Agenda Graphene

A new Swedish area of strength

VISION 2030

"Sweden is among the world's top ten countries in deploying graphene to ensure industrial leadership."

Contents

THE FUTURE GRAPHENE BASED INDUSTRY

The graphene based industry in Sweden 2013 can be summarized as immature, where most established companies have a strong interest but with limited experience with graphene, a few companies with close connections to academia has some experience with graphene in the R&D phase, and university researchers with theoretical and experimental knowledge on several graphene research areas. **The SIO program will start transforming this immature and fragmented industry to an established industry where Sweden is among the world's top ten countries in deploying graphene to ensure industrial leadership.**

On the positive side, there is a lot of attention, a lot of curiosity both from R&D representatives within companies and from the general public, and a lot of innovation funding possibilities ahead. Smartly done, Swedish industry can use this attention and these funding possibilities for developing new products and new business strategies.

Chalmers is currently leading the high profile project the Graphene Flagship – an advantage Swedish industry can use for visibility, credibility and for partnering with European enterprises and researchers.

Since the graphene material can be used to improve several physical properties, in many diverse applications, in several industries, there is a unique opportunity to start cross-industry collaboration with actors that normally do not work together. Crossing these boundaries leads to possibilities of knowledge transfer, not only in the graphene or even the material area, but an opportunity to learn from each other in innovation processes, manufacturing processes, market approaches, and quality work and so on. It is important to act on this opportunity from a Swedish perspective. The national agenda outlined here will give Sweden a head start in the coming innovation, development and commercialisation activities.

For graphene, few straightforward innovation paths exist today since the development will rather be disruptive than incremental. Due to graphene's wide application potential and the lack of large and fully integrated industrial companies that can take the lead, new collaborations across industries and value chains will be needed. The national agenda will lead the way to new clusters, networks and innovation paths.

One should bear in mind that it is not only in Sweden where the graphene based industry is immature and fragmented, but other countries face the similar challenge. If we act now Sweden has a good chance of claiming market shares and of increasing the competitiveness of our industry.

Our recommendations in short

In short, we recommend the following activities for strengthening the Swedish graphene based industry;

1. Demonstrators and validation projects – open call for groups of Swedish companies.
2. Strengthening of material providers and of SMEs that develop and produce components – to remove a weak link in a future production value chain.
3. IP, research and business intelligence with newsletter for the members – to provide a knowledge and information platform
4. Create and foster meeting places – to connect the emerging industry
    a. Workshops six times during 2014 and the following years, workshops two times per year to establish new collaboration groups, and secure knowledge transfer. A meeting place for all involved companies and researchers.
    a. Additional meeting place for strengthen entrepreneurs and researchers relation.

WHY SWEDEN AND WHY GRAPHENE ?

In October 2013, the *Graphene Flagship* started - EU's largest research initiative ever. With a budget of one billion euros, the Graphene Flagship targets taking graphene from the realm of academic laboratories into European society in the space of ten years, thus generating economic growth, new jobs and new opportunities for Europeans as both investors and employees. There are already 126 research groups from universities, research institutes and companies on-board the flagship. The flagship will expand the coming years, to include even more innovation partners.

Chalmers is leading and coordinating the flagship. The director is Jari Kinaret, Professor of Physics at Chalmers who is also a board member of this agenda. This is a rare opportunity that can be turned into advantages on the national level.

Besides the coordinating role, Sweden is partaking in many other ways. Chalmers researchers are part of the work package sensors, fundamental science, and high frequency electronics. Umeå University is part of the energy application work package, Linköping University is part of materials and KI health & environmental aspects. Chalmers Industrial Technologies, CIT are leading the innovation work package. No Swedish company is yet a partner in the flagship.

Graphene has been subject to a scientific explosion since the ground breaking experiments on the novel material less than ten years ago, recognized by the Nobel Prize in Physics in 2010 to professors Andre Geim and Konstantin Novoselov at the University of Manchester. Graphene's unique combination of superior properties makes it a credible starting point for new disruptive technologies in a wide range of fields. Consisting of only one layer of carbon atoms, it is stronger than steel but still light and flexible. Electrons move up to 100 times faster in graphene than in silicon and it is also a transparent, combining electrical and optical features in an exceptional way.

Graphene has many exceptional properties, to the point where it can spark a technical revolution. The material has the potential to impact several future challenges e.g. within the areas of sensors, ICT, energy, new materials and life science.

Picture: Mikael Syväjärvi

Three significant properties on the atomic/molecular level give rise to a long list of desired physical and chemical properties on the macro level:

- **The carbon-carbon bond** is very strong (*cf*. hardness of diamond) which gives rise to excellent strength, as well as chemical and structural stability.
- **sp^2 hybridization** leaves one electron in a π-orbital that does not contribute much to the strength but is free to move around. This makes the two-dimensional structure possible, and makes graphene conduct heat and electricity extremely well.
- The **symmetry** of the hexagonal lattice results in an electronic structure half way between metals and insulators (*semimetal*) and linear energy spectrum near the Dirac Point level give rise to a constant optical absorption ($A = e^2/(4\varepsilon_0 \hbar c) \approx 2.3\%$) independent of wave length. This energy structure makes massless behaviour of electrons.

All these exceptional properties enable graphene to meet challenges within diverse areas, like;

- Flexible electronics: pressure sensor for pressure sensitive displays, electronic paper, flexible mobile phones, printed antennas
- Composites: lighter and more energy efficient transportation, electric conductive composites, thermal conductive composites.
- Energy: supercapacitors, batteries, electrodes
- High frequency electronics: transistors, terahertz imaging
- Medical applications: artificial retina, real time DNA sequencing, real time MR scan.
- Sensors with high sensitivity
- Desalination and filtering of water and other nano- or microfluidic applications

Examples of new products that can be enabled by graphene technologies include fast, flexible and strong consumer electronics such as electronic paper and bendable personal communication devices, and lighter and more energy efficient airplanes. On the longer term, graphene is expected to give rise to new computational paradigms and revolutionary medical applications such as artificial retinas. The applications are expected to contribute to solutions to several of the grand challenges stated in Horizon 2020 such as health, clean and efficient energy and green transport.

