Strategic opportunities and fundamental risks for Europe

In the previous sections we have described the roles that European R&D and industry are operating in today and how these can open up with new approaches towards ambient intelligence with smart displays including organic electronics. This immediately shows open opportunities to move towards a bigger involvement in display technology and large area production, potentially with organic electronics. We want to briefly summarise strategic windows of opportunity but also risks if Europe does not respond to them in an appropriate way.

Since salaries represent a very small fraction of total costs, low wage areas do not have a very significant advantage, except in the assembly of small displays today. There are other decisive factors to be taken into account for choosing a manufacturing location: capital costs, interest rates, import and other taxes, working practices, utility costs, transport costs, legislation, and the stability of the political system are very important. The supply chain proximity and the availability of trained personnel play also a significant role in production location decisions. Europe has some very good incentives here!

Displays will always get cheaper

Although it is true that almost all display manufacturing is done now in Asia, there are no insurmountable barriers to making displays in Europe. The fact that Korea and Taiwan have taken leadership away from Japan shows that it is possible for new entrants to the industry to be successful.

However, a striking fact is that there are many non-flat displays (CRTs) made in Europe every year – around 18 million. The CRT industry has moved production close to consumption because it made less and less sense to ship large amounts of glass with relatively low added value around the world. It seems likely that as the other display technologies such as PDP and LCD mature in manufacturing and further grow in size, this will also happen for them. Europe remains a large market for TVs and makers are likely to want to move display production close to TV set makers for this reason.

EU enlargement could foster manufacturing

Eastern Europe has a sound knowledge base in optoelectronics and display technology. Bringing this expertise into joint projects could be very beneficial to the entire community.

Furthermore, the lower labour costs in the East of Europe can reduce the barrier to competition with Asia. A model other European industries such as the car industry have already followed is to keep highly automated "front end" parts of manufacture in the high-wage countries and move the more labour intensive parts like assembly to lower wage countries in Eastern Europe. Japan follows the same strategy by partnering with China.

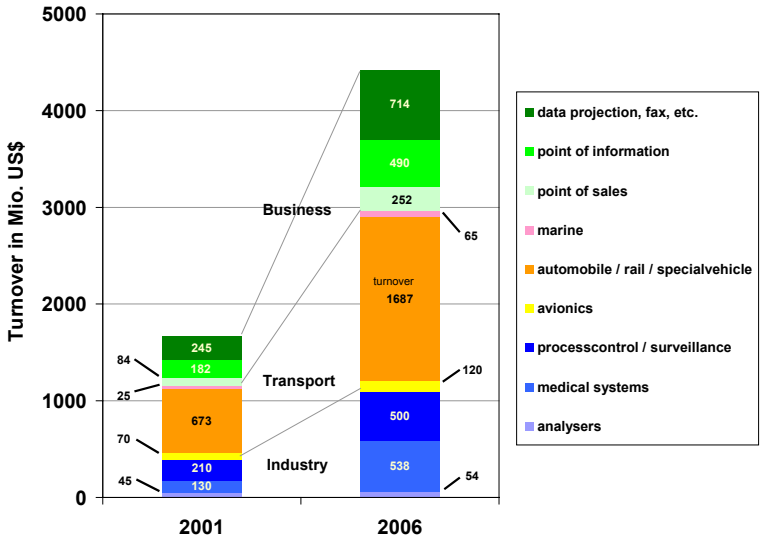

Fig. 14: Attractivity of industrial displays for different sectors. Sales per branch and market segments in Europe and North America in Mio. US$. (Graph by courtesy of W. Mildner)

The graph shows the need for such customised displays for Europe and the US (both share these markets approximately equally). Customisation is therefore a market opportunity that will drive innovations in the above mentioned sectors. This is true for both, customized modules and custom substrate design. It also means shifting away from a "bigger is cheaper" display manufacturing mentality, into **rapid prototyping and custom design fabrication**, be it low or high volume.

This kind of development would have the effect of keeping labour in Europe, with reduced geographic and cultural barriers and reduced transport, thus highly reducing harmful environmental aspects like greenhouse gas emissions.

Rapid prototyping and custom design fabrication vs. "price-wars" in mass manufacture

Display end-user industries differentiate their products more and more through design features. Displays play a very important role here. Moreover, their applications require also special features like temperature resistance, brightness for use in sun- and daylight, shock- and vibration resistance (if you think e.g. about a car or mobile phone display or a display in a ruggedised environment). There is also a growing demand for mission critical applications. All this requires to a large extent the employment of customised displays. Standard modules from Asia usually cannot meet the special requirements.

Integration of the best of organic and inorganic technologies as a short-term hybrid approach

The performance of organic electronic devices produced by additive printing methods today are as yet limited and adoption in consumer markets and large-scale manufacturing has been slow. Nevertheless, the technical gains have been so great that the electronics industry now has a much broader range of tools available. These can lead to commercially successful products even before "fully organic" methods are readily available.

One viable route for a short-term approach for enhanced products can thus be the integration of the best of inorganic and organic materials, using the full suite of manufacturing techniques. The integration of system

functionality into the Polysilicon backplane of a display is being adopted already today, and could be further enhanced, for example by including basic decoding functions for video content directly on the substrate. Another example is provided by the success of Alien Technologies and ST Microelectronics in the fabrication of RFID tags by roll-to-roll processing on plastic substrates. In this application, all of the computational capability and memory can be contained in a single inorganic nanochip and the major challenge is to connect that chip to the antenna. More complex connections will be required in more sophisticated other devices which may require a display, sensor and battery or photovoltaic cell.

