordic countries.

In all Nordic countries large investments in laboratories for microsystems technologies have been made during the last 5 years. It is a common Nordic challenge to take advantage of these investments in other industry sectors than the electronics industry.

2 Conclusions

Microsystems in general:

- 1 Microsystems, or small, functional components, will be the key components in systems realizing “the instrumentation society” we are entering during the next 5-10 years.
- 2 Microsystems will have a value adding effect for other industries, and have influence on many industry processes and services.
- 3 There are numerous possible applications for microsystems. As a breakthrough technology, allowing unparalleled synergy between previously unrelated fields such as biology and microelectronics, many new microsystems applications will emerge, expanding beyond those that are currently identified or known.
- 4 The technology has a generic character. A microsystem developed for one application may be used for other applications as well with only small adjustments.

The Nordic perspective:

- 1 There is large potential for synergy and strong industrial acceleration when easy access is established between research centres, technology suppliers and companies across the borders of the Nordic countries.
- 2 A common Nordic competence platform of microsystem technologies will give Nordic companies access to design and production competence at a leading international level.
- 3 Microsystems activities is beyond 300 M€ yearly in the Nordic countries²¹
- 4 The research and industrial structures in the individual countries differ strongly in their organization and their topics and application areas
- 5 Microsystems are firmly established in a few specialized applications. At least 10 companies in the Nordic countries offer microsystems based products which are competitive on the world market. Over 20 universities are active in the field and together they cover a broad research platform.
- 6 Mainly companies involved in microsystem component production have invested in using the technology.
- 7 The Nordic technology base is firm and broad enough for wider use in many other industries.

²¹ Estimated value based on annual turnover from the major actors

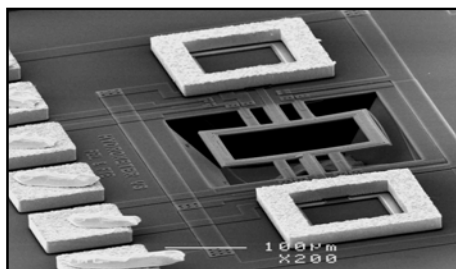
3 Introduction

3.1 What are microsystems?

A short description of microsystems technology²²

Micro-Electro-Mechanical Systems (MEMS) are devices containing extremely small mechanical elements, which are usually integrated together with electronic processing circuitry. Microsystem is the integration of sensors, actuators, and electronics in one module. MEMS components are manufactured with techniques similar to those used for the manufacture of the microelectronics. While the microelectronics are fabricated using integrated circuit (IC) process sequences, the micromechanical components are fabricated using "micromachining" processes that selectively etch away parts of the silicon wafer or add new structural layers to form the mechanical and electromechanical devices.

Microsystems promises to revolutionize nearly every product category by bringing together silicon-based microelectronics with micromachining technology, making possible the realization of complete systems-on-a-chip. Microsystems is an enabling technology allowing the development of smart products, augmenting the computational ability of microelectronics with the perception and control capabilities of microsensors and microactuators and expanding the space of possible designs and applications.



A MEMS viscosimeter

Microelectronic integrated circuits can be thought of as the "brains" of a system and MEMS augments this decision-making capability with "eyes" and "arms", to allow microsystems to sense and control the environment. Sensors gather information from the environment through measuring mechanical, thermal, biological, chemical, optical, and magnetic phenomena. The electronics then process the information derived

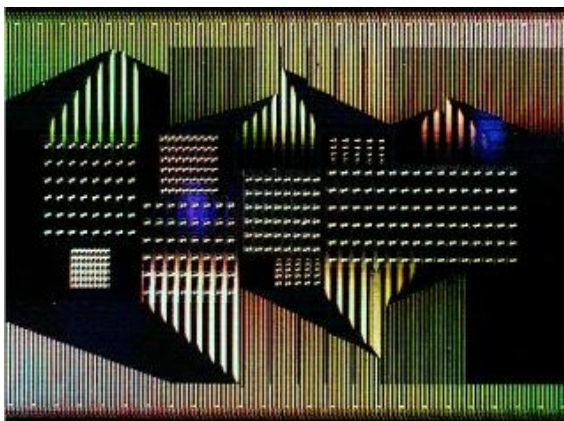
from the sensors and through some decision making capability direct the actuators to respond by moving, positioning, regulating, pumping, and filtering, thereby controlling the environment for some desired outcome or purpose. Because MEMS devices are manufactured using batch fabrication techniques similar to those used for integrated circuits, unprecedented levels of functionality, reliability, and sophistication can be placed on a small silicon chip at a relatively low cost.

²² Sources: NEXUS task force report, Feb. 2002, MEMS Exchange website, MSTNEWS newsletter

3.2 Some microsystems applications

There are numerous possible applications for microsystems. As a breakthrough technology, allowing unparalleled synergy between previously unrelated fields such as biology and microelectronics, many new microsystems applications will emerge, expanding beyond those that are currently identified or known. Here are a few applications of current interest:

Biotechnology



A MEMS biocrater

Microsystem technologies is enabling new discoveries in science and engineering such as the Polymerase Chain Reaction (PCR) microsystems for DNA amplification and identification, micromachined Scanning Tunneling Microscopes (STMs), biochips for detection of hazardous chemical and biological agents, and microsystems for high-throughput drug screening and selection.

Communications

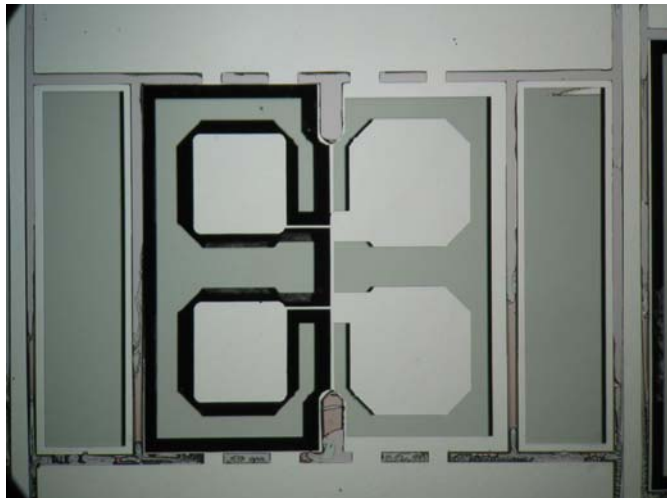
High frequency circuits will benefit considerably from the advent of the RF-MEMS technology. Electrical components such as inductors and tuneable capacitors can be improved significantly compared to their integrated counterparts if they are made using microsystem technologies. With the integration of such components, the performance of communication circuits will improve, while the total circuit area, power consumption and cost will be reduced. In addition, the mechanical switch, as developed by several research groups, is a key component with huge potential in various microwave circuits. The demonstrated samples of mechanical switches have quality factors much higher than anything previously available.

Reliability and packaging of RF-MEMS components seem to be the two critical issues that need to be solved before they receive wider acceptance by the market.

Accelerometers

MEMS accelerometers are quickly replacing conventional accelerometers for crash air-bag deployment systems in automobiles. The conventional approach uses several bulky accelerometers made of discrete components mounted in the front of the car

with separate electronics near the air-bag; this approach costs over \$50 per automobile. Microsystem technologies have made it possible to integrate the accelerometer and the electronics onto a single silicon chip at a cost between \$5 and \$10. These MEMS



A MEMS gyro for air-bag applications

accelerometers are much smaller, more functional, lighter, more reliable, and are produced for a fraction of the cost of the conventional macroscale accelerometer elements.

MEMS devices are extremely small -- for example, MEMS has made possible electrically-driven motors smaller than the diameter of a human hair -- but microsystem technologies is not primarily about size.