Research of other 2D-layered material is coming strong and will be included in the graphene class of materials when appropriate. In this agenda, however, we focus on graphene for clarity reasons.

Graphene can be a material solving several sustainability challenges;

- Exchange materials in existing products e.g. Indium Tin Oxide, ITO, and other scarce materials.
- Lower weight in vehicles will reduce fuel consumption.
- New products for future challenges; desalination of water, water purification, waste clean-up (even of radioactive waste), antibacterial solutions (implying less need for antibiotics), identification and removal of toxic substances inside the body.
- New challenges not foreseen today.

Several on-going projects evaluate graphene impact on health and environment, within the Graphene Flagship, as well as other on-going and finalized research project. So far, no alarming results have been reported. It is of participial importance to keep health and environmental issues in mind when developing manufacturing methods of graphene. Joint events with the nano-safety agenda are also foreseen.

The flagship has boosted awareness of the industrial possibilities offered by graphene all over Europe and has already resulted in substantial national programs on engineering applications of graphene in, e.g., the United Kingdom (70 million GBP), Poland (60 million PLN), Denmark (54 million DKK) and Sweden (60 million SEK). In addition, several European companies make large investments in graphene technology. In the flagship several European companies are partners: Nokia, Airbus, Philips, Thales, Repsol, ST Microelectronics, Alcatel Lucent, AMO GmbH, Graphenea, Aixtron, and Oxford Instruments.

In US and Asia, especially in Korea and China, large efforts are put into R&D and mass production processes of graphene. While the scientific production is evenly divided between Europe, Asia and North America, the data on patent applications in several key areas shows that Europe is clearly lacking behind in technological exploitation of the results – the European paradox. For instance, China has 2200 graphene related patents, US 1750, South Korea 1160, and UK 54[1]. The Swedish companies ABB, Impact coatings AB, Graphensic AB, Sensic AB, LunaLEC AB, SHT Smart High Tech AB, Borealis Group and Sony Ericsson Mobile Communication AB all have patents in the graphene area[2].

The technology areas with most graphene related patents approved today are electronics and synthesis, followed by composites and energy.

The first graphene-based touch screen was demonstrated in a collaboration between SKK University and Samsung in Korea. Sony in Japan has produced a 23 cm wide and 100 m long high quality transparent conductive graphene film by roll to roll CVD and transfer process. Both Samsung and Sony have capabilities of developing new technology, scaling up and mass produce, all in one company. Equivalent organization does not exist in Europe. Collaboration over production value chains is therefore necessary here.

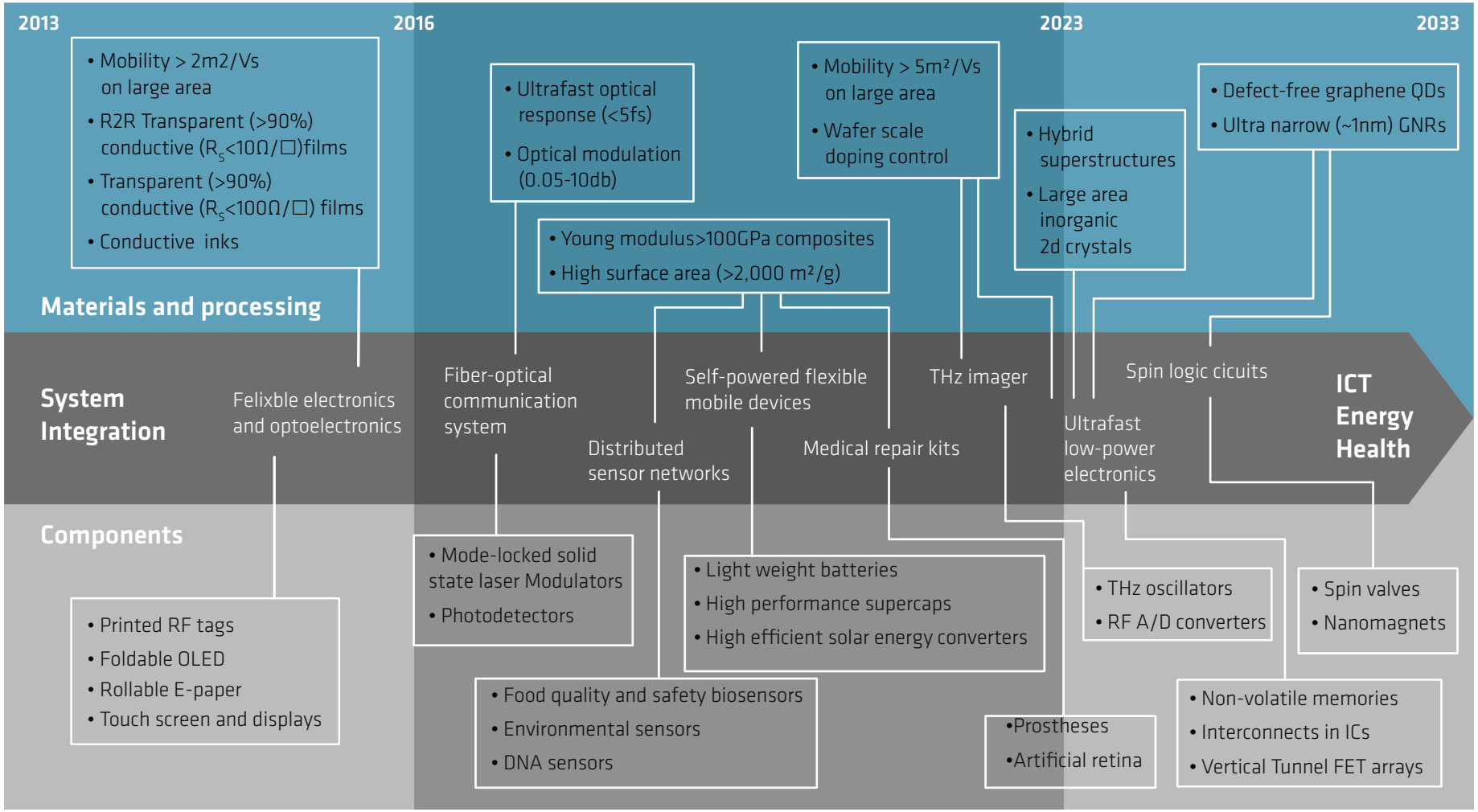
1 Sources; Patent data: Graphene Patent Landscape dataset CambridgeIP (January 2013); Journal article data, Global Research Report, Material Science and Technology, Thompson Reuters (2011).

2 source esp@cenet. This list does not claim to be complete.

Different applications have different technology readiness, in a 1-9 scale TRL the following situation apply today;

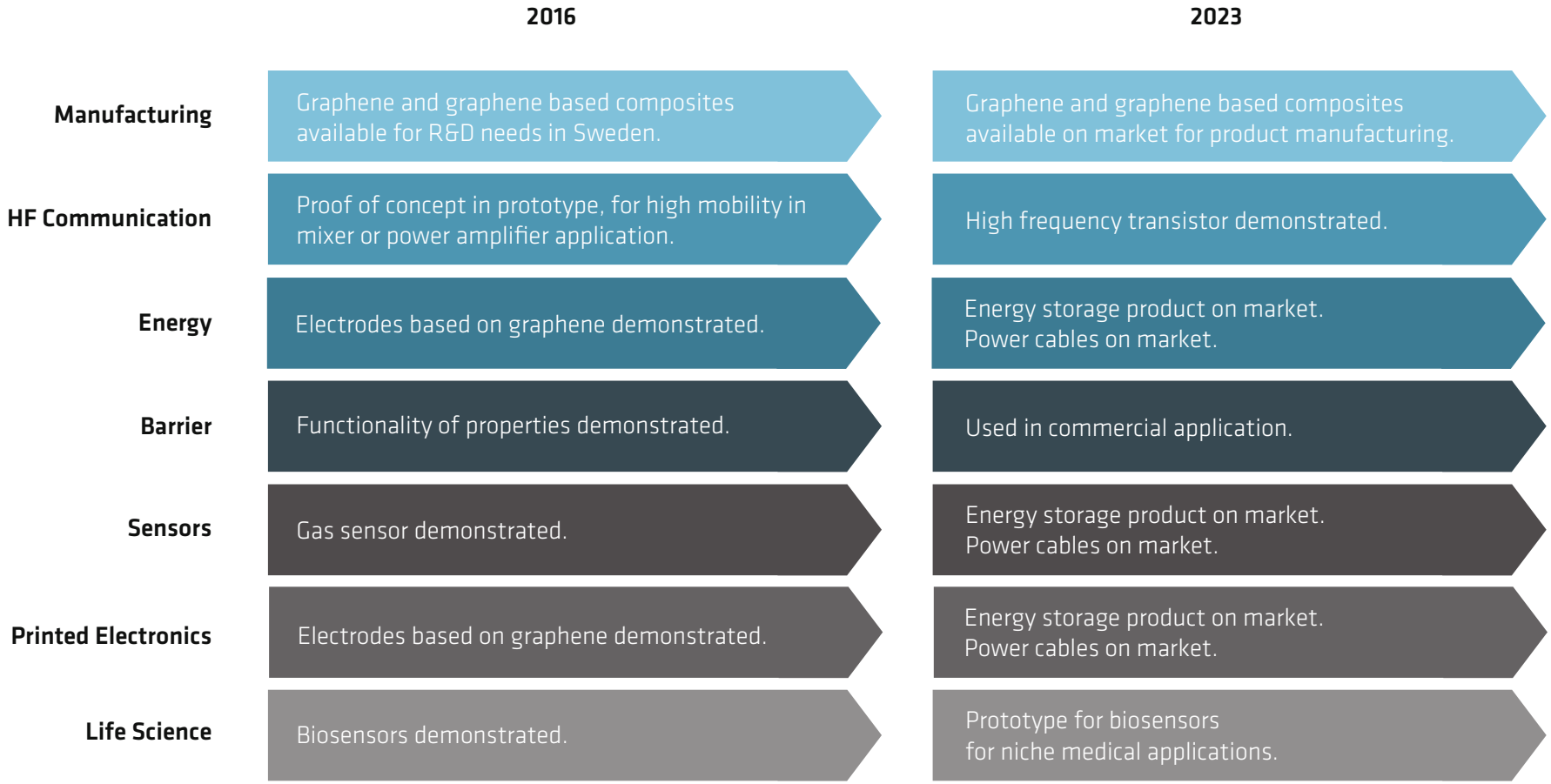
- TRL 7-9: composites, material production (the first products have been introduced on market)
- TRL 4-6; packaging, touch screens, supercapacitors, flexible screen (prototypes of components demonstrated)
- TRL3-4; High frequency electronics, spintronics, other layered materials (research proof of concepts have been performed)

A picture summarising the technology roadmap in relation to the graphene flagship is shown below (an upgrade is soon to be published, but not finalised at the publication date of this agenda). Some of these areas coincide with areas of strength in Swedish industry as well, but not all.