3.3 Markets for microsystem products

The outstanding feature of the microsystem market is its universal manufacturing technology with applications in a large variety of industrial segments. This unique feature explains why the microsystem market is predicted to grow steadily by 16% p. a. from \$ 12.000 million in the year 2004 to an estimated \$ 25.000 million by the year 2009.

Table 2.1

Products	2000		2005	
	Units (millions)	\$ (millions)	Units (millions)	\$ (millions)
inkjet head	375	11 200	840	21 500
read/write head (disk head, tape drive head)	1 330	8 260	2 680	13 400
in vitro diagnostic (glucose test strip and OTC)		1 250		5 200
heart pacemaker	0.7	3 100	1.0	4 700
bio-chip	30	645	400	4 440
optical mouse	30	750	230	3 400
hearing aid	650	2 140	9	3 100
pressure sensor	130	1 050	310	2 030
gyroscope	13	340	37	770
accelerometer	100	470	190	690
magneto optical head	2	20	5	50
flow sensor	11	230	25	360
infrared sensor	7	19	20	340
inclinometer	9	54	20	100
micromotor	0.01	2	3	100
microspectrometer	0.03	8	0.5	75
Total		29 538		60 255

World Market for MST products

Figure 15 World market for MST products 2000-2005 (NEXUS)

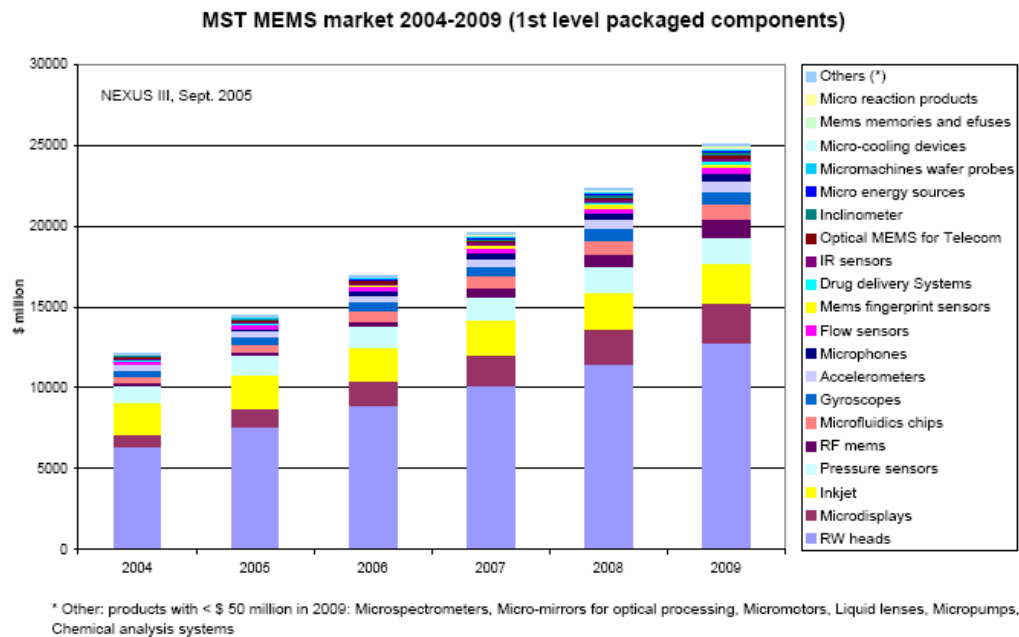


Figure 16 Estimated development of the total world market for microsystem products
2004 – 2009 (NEXUS III Sept. 2005)

The microsystem market does not experience cycles similar to those of the semiconductor industry. In addition, the microsystem market is not as sensitive to the downturns experienced by, for example, the telecommunications segment in the year 2001. Many products and process technologies have proven maturity and there is

currently a real market pull which has replaced the technology rush of the early nineties. The most important market segment in the period until 2009 is in IT peripherals encompassing producers with the largest volumes: inkjet heads, read/write heads, micro displays and inkjet headers. Pressure sensors will also find new markets during the period. The most important new emerging fields will be RF MEMS, microfluidics chips and gyroscopes.

Biomedical applications offer the largest potential for emerging microsystem producers over the ten year span; examples of such products include bio-chips, intelligent drug delivery systems, implantable artificial organs, minimal invasive surgery and non invasive diagnostics. The automotive field was the driving force for microsystem process developments in the early nineties and is still a major segment with producer diversification into other fields such as avionics or military applications. A number of household applications are, meanwhile, introduced in the market whereas a breakthrough for telecommunication is likely to materialise within a few years.

MST products and technology have a number of distinguishing attributes that make them attractive for the advanced manufacturing industries of the coming century. These include:

- suitability for low cost and high volume production
- reduced size, weight, and energy
- suitability for consumable products
- high functionality
- improved reliability and robustness
- bio-compatibility

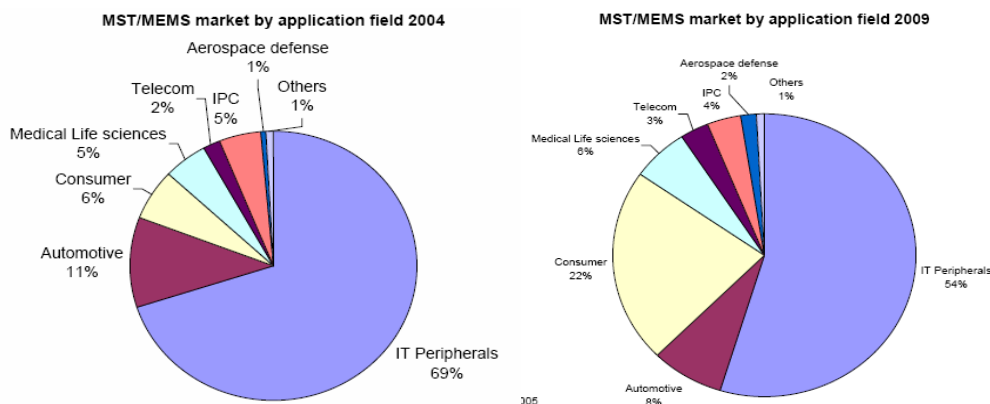


Figure 17 MST/MEMS market by application in the period 2004-2009. The total market will double in the period. Largest growth is expected in the consumer and medical life sciences segments.

Despite its relatively young history, microtechnology has already developed into a key multidisciplinary field. This is largely due to the fact that engineers in many technical areas are intensively searching for innovative solutions achievable only with the help of microtechnical components. Microsystem technologies merges the functions of computing, communication and power together with sensing, actuation and control to

change completely the way people and machines interact with the physical world. Using an ever-expanding set of fabrication processes and materials, microsystems will provide the advantages of small size, low-power, low-mass, low-cost and high-functionality to integrated electromechanical systems both on the micro as well as on the macro scales.

To date, microsystems technology still is most widely spread in the automobile industry. Miniaturization makes possible a growing number of innovative applications with a significant decrease in space and weight.

3.4 One chip, many applications

MEMS components may be used as a key-component in microsystems for a wide range of applications. To illustrate this, let us study a pressure sensor element like the one showed underneath. This MEMS-based pressure sensor could be integrated into several different microsystem applications, from tyre pressure measurements in automobiles to medical equipment and pump valves.