Areas of strengths in Sweden

Sweden's potential future areas of strength in the graphene field are described below. Several strong areas have been identified, where several Swedish actors have a common graphene interest. These should be viewed as industrial of technology platforms. Neither the possible areas of strength, nor the actors in each area, are by no means exclusive - but can be subject to change within the coming years. As the technology readiness level increases, more interested actors are believed to adapt to the new technology, and participate in joint R&D activities.
It will be necessary to continue identifying actors and market segments where graphene can make a difference in the coming years. The agenda needs to be deeper established among the actors that have not committed to it initially.
The roadmap for strong areas of Swedish industry is summarised in the picture below:



High frequency Communication

Communication is a particularly strong area, where several actors already are interested, and some have made small initial studies on graphene.

Graphene can contribute to higher output, lower power consumption, nonlinear effects, work at room temperature, and so on. The draw back with graphene for this area is the low technology readiness level. The estimation is that high frequency electronics with graphene have 10-15 years to market. Pushing this sector implies a risk of inducing a hype where high expectations will be met only in the long run. It is therefore crucial to balance the encouragement of this strong area and ensure that expectations are reasonable.

10 commercial actors have showed interest in this area, representing large end producers, system providers, as well as component providers. Research in this area is represented by Chalmers.

Sensor technologies

The performance of sensors critically depends on an efficient coupling between the signal and the measuring device. Graphene membranes offer the ultimate sensitivity to detect small changes due to their extremely low mass and large surface-to-volume ratio. Several read-out schemes can be envisioned, based on electromechanical, optomechanical, optical, or electrical transduction schemes. Especially the latter option is appealing as graphene has high room-temperature electron mobility.

At least eleven companies have an interest in developing and/or using sensors based on graphene. This is one area where it is possible to make a demonstrator within the time frame of an SIO project. Research in this area is represented by Linköping University and Chalmers.

Composites

Graphene-based composites use low quality graphene, like liquid exfoliated platelets. There are already products available on the market, for instance the tennis racket made by HEAD where graphene is used for changing the weight distribution in the racket.

Graphene could be used in composites to increase mechanical strength, lower weight, transfer of heat and/or increase electronic conductivity.

Companies from several Swedish industries are interested in composites, and this is another area where it is possible to make a demonstrator within the time frame of an SIO project.

Energy distribution

Graphene one of the most promising and versatile enabling nanotechnologies to address the Horizon 2020 objective of *secure, clean and efficient energy*.

Graphene is believed to be used as transparent electrodes and replace Cd-based hetero-junction layers in photo-voltaics, replace electrodes in fuel cells, used for electrical energy storage in high power density super capacitors and high energy batteries, and for hydrogen storage.

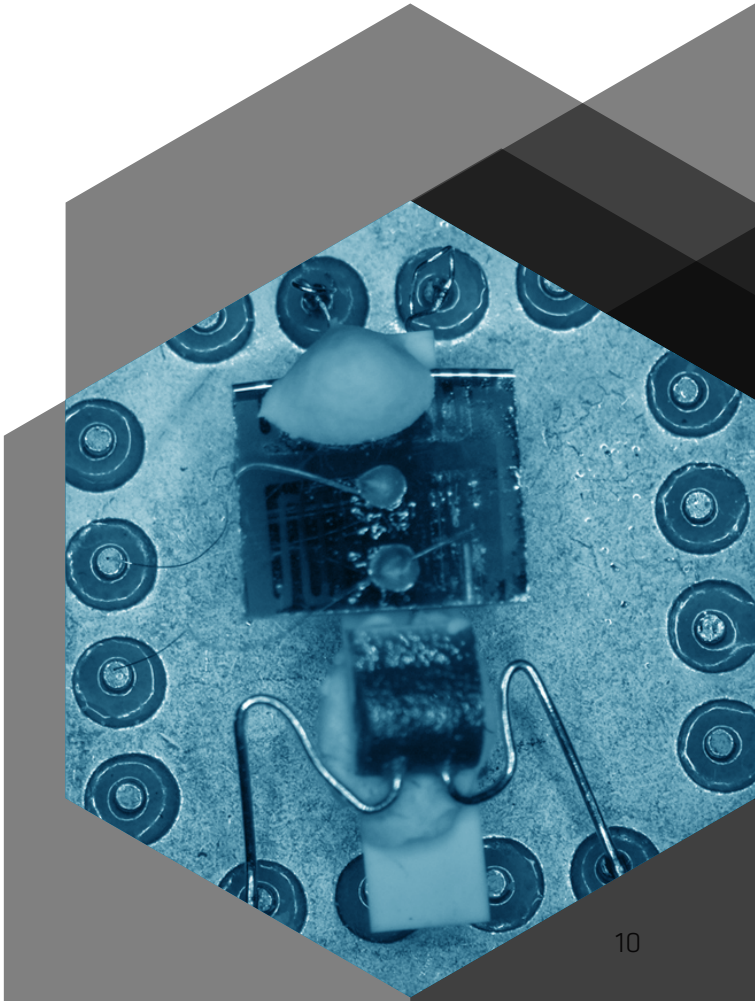
Swedish institute conduct R & D in the field of structural batteries and super-capacitors. For super-capacitors, graphene offers good power lines and large surface area. So far, mainly end users have expressed interest in these new energy conversion and storage solutions, but component and system developers are so far not participating. Research is represented by Umeå University and Swerea SICOMP.

Graphene in composites might be another energy related application, where this material can be used in energy distribution. Four actors have shown interest in this area.

Manufacturing

Manufacturing of graphene is not strong today, but is thought to be necessary in the coming years for providing material to entrepreneurial activities in new companies, to engineering activities in established companies and applied research and advanced engineering among universities and institutes.

Today Graphensic AB (Europe's first supplier of graphene on SiC) and SHT AB are small newly started companies providing graphene. There is also an initiative at Chalmers to manufacture CVD graphene that will be made available to industry as well as bundled R&D services.



Picture: Mikael Syväjärvi

Barriers

No known gas or liquid penetrates a graphene membrane. Several actors are interested in using this property in different applications.

The barrier properties in food packages are of highest priority for its functionality. Controlling water, carbon dioxide, oxygen and volatile substances are crucial for food quality and safety. The unique properties of graphene are supposed to replace aluminium and synthetic polymers with higher environmental load. In microwave heating applications, graphene might be interesting as shielding material, or as part of packaging material in microwave heating applications. Interested actors are institutes, suppliers of packaging materials, equipment suppliers, and system providers.

In medical applications it is believed that the barrier properties of graphene can be used to develop new dialysis technology, among others. The interested actors in the medical area are large producers of end-user products.

Graphene barrier could also be used for hydrogen gas or liquid hydrogen, with applications in space fuel tanks, vehicle tanks, and transportable container. Graphene could reduce weight in composite based containers, as well as eliminate diffusion through small cracks compared to today's solution. There are interested actors in this field from different industries. If these actors find a common R&D question, this could be a boundary crossing project.

Printed electronics

Flexibility is one of the key rising trends of the electronics industry. It will enable completely new form factors, conformal systems and large "wow effect" for consumer electronics, but it will also improve reliability and enable completely new kind of electrical systems. Smaller, thinner and flexible electronic devices could be embedded to our world (or even into us) in a completely new fashion. For instance, enhanced flexible electronics solutions can deliver miniaturised, low cost and disposable sensors integrated in transparent and flexible surfaces. This would enable ubiquitous and energy autonomous sensors for the long awaited realisation of *internet-of-things* and *everything-connected* sensor web, with application to smart homes, industrial processes, environmental monitoring, personal healthcare and more.

Developing new manufacturing processes and instrumentation is key activities in the coming years. Interested actors in this area are, initially, institutes, and small spin-off companies, but specific applications within printed antenna would also attract large producers of end-user products.

In order to use the graphene in composites or printed electronic, development of practical manufacturing technology is crucial for future production on graphene based composites.

Life Science

There are a lot of activities in other European countries where graphene is used as a biosensor, for drug delivery, imaging, photodynamic therapy, antimicrobials, retina (compare flexible display), and tissue engineering and so on.

So far, limited efforts have been made to attract life science actors to graphene society in Sweden. Actors showing interest today are represented by large producers of end-user products. More effort is needed to identify and interest actors earlier in the production chain, preferable in collaboration with the life science agenda. Research in biosensors from graphene has been initiated at Linköping University and Chalmers.

Conclusion

As the diversity of the areas of strength suggests, there are tremendous future possibilities, however not tied to one or a couple coherent value chains. This makes it even more important to focus on supporting areas of strategic importance for Sweden and on areas where the technology readiness level is sufficiently high – implying a shorter time to market. In those areas Swedish industry can take part and drive successful innovation projects with explicit and tangible value but also with the broader result, to create examples that can be role models and catalyse new initiatives.

GOALS AND METRICS

Goals and metrics

The strategic innovation agenda aims at building a national community, identifying important actors and applications and at evaluating areas of strength. It also aims at suggesting prioritized research and innovation areas including demonstrator projects and how to work in new and existing arenas and networks.

Objectives 2014-2018

- **Establish the first graphene area of strength in Swedish industry.** The SIO will focus on the areas with the strongest impact on Swedish industry which means selecting a few key ones to start with. When these are established – transfer of knowledge, processes and infrastructure to other areas will follow.
- **Ensure availability of graphene material.** Several companies have indicated the need for technical evaluation of graphene in relation to their application and/or product.
- **More than 25 Swedish companies have invested in graphene development.** Starting off with co-financing of demonstrator, prototype, field trials or other validation projects within the SIO (or other programs like the Flag-ERA or Graphene Flagship programs) the aim is to pave the way for a self-supporting market.
- **At least three graphene-based products have been introduced to the market by Swedish companies.** Initial focus on applications with short time-to-market that will pave the way for other products with longer development lead-times.
- **Several Swedish companies involved in Graphene Flagship innovation projects,** to benefit from its results, financial support and network of R&D partners. The Graphene Flagship also needs more partners to fulfil its goal of turning research results into innovations.
- **Increased cooperation with academia.** Even though the SIO's ultimate focus is on industrial innovation it is necessary to use the knowledge of academic researchers as a base. By involving researchers in demonstrator or other validation projects, knowledge transfer will be secured.
- **Strengthened relations between entrepreneurs and academic researchers.** A platform for interaction between researcher and well renowned entrepreneurs will strengthen the possibilities of commercializing intellectual assets produced with universities.
- **Establish a common vision for the Swedish graphene based industry.** Several companies have shown interest, but still a lot of work needs to be done to form stronger value chains, especially with producers of components and subsystems

Goals and vision for 2030

Vision

Sweden is among the world's top ten countries in deploying graphene to ensure industrial leadership.

Goals

- Establish graphene as a new industry.
- New value chains are developed and established.
- Strong cross-industry and industry-academia knowledge transfer.
- Sweden is established as one of the leading European countries in graphene innovation.
- Graphene-based products and processes are significant sources of competitive advantage for Swedish companies, including SMEs.
- Electronics are based on materials with less environmental impact.
- Sensors are based on solutions for advancing improved health.

Metrics SIO 2014-2016

1. Ten or more Swedish companies have invested in graphene innovation or R&D projects.
2. Two or more Swedish companies applied for Graphene Flagship partnership.
3. Four newsletters published each year, twelve in total.
4. Six workshop 2014, two workshops 2015 and 2016, ten in total.
5. Demonstrator projects have led to prototypes and 1-2 products on market.

RECOMMENDATIONS IN MORE DETAILS

As mentioned, the strategic innovation agenda aims at building a national community, identifying important actors and applications and at evaluating areas of strength. It also aims at suggesting prioritized research and innovation areas including demonstrator projects and how to work in new and existing arenas and networks.