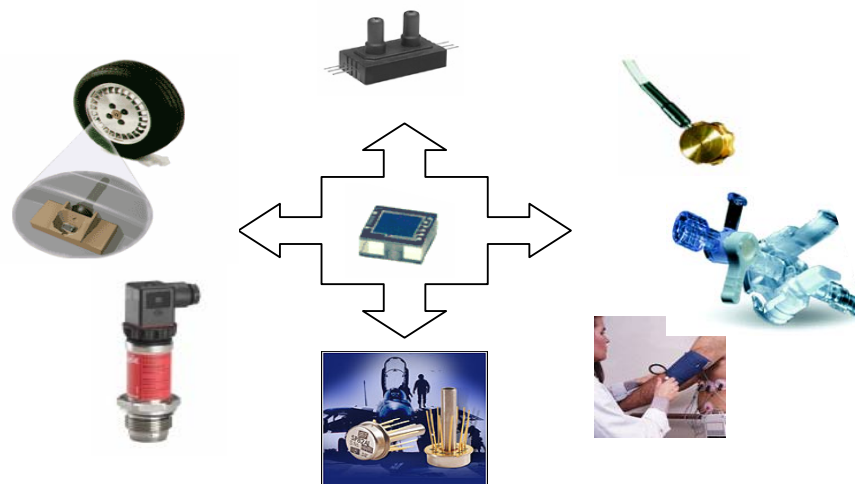


Figure 18 Illustration of the generic character of the technology. A MEMS-based pressure sensor element could be integrated into a wide range of different microsystem applications.

3.5 Current Challenges

Some of the obstacles preventing a wider adoption of microsystems are:

Limited Options

Most companies who wish to explore the potential of microsystem technologies have very limited options for prototyping or manufacturing devices, and have no capability

or expertise in microfabrication technology. Few companies will build their own fabrication facilities because of the high cost. A mechanism giving smaller organizations responsive and affordable access to MEMS fabrication is essential.

Packaging

The packaging of MEMS devices and systems needs to improve considerably from its current primitive state. MEMS packaging is more challenging than IC packaging due to the diversity of MEMS devices and the requirement that many of these devices be in contact with their environment. Currently almost all MEMS development efforts must develop a new and specialized package for each new device. Most companies find that packaging is the single most expensive and time consuming task in their overall MEMS product development program. As for the components themselves, numerical modeling and simulation tools for MEMS packaging are virtually non-existent. Approaches which allow designers to select from a catalog of existing standardized packages for a new MEMS device without compromising performance would be beneficial.

Fabrication Knowledge required

Currently the design of a MEMS device requires a high level of fabrication knowledge in order to create a successful design. Often the development of even the most mundane MEMS device requires a dedicated research effort to find a suitable process sequence for fabricating it. MEMS device design needs to be separated from the complexities of the process sequence.

4 Nordic microsystems activities – an overview

All Nordic countries have invested in competence and facilities supporting and stimulating the development of microsystems. The microsystem technology programmes in each country have different focus and size and are targeted towards different goals and directions. Realizing a common Nordic knowledge base on microsystem technologies will open unique opportunities for Nordic companies looking into areas for future product applications. In the following, an overview of the competence and the main actors and activities in each country are described. Appendix 1-4 present a list of actors at universities, institutes and industrial enterprises in each country as a supplement to this chapter.

4.1 Sweden

4.1.1 Summarizing the activities in Sweden

Microsystem technology is in Sweden ranked as an area of strategic industrial importance. Sweden has a large range of companies that are seen as future users of microsystems, companies highly suitable for microsystems applications. These companies represent a number of different application areas, such as IT, Automotive, Medicine, and Biotechnology. The concept of microsystems fits very well into the classical Swedish industrial focus on niche applications.

The growth of industrial companies in Sweden using microsystems has unfortunately not met the expectations. The Swedish position is today characterised by a strong investment on research and development of the fundamental micromechanical processes. Less has unfortunately been invested on factors important to the commercialisation and industrialisation of microsystems. These are factors such as reproducibility, reliability, cost optimization and industrial infrastructure. Another growth constraining factor is the low knowledge and awareness of the concepts and possibilities of microsystems within the Swedish industrial community. An important initiative has been taken by KKstiftelsen (The Swedish Foundation of Knowledge and Competence) which during 2004 has invested in a two-year program called MinST. The overall objective of the program is to enhance the competence level of Swedish SMEs in Micro and Nano Technology. The program has now successfully been running for one year and more than 100 SMEs has been involved in the program. The intention from KK-stiftelsen is to make further investments in the program after the two-year starting period. But there must be more and stronger initiatives made, oriented towards industrialisation and commercialisation of microsystems if Sweden is to be able to benefit from the investments made in universities and institutes. The estimated value of the R&D-work carried out at universities and institutes is in the order of 100 man-years per year, the Swedish industry is estimated to be engaging approximately 200 man-years per year, thus resulting in a total of approximately 300 man-years per year.

4.1.2 Actors in Sweden

Universities and Universities of Technology

Uppsala University (UU), Division of Materials Science and the Division of Solid State Electronics at the Ångström Laboratory, is the leading university today for research and development in the microsystems area in Sweden. The activities are focused in three centres

- SUMMIT (The Center for Surface and Microstructure Technology), Microfluidics, Radio Frequency Applications (μ RF), Micro-optics (μ O) and Generic MST (μ G)
- AME (The Strategic Centre for Advanced MicroEngineering) recently transformed into AMNE (Advanced Micro and Nano Technology), Medical/biomedical/ biological applications, microoptical materials and modules for telecommunication
- ÅSTC (The Ångström Space Technology Centre) projects related to nano satellites, micropropulsion, thermal Switches and micro Pyros are carried out.

Chalmers University of Technology (CTH), the research related to microsystems is performed within the Department of Microtechnology and Nanoscience, MC2, which also houses the most advanced clean room facilities in Sweden. The Department is divided into 6 Laboratories, of which five are research laboratories and one is the clean room Laboratory. Large efforts, experimental as well as theoretical, are directed at materials, devices and subsystems for future micro/nanoelectronics in the fields of microwave electronics, quantum devices, photonics, micro- and nanosystems, superconducting devices and circuits and molecular electronics. There are three research centres:

- HSEP (High Speed Electronics and Photonics), an SSF Strategic Research Centre) 2003-2007,
- NANODEV (A research centre on future electronic components and quantum computing), supported by SSF, 2003-2008.
- CHACH (Chalmers Center for High-Speed Technology), Swedish competence centre, where Chalmers and companies jointly perform research.

In 2004, an International Master Program in Microsystem Integration Technology has started at Solid State Electronics Laboratory. On going projects within this are Beam steering, Fuel cells, Coriolis mass flow sensor, Viscosimeter, Micro-optics and RF-MEMS switches.

Royal Institute of Technology (KTH), Department of Signals, Sensors and Systems, Microsystem Technology (MST) and the Electrum Laboratory in Kista outside Stockholm are working in a number of different activities in the medical field (MedMEMS), the biotechnology field (BioMEMS), optical components (optoMEMS) and radio frequency signal components (RFMEMS).

Linköpings University (LiU), The Department of Physics and Measurement Technology, Biology and Chemistry, at the competence centre of S-SENCE (Swedish Sensor Centre). A number of projects are performed within the field of bio- and chemical sensor science and technology, comprising a direct co-operation between the Division of Applied Physics at Linköping University and industrial partners

At Lund institute of Technology (LTH), the Department of Electrical Measurements mainly focus on medical applications for microsystems. A number of spin-offs have been generated utilizing the microsystems research in medical applications.

Mälardalen University (MDH), The Department of Electronics are working on research projects concerning micro CO₂ sensors and dielectrophoresis for cell separation.

Institutes

Acreeo, working mainly in the field of BioMEMS (chip for protein analysis, immunoassays, neuroprobes) and OptoMEMS (design for optical broadband communication). Acreeo is also involved in various industrial projects for sensor development.

FOI (The Swedish Defence Research Agency), is mainly financing different research projects within the microsystems area, these projects are carried out in cooperation with Universities, institutes and industry.

Imego (Institute of Microelectronics in Gothenburg), specializes in microsystems technology in the field of biosensing, micromechanical systems, as well as sensor systems based on optical- and magnetic sensor elements. A motion tracking system has been developed based on some of Imego's patented inertial sensor components.

IVF (Industrial Research and Development Cooperation), working in projects concerning , microsystem integration and Micromechanical packaging and assembly. The Ceramic Institute is now being part of IVF. They are involved in materials (ex. LTCC) for new hybrid integration with Micro System Technology.

Industry

Some of the large companies in Sweden are at present involved in development and manufacturing of Microsystems. These companies, such as ABB, Alfa Laval, Autoliv, Bofors, Electrolux, Ericsson, Saab, Tetrapak, and Volvo play a major role in this development. Daughters of foreign companies are also involved in the development of Microsystems; these are for instance branches of Amersham, Agilent and Datex-Ohmeda. There are also a few small companies involved in development and manufacturing of microsystems, these are companies like Silex and Åmic. But the vast numbers of companies engaged in the microsystem area are very small companies, often spin-offs from universities and institutes.

Laboratories

During the last couple of years there have been some heavy investments made in large clean room and laboratory facilities in Sweden, such as the MC2 in Gothenburg, the Ångström Laboratory in Uppsala and the Electrum in Kista. The main parts of the investments are closely linked to universities and research institutes. Sweden has a very good base for development of microsystems. Mainly due to a lack of response from the government and the industry, these laboratories today have problems with their financing.

4.2 Denmark

4.2.1 Summarizing the activities in Denmark

The Danish microsystems activity has a relatively short history. Before 1990 only one company, Danfoss, had a MEMS-based product and the university research had a very low level of 5 man-years per year. At 1990 MIC at DTU was established and later in the 90's the MOEMS activities was spun out into COM at DTU. COM and MIC has since that time been the centre of the Danish activities.

The research is still concentrated around MIC and COM and the total activity is more than 120 man-years per year. To support the commercialization, 5 service providing institutes has established activities of 35 man-years per year. DELTA is the strongest and started its activities more than 10 years ago²³. The industrial activities in Denmark have risen from nearly nothing in 1990 to an activity of 250 man-years per year. The industrial activity is characterized by having a handful of companies who now have their own production facilities, 10-15 start-up companies and 5-10 established companies, mainly with the medical field who now are entering into R&D. Nearly all industrial activities are related to or spin-offs of the research done at MIC and COM. Therefore the microsystems community in Denmark is closely linked and enjoys very good collaboration and only very little competition.

In research and product development the Danish activities are strongest within Lab-on-a-chip (MIC and Danfoss), pressure sensors for industrial use (Grundfos and Danfoss), silicon microphones (Sonion) and integrated optics for telecom (COM and NKT-integration and Hymite). The strong industrial focus on the Danish activities has resulted in focus on packaging and test, and establishing an R&D lab (PackLab) which is common for 4 industrial companies together with DELTA.

In terms of annual economic activities the government spends approximately 100 MDKK and the companies spends approximately 300MDKK on R&D and production of microsystem based products.

²³ ref. fact sheet on MEMS and MOEMS in DK

4.2.2 Actors in Denmark

Universities

MIC, Mikroelektronikcenteret and COM²⁴ at DTU have the highest activities in microsystems research in Denmark. The activities include MEMS design and MEMS prototype processing, which is possible because of the 1000m² processing clean-room (class 100). Furthermore the activities involve a bio- and a nanogroup.

At the two departments 7 professors are involved with research of microsystems. Besides education of Post Docs and Ph.D. students in the field, MIC and COM also offers master courses of different kinds in microsystems.

IPL is another institute at DTU working mainly with electroplating and surface plating of MEMS for various purposes.

Ålborg University, SMI has sensor activities for medical purposes. The activities are based on mostly designing and use of MEMS.

Institutes

DELTA has a business area, Microsystems, where the activities are concentrated on MEMS-wafer testing, MEMS-prototyping, MEMS-packaging and MEMS-failure analysis. DELTA has clean-room facilities for interconnection prototyping and a packaging clean-room in collaboration with 4 companies next to MIC. Another division at DELTA is Optical sensor systems, where some of the work has been concentrated on miniaturized optical sensors.

RISØ has activities in the MOEMS area, and in collaboration with COM and MIC education of Post Docs. , Ph.D. students and Master students.

Technological Institutes departments Microtechnology / Surface analysis and Polymers offers injection moulding and laser cutting of microstructures in polymers. Microtechnology / Surface analysis also have surface and failure analysis of microelectronics.

STC, Sensor technology center, is a network organization owned by 5 GTS²⁵ institutes, including DELTA and Technological Institutes. STC is offering knowledge in the sensor area and contact to the owners. The conclusion of an evaluation of STC is that the center is joining and focusing the work in the microsystems area for all of the 5 owners²⁶.

²⁴ COM – the Department of Communication at DTU, Danish Technology University

²⁵ GTS – Godkjente Teknologiske Serviceinstitutt (DK)

²⁶ ref: International Evaluation of Sensor Technology Center and the Danish Sensor Initiative

Industry

Several companies have started production of MEMS and MOEMS components in their own cleanroom production facilities. As well as using the MEMS components for own products, they also offer MEMS-fab services. The companies are Grundfos, SonionMEMS and NKT-research.

Danfoss and Dicon do not have MEMS-processing facilities, but have production of finished packed MEMS components.

Grundfos has succeeded in developing a MEMS pressure sensor for the core product, pumps. Other companies are interested to implement MEMS sensors in their products and have parts of their research departments to look actively into this area. This group mostly counts hearing aids companies and medical companies.

Some of the larger companies have researchers placed at MIC for processing in the laboratory, and some of these companies also join the Packlab partnership with DELTA

A lot of start-ups and spin-off companies have started within the MIC. These companies use the process laboratory at MIC. Since this collaboration between MIC and the smaller companies the process facilities are expanded with Danchip.

The smaller companies are divided in two groups, one that produce or develop own products and one group that has services in MEMS. The latter group includes MEMS-fabs as NanoNord, SMB, Hymite. The first group is smaller companies with a few products. The counterpart of the small companies is still mostly research units and is funded by investments funds.

Strategic projects

Of the financed projects there is some different issues that has been covered such as MEMS design, Miniaturized Sensors, MEMS packaging, MEMS production.

- MEMS design: MiNAP, μ KAP, μ chem, Sesibon, Histack, Immunalyze, Freja, MicroTAS(Frameprogram)
- Miniaturized Sensors: MINOS, μ KAP,
- MEMS Packaging: SUM, MiNAP, μ KAP, Histack, Sesibon
- MEMS Production: SUM, MiNAP, NORMIC

The projects have a wide range of application area from bio, medical and chemical use (μ KAP, Immunalyze, μ Chem, MicroTAS (Frameprogram)) to pressure sensors (SUM). Optical sensors mostly for flow measurements have been developed in MINOS.

Networks, conferences and supplementary training

Different kinds of networks have been established at national and Nordic level. A SPM-erfagroup called “Microsystem and minisensors – production and quality” has been started by DELTA. A Nordic chapter of the IEEE-CPMT has lived successfully for several years.

During the last 5 years different kinds of conferences, workshops, theme days and exhibitions have been held in Denmark. Ex. EuroSensor, SUM-workshop, Workshop on MEMS Sensor Packaging, ECOC.

The TI is the only one to offer supplementary training in the area of microsystems technologies with the course “Lab-on-a-chip”.

4.3 Norway

4.3.1 Summary of Norwegian MST activities

Microsystem technologies have a long history in Norway. Research activities carried out at SINTEF during the last 30 years, have been industrialised by companies like SensoNor, Memscap, Presens and AME with great success. The airbag-sensor SA20 to SensoNor could be found in 35 million cars all over the world. But other parts of Norwegian industry have not looked into the possibilities offered by the technology, and at the moment there is a need for “industry push” for applications realised by microsystems. Nor the Norwegian universities have traditions in this area, and the activities in the different groups nowadays have only been going on for some years. The Norwegian Microtechnology Centre (NMC) initiative was developed and pushed from SINTEF in 1997 and in 2003 a new laboratory with state-of-the-art facilities will be opened as a result of this initiative. A packaging lab and a realisation of a new institute for microsystem technologies at Vestfold College are also results of the initiative.