The recommendations are activities suggested to meet the short term goals and to pave the way for fulfilling the vision.

1. Demonstrator projects

In order to establish the first area of strengths for graphene in Sweden, one of the short term goals of the agenda, demonstrator projects are suggested. These demonstrator projects would preferable be performed in groups of several actors representing different places in a production value chain. The projects should be aiming at producing prototypes and preferable even a product – for showing that it is possible to already today use graphene in real products, developed by Swedish industry.

The demonstrator projects will also serve to fulfil the goals of several companies invested in graphene development, securing material availability, and increase collaboration with academia.

These demonstrator or validation projects will be subject of an open call within the SIO project, with VINNOVA as evaluator and decision making body.

Within the SIO graphene organization there will be a program committee that coordinate calls and catalyses cooperation and communication of these calls and project results.

Examples of suggestions on demonstrator projects, from groups of actors;

- Manufacturing methods of graphene composites. It is not as easy as just mixing graphene with different polymers. Development and verification studies are necessary.
- Sensor platform. A generic sensor platform to be used in various applications after functionalization.
- Graphene sensor for extreme sensitive gas/air detection. By combining different metal layers on graphene different sensitivities for varying Volatile organic compounds and other emissions.
- H_2 container with graphene as barrier and sealing material.
- Develop faster micro wave links and optical modulators with higher frequency, high band width.
- Graphene electrodes to replace ITO. Development of production methods.
- Printed antennas.
- Barrier material for food or life science applications.
- Thermal conductivity property used for cooling.

Strengthening of manufacturing capabilities

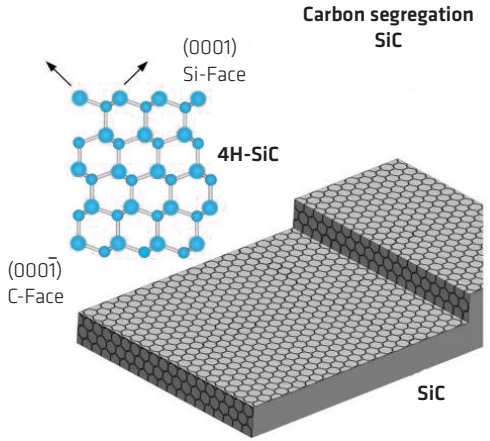
Production includes both manufacturing of graphene material and production methods for graphene based composites. The activity aims at fulfilling the goals for securing material availability and strengthens SME competitiveness.

Several different fabrication methods exist where each one yields graphene with different properties, cost and application possibilities.

Mechanical exfoliation of graphite, where gradually thinner layers is repeatedly pealed of until only one layer of graphene remains, yields high quality material. This method is, however, not suitable for larger volumes.

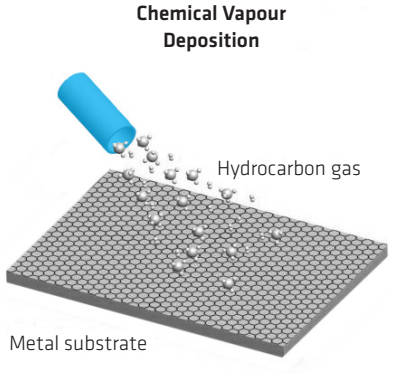
Heating of silicon carbide (SiC), with a sublimation of silicon in the outer atom layer as a result, gives a high quality graphene layer on a silicon carbide substrate. This method is suitable for applications where the substrate in itself gives an added value, like in high frequency electronics or sensors. In those cases, the graphene layer is a part of the component in silicon carbide.

Graphensic AB in Linköping is a commercial producer of graphene on silicon carbide.



CVD, Chemical Vapour Deposition, of hydrocarbon gas over a metallic surface like copper, is a method that yields high quality graphene that is possible to transfer from the metallic surface to other materials or to stand-alone graphene. This method is a good candidate for large-scale manufacturing.

Graphenea (ES), Bluestone (Taiwan/US/UK) and Avanzare (ES) are the main suppliers. Current market price for a single SiO_2-based 4 inch wafer is 675 €. (September 2013).



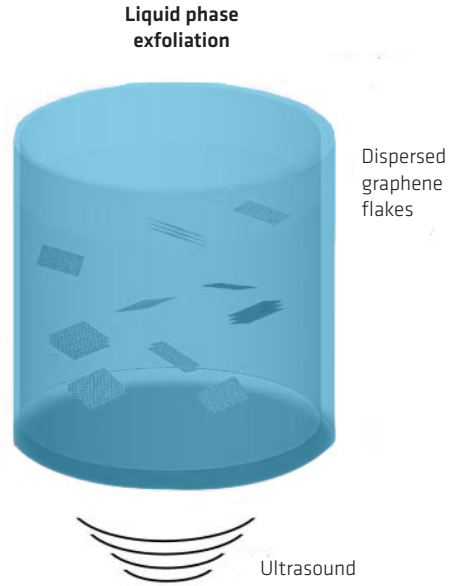
Liquid exfoliation results in graphene of lower quality and at a lower cost compared to other methods. Graphite dispersed in a liquid medium is separated into flakes of one or a few layers of graphene by the means of ultrasound. The flakes are typically micrometer wide and the number of graphene layers varies. The properties are not as high as for SiC or CVD methods, but good enough to be used for applications such as composites, inks and coatings.

Today, flakes are provided by Avanzare (ES), Vorbeck (US). Current price for a small batch is 935 €/100g (September 2013).

Several Swedish actors have confirmed the need of engineering graphene to get specific and hands-on knowledge of the possibilities and challenges of their applications and products. Supply of well characterized small test batches is identified as important for the industry.

Actors in the defence industry have demands on using subcontractors from Europe, and strongly encourage Swedish production.