4.3.2 Actors in Norway

Universities and colleges

During the last 5 years the interest for MEMS and microsystem technologies at the universities has increased a lot. Both the University of Oslo and the Technical University of Trondheim have been running different programs and projects focusing aspects of microsystem technology.

At the University of Oslo, two departments are running MEMS related activities. The University will run one of the clean-rooms in the new Micro- and nanotechnology Research Laboratory (MRL) and start teaching classes in MEMS processing and optical MEMS as a supplement to the existing course in design and modelling.

At the University of Trondheim, department of Physical Electronics, ASIC for MEMS and micro optic components are two research areas.

Vestfold College, HVE, in Horten has the last years established a new department of microsystem technology. A bachelor education was started in 2002 as one of the first in Europe at this level. Master education is planned from 2005. Packaging and interconnection technologies is the main focus for the institute together with MEMS design and modelling.

Institutes

SINTEF has a history of research activities within microelectronics and microsystems since 1960. The Electronics and Cybernetics institute has been the main national player in the development of microsystems, and is offering both design competence and production facilities to national and international customers.

Electronics and Cybernetics offers research based innovation based on microsystem technologies. The institute covers all aspects of microsystem technology (sensor, microelectronics and actuator), from MEMS design and production to packaging and integration and ASIC design. The new laboratory, which will also house groups from the University of Oslo, will drastically improve the capabilities in MEMS design, process development and production.

Some other SINTEF institutes have started looking into the micro- and nanotechnology areas

Industry

SensoNor is one of the world's leading designers and volume producers of sensors and devices based on silicon microtechnology (MEMS). Since 2004 SensoNor has been an Infineon-company, and their competence centre within MEMS. In addition to its own multi-disciplined MEMS design team, the company has its own waferfab and high volume backend production and test facilities. SensoNor also offers foundry production services to international customers within the MultiMEMS project.

Some other companies, like PreSens, AME and Memscap, are also doing design and production of MEMS-based sensors. During the last years many start-up companies, like Idex, Alertis Medical and NorChip, have been established based on an idea of developing a MEMS-based sensor or product.

Other parts of Norwegian industry are in general not aware of the possibilities with MEMS technology. A few have started looking into the possibilities.

Research activities

Both SINTEF and the universities (UoO, NTNU and the last years HVE) have been running strategic research projects during the last 5 years.

SINTEF has been involved in 8 different EU-projects financed in the 5th framework program in EU. For the 6th framework program, the institute is involved many projects within Microsystems, at least three of them as the project coordinator.

In Horten, Microtech Innovation is developing an incubator concept focusing innovation through microsystems. This incubator is set up in close co-operation with HVE and SINTEF.

During the last years, FFI – the Norwegian Defence Research Establishment, has built up competence within MEMS design and applications.

Laboratories

The new MRL laboratory in Oslo with state-of-the-art equipment will make it possible to exploit the potential of microsystem technology. The facility will be an excellent national facility for micro- and nanotechnology. SINTEF will put efforts on the design and production of advanced microsystems, whereas the University of Oslo also will look into the nanotechnology area. The laboratories will be up and running during 2004.

At NTNU, the clean-room at the Department of Physical Electronics has equipment for e.g. thin film sputter deposition, optical analysis, Surface Acoustic Wave laser probing and semiconductor processing.

In Horten, Microtech Innovation has established a packaging and interconnection laboratory together with Vestfold college, HVE. The research activity at HVE will be concentrated at this lab. HVE is also establishing a clean-room facility for the student activities at HVE.

4.4 Finland

4.4.1 Overview of the status in Finland

The microsystem activities are quite plentiful in Finland. There is one high-volume manufacturer of MEMS devices (VTI Technologies), medium-volume microsystems production for specific applications between Vaisala and VTT, silicon and SOI wafer manufacturing with focussed emphasis toward the MEMS market, a silicon IC / integrated passive device manufacturer, some other semiconductor, contract manufacturing, and packaging companies as well as enterprises interested in applying novel microtechnologies in their various electronic products.

4.4.2 Actors in Finland

Universities

The most intense academic microsystem activity in Finland is within Helsinki University of Technology (HUT). HUT has a high-quality clean room facility in the Micronova building with good equipment base to perform various fabrication studies. They also have long history in MEMS modelling, partly together with Centre for Scientific Computing (CSC). University of Jyväskylä strives for nanoelectronic expertise. Tampere University of Technology has strong background in (non-MEMS) III-V device development. Other supportive microelectronics activities are available for example in the University of Helsinki (Atomic Layer Deposition), University of Oulu (laser ablation), and University of Joensuu (electron-beam writing).

Industry

VTI Technologies fabricates well beyond 10 million micromechanical devices yearly, most of those for automotive applications. It is a world leader in the design and production of low-g accelerometers. VTI offers solutions in acceleration, motion, shock, vibration, inclination and pressure measurements to a wide global customer range. Their goal is to increase the turnover to 1500 MDKK by 2009. Okmetic produces silicon wafers, striving for high quality products for semiconductor, sensor, and microsystems market. In addition to silicon wafers they also have silicon-on-insulator (SOI) products. Silicon-based analog-digital integrated active as well as passive circuits are produced in Micro Analog Systems or MAS and SiP Technologies. They participate in national and international microsystems projects. Companies already utilizing or developing microsystems in their products include Vaisala (CO₂ transmitters, radiosondes, and weather stations), Polar, Suunto, (fitness / sports instruments), Nokia, and Datex-Ohmeda / GE Medical Systems (patient care). Companies with component, back-end and packaging expertise include Filtronic Comtek, LK Products, Selmic, and Elcoteq, and to name a smaller one, Rikola Ltd. Nokia is a major user of microsystems in their mobile terminals but has rather limited component development activities. Polar manufactures modern fitness/sports -related goods. Honeywell has recently opened the Center of Excellence Finland, which acts as a developer of products, solutions and services for the pulp, paper, and printing industries. Part of PerkinElmer Life and Analytical Sciences, former Wallac is another potential user of advanced microsystems in their products. They, alike Thermo LabSystems or Fluillogic might find use e.g. for microfluidic products. Companies that already have expressed their interest in modern microelectromechanical products through participation in national projects can be listed as follows: Metso Automation, Fortum, Oras, Enermet, Coherent Tutcore, among others. Silecs produces low-k dielectric materials for microelectronic fabrication and ASM Microchemistry, Picosun, and Beneq work on ALD processes. Planar Systems manufactures electroluminescent display devices (although not presently utilizing microsystem technologies). Some detector companies – Oxford Instruments, Detection Technology, and Ajat - may also find interest in fabrication techniques originally developed for MEMS.

Institutes

VTT, the Technical Research Center of Finland, has been working on surface micromachining since the early 90's. The starting point was polysilicon-based thin film technology making use of oxide sacrificial layers. More recently (1997) SOI technology has been elaborated, and amorphous metal micromachining was initiated in 2000. VTT can also monolithically integrate CMOS and MEMS. Some discrete devices are commercially produced at VTT Micronova facilities, either using industrial or VTT personnel. Fabry-Perot interferometers and thermopiles, optimized for infrared wavelengths, are manufactured. Other commercially produced microdevices (non-MEMS) are ultra-sensitive magnetic field sensors (SQUIDS) and radiation detectors. Pressure sensors and capacitive micromachined ultrasonic transducers also have mature fabrication technology. Additionally, devices such as microresonators (silicon, AlN, and ZnO), acoustical emission sensors, and microphones have successfully been made.

Centre of expertise of Adaptive Materials and Microsystems (part of Culminatum) promotes utilisation of microsystems in business, job creation and regional development.