In order to use the graphene in composites or printed electronic, development of practical manufacturing technology is a prerequisite for the production of high-performance graphene based composites. Suggestions on R&D projects are develop manufacturing technology for nano composites based on graphene nano-paper (type bucky-paper), based on electrophoresis, nano-paper or graphene modified fibres) which permits the manufacture of graphene modified carbon or glass fibre composites.



Pictures: Andrea Ferrari – Recoloured: BOID AB

The open call will pinpoint activities to strengthen Swedish manufacturing capabilities for this purpose

Actors:

- Graphensic AB – graphene on Silicon carbide.
- A research group at Chalmers lead by prof. Avgust Yurgens evaluates industry's needs of a stronger CVD-based manufacturing capability at Chalmers.
- SHT- Smart High Tech AB is a spin-off company from Chalmers with the aim of providing flakes of graphene on commercial basis and graphene on metal.
- Swerea SICOMP – methods for graphene based composites.
- Myfab – infrastructure provider in the area of nano and microfabrication at Uppsala, KTH and Chalmers.

The Graphene Flagship will initiate activities on standardization projects in the spring of 2014. These results should be monitored and transferred to the Swedish actors.

2. Strengthen value chains

Development and manufacturing of graphene-based components have been identified as weak parts of the production value chain. Companies populating these niches are often SMEs that need particular stimulus to enter into new fields such as graphene since their business models are significantly impacted.

Activities:

- Information campaign to identified actors – aiming at getting them involved in development projects.
- Hands on support with project planning, finding project team participants and resources.
- Hands on support in delineating new graphene-based business models.
- Arena for exchanging experiences.
- Establish the agenda vision for new actors.

These activities aims at fulfilling the goals of establishing the area of strength, develop new value chains, and strengthen competitiveness for Swedish SMEs.

3. IPR, research and business intelligence with newsletter

The agenda work has confirmed the concern among Swedish actors that the patent landscape already could be claimed by US and Asian companies. As a consequence the need to evaluate various parts of the patent landscape has been identified.

Within the SIO it is suggested to perform so called freedom-to-operate studies, FTOs, within certain areas. Some areas are defined from the start and others will be defined in relation to the content in the upcoming calls.

Research newsletter will contain updates on state- of-the-art for graphene and other layered materials.

Business newsletter will give updates on new companies, new products and services, as well as an evaluation of the status of graphene market. This work will include visits to world leading commercialization conferences twice a year with extensive reports to distribute.

These activities are tools for strengthening the area, as well as approaching the vision.

4. Meetings – workshop twice a year

To meet in person is a prerequisite for good collaborations. Dedicated workshops will take place at least twice a year with the purposes of community-building and of strengthening and expanding personal contacts of members of the graphene community. The first year it is suggested to give up to six workshops to facilitate project applications for the open call with groups of actors representing more or less an entire production value chain.

Workshops will for instance focus on state-of-science, presentations of on-going SIO-projects, and match-making events dedicated to strengthening and introducing new partner relations. The workshops will preferable be organized in collaboration with the Graphene Centre at Chalmers that provides direct access not only to the main concentration of academic graphene research in Sweden, but also to the Graphene Flagship.

This activity aims at the goals of increasing cross boundary activities, strengthen entrepreneur/researcher relation, establish a common vision, and to establish the area of strength.

SYNERGIES WITH OTHER AGENDAS

Some agendas have activities that partly overlap with the activities and goals of the graphene agenda. There might be possibilities of cooperation with some common calls in the future, for instance with;

1. Lightweight materials - especially within the composite area.
2. Aerospace – especially within composite area.
3. Nano- safety. Sweden is strong in nano-safety research and several activities concerning both graphene and other nano particles are on-going. The graphene agenda will not specifically focus on health or environmental issues, but rather keep track on the results from these studies. There will be possibilities of engaging each other in workshops and projects.
4. Life science. We do not currently have a confirmed interest from actors throughout the entire life science value chain. However, we have identified the possibility to work together with the life science agenda to identify actors and to establish the graphene agenda in the medical technology industry area. Further on, we foresee joint workshops and calls.

Apart from other SIO areas, there will be possibilities for actors to exploit synergies with the Graphene Flagship, FLAG-ERA calls and other on-going and upcoming programs within particular technology areas.

TIME PLAN

2014 May	Starting up SIO - Graphene
2014	Start intelligence/newsletter activity
	Interaction with European actors at Flagship industry workshop in Göteborg
	Start open call for demonstrator project
	First workshop in September
	Establish the agenda to new actors
2015-2016	SIO projects
	New open calls, new activities.
	Workshops twice a year
2016	Graphene products on market
2016	Secure financing for coming period
2016 – 2020	Continue activities
2016-2023	Several Swedish industries are part of flagship

Activities performed 2013

As the Swedish graphene based industry is very limited today, a big part of the agenda work has been allocated to identify actors that can take an active part in forming the future graphene based industry in Sweden.

Presentations were held on an industry events in Göteborg in June (at Johanneberg Science Park) and in Västerås at the Automation Region. In addition, company contacts were identified via personal networks graphene researchers, industry representatives, innovation offices, science park organizations and the contacts of the people involved directly in the agenda work including board committee members and project co-workers.

45 telephone interviews were performed with industry representatives, giving valuable information on what application areas are most relevant as well as what properties they would like to improve with graphene. The results from these interviews were used to decide on topics for the group discussions in a subsequent workshop.

On September 23, a workshop with 80 participants from 50 companies was performed. 14 different group discussions were held. Invitations were sent out to specially selected persons and clusters such as the science and technology parks, innovation offices, SwedNanoTech, business regions and Elektroniktidningen i Norden.

The group discussions were based on choices from participant in advance. Groups were divided after physical properties the actors would like to improve with graphene and after application areas, respectively.

The properties were:

- Electric and thermal properties
- Thermal conductivity
- Mechanical strength
- Weight reduction
- Sensor sensitivity
- Electric and optical properties
- Optical properties

The application areas were;

- Sensors
- High frequency/Radio frequency electronics
- Composites
- Coating/membrane
- Energy storage
- LCD/Flexible or printed electronics
- Biosensors

A closed LinkedIn group called “Framtidens svenska grafenindustri” was started with the purpose of discussing the future SIO-project and for community-building purposes.

Actors in the agenda project

Project manager;

PhD Helena Theander, Stiftelsen Chalmers Industriteknik, Group director sensor system

Board;

Michael Balthasar, AB Volvo, Director New Technologies & Innovation

Christer Svanberg, Borealis Group, Group Leader - Power Cable Applications

Mikael Syväjärvi, Graphensic AB, Cofounder

Prof. Jari Kinaret, Chalmers

Prof. Rositza Yakimova, Linköpings universitet

Fredrik Hörstedt, CEO, Stiftelsen Chalmers Industriteknik

Reference group (participated in workshop and interviews)

Brodnner	Pontus	3M
Lexén	Daniel	AB Volvo
Callavik	Magnus	ABB
Fredriksson	Hans	ABB CEWE
Malmqvist	Helena	ABB research
Olsson	Bo	ABO
Dyreklev	Peter	Acreo
Andersson	Gert	Acreo Swedish ICT AB
Andersson	Jan	Acreo Swedish ICT AB
Persson	Michael	AkzoNobel
Nilsson	Magnus	Alfa Laval
Nilsson	Peter	APR Technologies AB
Nyström	Peter	AstraZeneca
Selmi	Nidhal	AstraZeneca
Skrtic	Stanko	AstraZeneca
Pontén	Fritiof	AstraZeneca R&D Mölndal
Boström	Ola	Autoliv
Höij Noren	Malin	Automotive Sweden/BRG
Bjerndell	Per	Bergenstråhle & Lindvall AB
Rodal	Michael	Biolin Scientific AB
Svensson	Peter	Biolin Scientific AB
Svanberg	Christer	Borealis AB
Görsch	Joel	Business Region Göteborg
Rydberg	Alexander	Cewe, ABB AB
Nilsson	Tomas	Chalmers AB
Gustavsson	Ulf	
Hörstedt	Fredrik	Chalmers Industriteknik
Mangold	Stephan	Chalmers Industriteknik
Theander	Helena	Chalmers Industriteknik
Ghavanini	Farzan	Chalmers Industriteknik
Liu	Johan	Chalmers, MC2
Stake	Jan	Chalmers, MC2
Yurgens	August	Chalmers, MC2
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Fredrik	Höök	Chalmers, Teknisk fysik
Svedhem	Sofia	Chalmers, Teknisk fysik
Kinaret	Jari	Chalmers, Teknisk fysik
Svensson	Gudrun	create4future
Hammarlund	Bo	deZtar
Hägglund	Magnus	Eco Spark
Harrysson	Fredrik	Ericsson AB
Alping	Arne	Ericsson AB
Patryk	Urban	Ericsson AB
Greiff	Martin	Exova Material Technology
Reinholdsson	Per	Exova Material Technology
Lundahl	Karl	Fingerprint Cards AB
Savage	Steven	FOI
Palm	Anders	Försvarets Materielverk, FMV
Sternby	Jan	Gambro
Eriksson	Örjan	Gapwaves AB
Syväjärvi	Mikael	Graphensic AB
Nilsson	Jonas	Graphensic AB
Lundblad	Bo	Huawei Technologies
Madeberg	Bengt	Huawei Technologies Sweden AB
Wilandh	Hans	Hways Consulting

Reference group (participated in workshop and interviews)

Hultmark	Anders	IGC
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Strand	Ann-Marie	Johanneberg Science Park
Svensson	Iréne	Johanneberg Science Park
Havert	Göran	Johanneberg Science Park
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Westling	Björn	Johanneberg Science Park
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Axelsson	Olle	Lincio Consulting
Lind	Johan	Lincio Consulting
Wikman	Linnea	Lindmark Innovation
Lindmark	Curt	Lindmark Innovation AB
Eriksson	Jens	Linköpings universitet
Stafshede	Patrik	LunaLec
Swahn	Thomas	Myfab
Fabo	Tomas	Mölnlycke Healthcare
Bladh	Petter	Nordic Aircraft
Lundström	Patrik	Obducat AB
Kores	Martin	Omnisys Instruments
Petronis	Sarunas	Porenix
Åkerlund	Hans	Prevas AB
Brogren	Ulf	Promimic
Strindberg	Göte	Saab AB
Nordin	Pontus	Saab AB
Rolander	Ulf	Sandvik Venture AB
Bardh	Torbjörn	Sapa Profiler
Åhman	Leif	SCA
Eliasson	Anders	Seco Tools
Thole	Ulf	SenSiC AB
Ye	Lilei	SHT- Smart High Tech AB
Lorén	Niklas	SIK
Kälvesten	Edvard	Silex Microsystems
Kabir	M Shafiq	Sindre AB
Lindahl	Niklas	Sindri
Stoij	Christer	SiversIMA
Johansson	Anders	Smoltek AB
Bergsten	Tobias	SP
Hartmanis	Åsa-Lie	SwedNanotech
Hagström	Bengt	Swerea - IVF
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Wahlberg	Jan	Tetra Pak Packaging Solutions AB
Granbom	Lars	Trebax
Lext	Jonas	Umbra Corporation AB
Robertsson	Mats	VINNOVA
Karlsson	Sören	Wiretronic AB
Weber	Christoffer	Wiretronic AB
Balthasar	Michael	Volvo
Höfling	Ulla-Britt	Ypsomed AB