Projects

Tekes, the National Technology Agency, is a major player in supporting R&D in Finland. They previously had a focussed program on MEMS and precision technology. Presently the dominant programme covering the MEMS field is called ELMO, striving for electronics miniaturization. ELMO is carried out between 2002-2005, and its budget is about 100 M€. Of course, only part of its titles is microsystem-related. The listing of the separate projects is most conveniently achieved through Tekes web pages²⁷.

The Academy of Finland has a programme on Future Electronics. Finnish universities, institutes, and companies strongly participate in the 6th framework projects of EU and its Networks of Excellence on microsystems and MEMS. VTT is a coordinator in an Integrated Project on nanopatterning methods (NaPa), and also plays an important role in MIMOSA, Microsystems Platform on Mobile Services and Applications.

Lab resources

For R&D, VTT and HUT share a high-quality (class 10) clean room facility of 2600 m², housing BiCMOS, MEMS, microfluidic, and thin-film technologies. The Micromodule Centre at VTT in Oulu has additional facilities and technologies such as low-temperature co-fired ceramics (LTCC) that has been used for MEMS prototype packaging. Discrete process steps and manufacturing support can be obtained from various industrial and academic sources. The other R&D facilities but VTT have limited capabilities for producing volumes of devices. The personnel working closely on microsystems at VTT exceed 30. What seems to be missing in the Finnish scene is

²⁷ <http://akseli.tekes.fi/Resource.phx/tivi/elmo/en/description.htm>

the commercialization path for MEMS devices within industries not familiar with handling silicon-based devices or chips.

4.4.3 Conclusion

The Finnish infrastructure in the field of microsystems is quite well developed and self-contained. There is an important volume manufacturer of MEMS (VTI Technologies), although only a single one. There is a range of other micro / nanoelectronic industrial activities. Additionally, there is a spectrum of various companies generating application ideas and technology services. There exists also a well-equipped R&D institute for prototyping and low-to-medium volume production (VTT). An important link is, however, missing between VTT as a MEMS wafer or chip producer and the multitude of companies not familiar with handling microelectromechanical devices on chip-level but still possessing potential interest of using those in their systems. The company base in a small country like Finland is limited, and the infrastructure could be strengthened through effective Nordic collaboration.

5 Nordic research

During the last two years, some Nordic initiatives have been taken to stimulate the research activities with a Nordic perspective.

5.1 NORDITE

VINNOVA, The Research Council of Norway (RCN) and The National Technology Agency of Finland (Tekes) launched during the winter 2005 a new technology programme, NORDITE. The new programme is only open to research organisations in the above-mentioned countries, and it will focus on research projects that will bring about positive results for the Scandinavian ICT industry. Tekes and VINNOVA have co-operated earlier in two technology programmes: INWITE in 1996-1999 and EXSITE in 2000-2003.

On April 25th 2005 a call for proposals was opened in the fields of technology development for SW radio, wireless sensors, short-range wireless networks and RFID or MEMS utilizing RF technology. The purpose with the call is to assist Swedish, Norwegian and Finnish research institutes and companies to further develop and demonstrate their technical expertise in that area. The proposals should be collaboration projects between research groups in Finland, Sweden and Norway.

Decisions about which projects to be started are made during November 2005, and projects may start in January 2006. There exists proposals both within RFID-technology related to sensor applications and RF MEMS.

More information is available at <http://www.tekes.fi/english/programmes/nordite>.

5.2 Nordic MINT

Within the field of micro- and nanotechnology, development is quick and expectations on future benefits are growing even faster. The Nordic countries possess great know-how on already applicable inventions, e.g. micro-sensor and advanced and intelligent materials technology. However, possible application areas can be extended widely over disciplines, research projects and business units through sharing of knowledge and best practices.

To secure participation of the Nordic countries in safety issues and pre-normative work, the focus of Nordic MINT aims at promoting interaction and platform-building between the Nordic industries and scientific communities within micro- and nanotechnology.

Nordic Innovation Centre will launch a call for proposals probably during December 2005, and projects may be started around 6 months later.

More information is available at www.nordicinnovation.net.

Appendix 1 - Microsystems actors in Sweden

Microsystem research and services and microsystem based products in Sweden

Universities and Universities of Technology	Examples of on-going Projects	www
Chalmers University of Technology (CTH)	Beam steering Fuel cell Low temperature wafer-scale encapsulation and transfer technology Coriolis mass flow sensor Viscosimeter Micro-optics: SLM technology Fatigues and mechanical strength of microstructures RF-MEMS switches Nanoindenter Magnetic filed sensor Micromotor	www.ic.chalmers.se
Royal Institute of Technology (KTH)	Microbeads based processes On-chip liquid handling Mass spectroscopy spraying tips Transdermal liquid interfacing Transdermal biopotential electrodes Turbulent gas flow measurement Valve-less fluid micro-pump Micropneumatic gas control devices Thermal infrared-detector array Micromirror arrays MEMS for Antenna Systems Packaging and sealing Adhesive wafer and transfer bonding	www.s3.kth.se/instrlab
Linköpings universitet (LiU)	High temperature sensors based on SiC Time stable gas sensors	www.ifm.liu.se
Lund institute of Technology (LTH)	SI-integrated enzyme reactors Implantable nervus contact for control of artificial limbs	www.elmat.lth.se
Uppsala University (UU)	Micro dispensing MST for Microfluidics (μ F) MST for Radio Frequency Applications (μ RF) MST in Micro-optics (μ O) Generic MST (μ G) Nanosatellite programme Micro Propulsion Cold Gas Thrusters Micro Pyros Variable Emittance Panels Thermal Switches 3D-Multi Chip Modules 3D-Sun Acquisition Sensor RF-MEMS	www.mst.material.uu.se
Mälardalen University (MDH)	CO2 sensor DEEP - Dielectrophoresis for cell separation	www.mdh.se/iel/

Institutes	Examples of on going Projects	www
Acreo	BioMEMS Protein chip Immunoassays Neuroprobes Design of a optical system for broadband communication Generic MEMS Is mainly a financer of different research projects within the MEMS-area	www.acreo.se
FOI		www.foi.se
Imego	Micro switch for telecom applications Beam steering, using MEMS-technology for guidance of light beams Bonding of SI-chip to a multilayer LTCC Motion Tracking by Inertial Sensors Development of a 3-axis accelerometer-system Development of a new gyro-system for "flying objects" MOEMS-systems using LTCC-technology Development of a Micro analysis viscosimeter MEMS platform for Bio reaction analysis MIP applied on MEMS-structures Micro fluidics	www.imego.com
IVF	Micro system integration Mirco mechanical packaging and assembly	www.ivf.se
MEFOS	Optical Measurements of red-hot material	www.mefos.se
Companies active in the development of microsystems	Products	www
ABB Robotics	Industrial robots	www.abb.com/robots
Adamantis AB	Diamond optics Design, manufacturer and supplier of electronic and optical instruments, systems and solutions for testing and measuring	www.adamantis.com
Agilent		www.agilent.com
Alfa Sensors	Humidity Time Indicators (HTI)	www.alfasensor.com
Amersham Biosciences AB	Biosensors	www1.amershambiosciences.com
Applied Sensor AB	Chemical sensor components and sensor modules for Air Quality Control for Comfort and Safety	www.appliedsensor.com
Autoliv	Automotive safety	www.autoliv.com
Biacore AB	Biosensors	www.biacore.com
Biosensor Applications AB Sweden	Trace detection sensors for drug detection	www.biosensor.se
Bofors Defence AB	Military Defence Sensor applications	www.boforsdefence.com/sv/home.asp
Cellectricon AB	Advanced chip-based technologies, primarily, for the discovery of new drugs	www.cellectricon.s
Ecsibeo AB	Novel technology for fast in-plane switching of liquid crystals	www.ecsibeo.se
Ericsson Microwave Systems	Radar sensors and military information networks	www.ericsson.com/microwave
Ericsson Radio Systems AB		www.ericsson.com/se/
Instrumentarium AB / Datex-Ohmeda	Sensors for medical use	www.datex-engstrom.com/
Gyros AB	Gyros miniaturizes and integrates laboratory applications	www.gyros.se
Hök Instruments AB	Sensor for pulse oximetry and concentration of carbon dioxide	www.hokinstrument.se
Medirox AB	Sensors for haemostatic diagnostic	www.medirox.se
Micronic AB	Manufacturer of high-end laser pattern generators for	www.micronic.se

	the production of photomasks	
Optronic AB	Development and manufacture of a number of optronics products	www.optronic.se
PiezoMotor Uppsala AB	Linear piezo motor	www.piezomotor.com
Pyrosequencing AB	Sensors for DNA analysis	www.pyrosequencing.com/
RADI Medical Systems AB	Sensors for medical use OEM provider of modular continuous tunable laser sources for fiber optic telecom and sensing and spectroscopy applications	www.radi.se
Radians Innova AB		www.radians.se
SAAB Bofors Dynamics AB	Sensors for military use	www.saab.se/dynamics/
Saab Aerospace and Defence AB	Sensors for defence, aviation and space	www.saab.se
Samba Sensors AB	Sensors for pressure measurement	www.samba.se
SenseAir AB	Sensors for Indoor Climate Control	www.senseair.se
Silex AB	Designing MEMS applications for the telecommunications and life science industries	www.silexmicrosystems.com
Spectrogon AB	Manufactures and develops thin film products and holographic gratings	www.spectrogon.com
Åmic AB	Development and manufacturing of biochip platforms	www.amic.se
XaarJet AB	Invent and manufacture digital inkjet technology	www.xaar.se

Appendix 2 – Microsystems actors in Denmark

Microsystem research and services and microsystem based products in Denmark

Universities		www
MIC,		www.mic.dtu.dk
COM		www.com.dtu.dk
IPL		www.ipl.dtu.dk
Ålborg University, SMI		www.smi.auc.dk
Institutes		
DELTA		www.delta.dk
Risø		www.risoe.dk
Technological Institute (TI)		www.teknologisk.dk
STC		www.stc.dk
Companies	Products	www
Atonomics	Bio-chip, allergy	www.atonomics.dk
Brüel & Kjær	Accelerometers, microphones	www.bk.dk
Cantion	Chemical analysis systems	www.cantion.com
Capres	Micro-4-point probes	www.capres.com
Chempaq	Medical sensors	www.chempaq.com
Dancotech	Assembly	www.dancotech.dk
Danfoss	Pressure sensors, chemical analysis systems	www.danfoss.com
Dantec	Flow-measurement (optical)	www.dantec.dk
Dicon	MOEMS	
DME	AFM/STM/SNOM-microscopes	http://www.dme-spm.dk/
Exiqon	DNA-chips	www.exiqon.dk
Flextronic	Assembly	www.flextronic.com
Foss	Food-sensors	http://www.fossdanmark.dk/
GN Resound	Hearing aids	www.gnresound.dk
Grundfos	Pressure sensors	http://www.grundfos.dk/
Hymite	Optical component	http://www.hymite.com/
Ibsen Photonics	MOEMS	www.ibsen.dk
NanoNord	Clean-room, foundry	www.nanonord.dk
NKT Integration A/S	MOEMS	www.nktintegration.com
NKT Research Center A/S	MOEMS	www.nkt-rc.dk
Novo Nordisk	Biomedical analysis	http://www.novonordisk.dk/
Oticon	Resonators	www.oticon.dk
Radiometer	Medical sensors	http://www.radiometer.dk/ http://www.radiometer.com
Scandinavian Micro Biodevices A/S (SMB)	DNA-chips, Microflow components	www.smb.dk
SonionMEMS A/S	Microphones, resonators etc.	http://www.sonionmems.com
Sophion	Medical components	http://www.sophion.dk/
Thomsen Bioscience	Bio-chip	www.thomsen-bioscience.com
Topsil	Silicon wafers for special applications	http://www.topsil.com/
Widex	Assembly of hearing aids	www.widex.dk
Vir A/S	Polymer systems for 'surface plasmon resonance'-measurement	http://www.vir-tech.dk/
Xenogenix	Systems for GMO-detection in food	http://www.xenogenix.com/
Giga, Intel		http://www.giga.dk

Projects (national & European)	Danish participants
SUM (DK)	DELTA, Danfoss, Grundfos, Capres, MIC, SonionMEMS
MiNAP (DK)	DELTA, Capres, MIC, NKT-research, Flextronic, Århus Universitet
Mikrokap (DK)	TI, DELTA, Danfoss, Vir, Radiometer, STC, MIC, IPL, Atonomics
Microchem (EU)	MIC, Danfoss
Sesibon (EU)	MIC, Danfoss
MINOS (DK)	DELTA, Risø, IPL, TI, Dantec, Kamstrup, Radiometer
Rammeprogram (DK), MicroTAS	MIC
Freja (DK)	MIC
Histack (EU)	MIC
Immunalyze (DK)	MIC, Exiqon
Normic (EU)	MIC, DELTA

Appendix 3 – Microsystems actors in Norway

Microsystem research and services and microsystem based products in Norway

Companies	Products	www
SensoNor AS	Tyre pressure sensors, accelerometers, etc, wafer-fab, packaging, foundry services	http://www.sensonor.com
MEMSCAP AS	Pressure sensors, medical sensors	http://www.memscap.com
IDEAS ASA	Detection modules for gamma, beta and x-ray cameras	http://www.ideas.no
PreSens AS	Pressure sensors	http://www.presens.com
AME as	Photodetectors and optohybrids, manufacturing & assembly	http://www.ame.no
AME Space AS	SAW-filter etc. for space applications	http://www.alcatel-space.no
Scan-Sense AS	Pressure, temperature, load and force sensors	http://www.scansense.no
MicroComponent AS	Thick film substrates & hybrids assembly	http://www.microcomponent.no
Kitron Microelectronics AS	Design, manufacturing and assembly of MCM's and thick film hybrids	http://www.amitech.no
Ignis Photonix ASA	MOEMS component	http://www.photonix.com
NorChip AS	Biomedical diagnostic	http://www.norchip.com
LifeCare AS	Body-implantable wireless glucose-meter	http://www.lifecare.no/
Alertis Medical AS	Medical CO ₂ -sensor for ischemia measurements	http://www.alertismedical.no/
OptoMed AS	Medical sensors based on fiberoptics	
Fifty-four point seven AS	Photo-acoustic gas sensing	http://www.fifty-four.no
IDEX AS	Finger-print recognition technology	http://www.idex.no
Interon AS	X-ray imaging	http://www.interon.no
Sonitor AS	Positioning system based on ultrasound	http://www.sonitor.com
Tomra Systems ASA	Optical sensors	http://www.tomra.no
ABB Research	MEMS for instrumentation	http://www.abb.com/no
Simrad Optronics AS	Infrared radiation source	http://www.simrad-optronics.no
OptoSense AS	CO ₂ detectors	http://www.optosense.com
Tandberg Storage AS	MEMS for data storage systems	http://www.tandbergstorage.no
Nammo Raufoss AS / FFI	MEMS switch for ammunition	http://www.nammo.com
University / Institute / others	Field of work	www
SINTEF Dep. of Information and Communication, ICT	Research based development of microsystems Design and modeling of microsystems MEMS processing and characterization Radiation detectors Microsystems for demanding environments Packaging and interconnect ASIC for microsystems High-temperature ASIC	http://www.sintef.no
FFI the Norwegian Defence Research Establishment	MEMS switches, military applications	www.ffi.no
University of Oslo, UoO		http://www.uio.no
Dep. of Physics	Physical Electronics, defect generation in semiconductors, radiation defects in silicon, silicon carbide, point defects and diffusion in semiconductors. MST Micro System Technology	
Dep. of Informatics	FIN Films, Interfaces and Nanomaterials Device modelling and circuit simulations MOEMS and MEMS, Micro-opto-electromechanical and Micro-electromechanical Systems	

University of Trondheim, NTNU		http://www.ntnu.no
Dep. of Physical Electronics	Synthesis, analysis, characterisation, and fabrication of fibre Bragg gratings for sensors and communications, quantum optics Design of ASICs for microsystems Fiber- and Micro-optic Components and their Applications in Medical Sensors	
Vestfold College, HVE		http://www.hive.no/
Dep. of Microsystem technology	Design and modeling Microsystem packaging Bachelor education in Microsystem Technology (since 2002). Master education from 2005 Process/packaging lab facilities	
MicroTech Innovation AS	Incubator	http://www.microtech-innovation.no
Laboratories	Equipment	www
MRL - Micro- & Nanotechnology Research Laboratory	The facility will be an excellent national facility for micro- and nanotechnology research with a broad range of equipment for processing and characterization	
SINTEF & UoO, Oslo		
MTI - Microsystem Packaging Laboratory	Characterization of MEMS-components	http://www.microtech-innovation.no
HVE & MTI, Horten	Packaging of bare dies Wire-bonding Chip-on-board / thick film ceramics Biocompatible encapsulation	
Clean-room, Dep. of Physical electronics	Thin film sputter deposition	
NTNU, Trondheim	Optical analysis Surface Acoustic Wave laser probing and semiconductor processing.	
Research projects	Project focus	Participants (N)
MicroSystemTechnology (MST) - strategic institute project		SINTEF
FIN Films, Interfaces and Nanomaterials		UoO
Fiber- and Micro-optic Components and their Applications in Medical Sensors		NTNU
MOEMS and MEMS, Micro-opto-electromechanical and Micro-electromechanical Systems		UoO
Design of ASICs for Microsystems		NTNU
MST Micro System Technology		UoO
TESS (EU)	Photo acoustic gas sensing	SINTEF
PAMPAS (EU)	Photo acoustic gas sensing	SINTEF, 54,7 AS
IPHITEMPS (EU)	High temperature sensor packaging	SINTEF
NCMEye (EU)	Oil well down-hole instrumentation	SINTEF
PharusIT (EU)	Oil well down-hole instrumentation	SINTEF
HISICON (EU)	Solar cells	SINTEF
MASCOT (EU)	Acoustic CO2 sensing	SINTEF, SensoNor ASA
NETGAS (EU)	Photo acoustic gas sensing	SINTEF, SensoNor ASA
NORMIC (EU)	Manufacturing Cluster around SensoNor	SINTEF, SensoNor
MEMSOI I & II (EU)	Manufacturing Cluster around Tronic's Competence Centre for microactuators and MST processes	SINTEF
CCMICRO I & II (EU)	Competence Centre for Physical Measurement Systems	SINTEF
CCMeSys I & II (EU)		SINTEF
MOEMSC I & II (EU)	Competence Centre for MOEMS	SINTEF SINTEF, SensoNor, MicroComponent, HVE
MultiMEMS (EU)	Manufacturing Cluster around SensoNor	
HASTAC (EC)	High stability Altimeter SysTem for Air data Computers Automatic Detection of Disease Related Molecular	SINTEF, MEMSCAP
MicroActive (EC)	Cell Activity	SINTEF, Norchip
SmartHealth	Smart Integrated Biodiagnostic System for Healthcare	Norchip
e-CUBE (EC)		SINTEF, SensoNor

Appendix 4 – Microsystems actors in Finland

Microsystem research and services and microsystem based products in Finland

Universities		www
Helsinki University of Technology	MEMS, microfluidics	www.hut.fi
University of Jyväskylä	nanotechnology	http://www.jyu.fi/
Tampere University of Technology	modelling, III-V optics	http://www.uta.fi/english/ http://www.joensuu.fi/englishindex.html
University of Joensuu	optics, nanotechnology	http://www.joensuu.fi/englishindex.html
University of Oulu	micropackaging	http://www.oulu.fi/english/
Institutes		
VTT	MEMS	www.vtt.fi
CSC	MEMS modelling	http://www.csc.fi/index.phtml.en
InFotonics Center	optics	http://www.ifc.joensuu.fi/
Company	Products	www
VTI Technologies	inertial MEMS sensors, pressure sensors	www.vti.fi
Vaisala	environm. measurements	www.vaisala.com
GE Healthcare (former Datex-Ohmeda)	patient care	http://www.gehealthcare.com/fifi/index.html
Suunto	sports / fitness	http://www.suunto.com/
Polar	sports / fitness	http://www.polar.fi/
Heptagon	micro optics	http://www.heptagon.fi/
Coherent Tutcore	lasers	http://www.tutcore.fi/
Modulight	lasers	http://www.modulight.com/
Liekki	specialty fiber	http://www.liekki.com/
Corelase	specialty fiber	http://www.corelase.fi/
Nanocomp	nanotechnology	http://www.nanocomp.fi/
Nanoway Cryogenics	nanotechnology	-
Photonium	manufacturing technology	http://www.photonium.fi/
Noptel	optoelectronics	http://www.noptel.fi/nop_eng/
Teleste	data communication	http://www.teleste.com/
Rikola	micro-optic modules	http://www.rikola.fi/
Filtronic Comtek	RF for handsets	http://www.filtronic.co.uk/home.php
LK Products	RF for handsets	http://www.lkproducts.com/
Selmic	micro modules	http://www.selmic.com/
Honeywell	optical sensors	http://www.honeywell.fi/
ASM Microchemistry	atomic layer deposition	http://www.asm.com/
Picosun	atomic layer deposition	http://www.picosun.com/
Beneq	atomic layer deposition	http://www.beneq.com/
Planar Systems	electronic displays	www.planar.com
Micro Analog Systems	IC, integrated passive design	http://www.mas-oy.com/
SiP Technologies	IC, integrated passives	-
Okmetic	sensor / MEMS wafers	www.okmetic.com
Nokia	handsets, networks	www.nokia.com
PerkinElmer	life and analytical science	http://las.perkinelmer.com/
Fluilogic	liquid handling	http://www.fluilogic.fi/
Thermo Electron Corporation	liquid handling and micro-plate instrumentation	http://www.thermo.com/eThermo/CD/A/BU_Home/BU_Homepage/0,1285,116,00.html
Ajat	detectors	http://www.ajat.fi/

Detection Technology	Detectors	http://www.deetee.com/
Oxford Instruments	Detectors	http://www.oxford-instruments.com
Rados	Detectors	http://www.rados.fi/
Clothing+	smart clothing	http://www.clothingplus.fi/

Projects	Participants	
Integrated MEMS	VTT, Finnish companies, Tekes	
MIMOSA, Microsystems Platform for Mobile Services and Applications	VTT, Finnish and European companies, EU, Tekes	http://www.mimosa-fp6.com/
NaPa, Emerging Nanopatterning Methods	VTT, European companies and institutes, EU	http://www.phantomsnet.net/NAPA/index.php
MEMS Magnetometer	VTT, Finnish companies, Tekes	
Silicon Microresonators	VTT, Finnish companies, Tekes	
WASP, Wafer Scale Packaging	VTT, Finnish and European companies, Tekes	

Nordic Innovation Centre

The Nordic Innovation Centre initiates and finances activities that enhance innovation collaboration and develop and maintain a smoothly functioning market in the Nordic region.

The Centre works primarily with small and medium-sized companies (SMEs) in the Nordic countries. Other important partners are those most closely involved with innovation and market surveillance, such as industrial organisations and interest groups, research institutions and public authorities.

The Nordic Innovation Centre is an institution under the Nordic Council of Ministers. Its secretariat is in Oslo.

For more information: www.nordicinnovation.net