Improved interconnect technologies will be one of the critical enablers for this approach. For example, the development of three dimensional PCB structures to allow displays to be driven from behind, rather than from the edge, will greatly simplify the fabrication of seamless tiled displays. Not only will this remove all barriers to the size of displays, it will also mean that panels can be cut into arbitrary shapes without losing functionality. These connections could include optical communication or other wireless techniques. This is also a great way to help the customisation of design.

In the long run, this will open possibilities to process and embed "e-grains".

3-D displays: Into a new dimension

3-D displays have the potential to completely change the way we handle information. "Real 3-D" would mean intuitive use without special glasses and with the display adapting to the user. Such 3-D would open up

- new ways of learning and perceiving information:
  - infotainment
  - edutainment
  - entertainment applications
- new user interfaces
  - virtual reality experiments
  - virtual reality simulations
  - 3D operation systems
- new information distribution method
  - 3D moving objects
  - 3D virtual reality scenes

However, the displays on the market today do not tap the full potential of 3-D. Japanese manufacturers have introduced 3-D displays with a very small sweet spot – the 3-D effect only occurs in a very small spatial area – so that the user basically cannot move their head. This is very tiring and makes people think that this is all that can be achieved. Therefore, 3-D displays have to be pushed "into a new dimension".

The market potential is huge and 3-D basically could be used in all areas where 2-D displays are used today:

- Mechanical engineering (e.g. CAD, simulation, training and education)
- Gaming, most games use 3-D information even today, but have 2-D displays

- Automotive (e.g. in-car displays)
- Telecommunication (e.g. mobile displays, network planning systems)
- Aerospace (e.g. realtime transmission of 3D images/video)
- The user interface for computer Operating Systems (Longhorn will contain 3D information)
- Other specialised areas: Research, Medical, Oil and Gas, GIS, Security, Military etc.

For mass production of real 3-D enabled displays – i.e. 2-D displays that are able to show 3-D for multiple viewers on the same image – new materials, new components, new standards and new technology will be needed. The display must, so to say, be born with the 3-D technology inside.

In Europe, there are a number of companies in this field – most of them are SMEs – and research institutes with very promising, innovative new technologies in the 3-D field, that need to be developed further and advanced into mass production.

Smart displays and organic electronics: a new chance to take the lead

As already stressed, organic electronics is emerging as a new area of printable large area electronics with a market potential even beyond displays. Since Korea and Japan have a very strong research base, with about 100 university groups as well as large corporate R&D divisions, regaining leadership in making commodity LCD and PDP in the short term is probably difficult. However, manufacturing approaches of LCDs and PDPs today highly depend on glass processing.

On the other hand, Europe has outstanding capabilities in printing techniques and in flexible displays, i.e. for non-rigid substrates. Europe is leading R&D in organic electronics, and Asia has no comparable activities in this field yet. Apart from that, Europe is also leading environmental R&D and has a track record in product design, and both areas will be significantly affected by organic electronics and flexible displays.

This could provide a basis for success in opening new display markets, as already recognized in 5th and 6th framework programme projects. Printing machines run in the places where the products are sold: Newspapers are printed in Europe, not imported from China. The move from sheet processing to roll-to-roll manufacture looks like a viable route for both, displays and organic electronics manufacture and opens a manufacturing future not only for big OEMs but also for SMEs.

The example of radio frequency identification tags (RFID) shows the huge market opportunities of low cost electronics. Large area, low cost printing has the potential to cut down the cost per tag to the values of a few cent per tag, "item level tagging" – i.e. every single product is equipped with an RFID-tag, as it contains a barcode today – then becomes economically attractive. As the price/tag is reduced by one order of magnitude the potential market – the number of "taggable" goods increases by three order of magnitude, resulting in a strongly growing market volume. Item level tagging enables new logistic concepts and will revolutionise logistics world-wide. With a cohesive European effort, this printed organic technology could well be developed into the next generations of displays.

Strategic investment into smart displays pays

The above scenarios show a broad variety of opportunities and illustrate why one should invest into the development of technologies such as displays and organic electronics, be it from private or from public side:

- Investment helps support R&D employment, training and exposure of science and technology in Europe. Europe is becoming a "knowledge economy", which will require a critical mass of industrial and university partners working together to remain globally competitive and credible. This "knowledge base" is necessary if we are to defend our position vis-à-vis the Far East. Public funding is key to encouraging partnerships where they might otherwise not occur.
- Europe is capable of being in the lead globally in the development of novel applications (both disruptive and not), new display types and novel manufacturing. It is also capable of using displays in many different ways in the value chain (from materials, to devices, to modules, and to products). This broad experience and range of industries is a good foundation for business.
- funding supports the development of disruptive applications in displays and organic electronics, which otherwise would not be able to bridge the time required to get to market.
- At present, world-class European companies such as Nokia, BMW or Mercedes simply cannot buy the kinds of displays that they would really like to use in their products - they have to make do with what gets developed in Asia. It seems clear that access to leading display technology is a factor in the success of new and aggressive world brands such as Samsung.
- Activities towards an enhancement of industrialisation of advanced displays R&D – i.e. driving R&D towards pilot and mass production in Europe – would have a tremendous impact on the improvement of competitiveness of the European advanced displays supply industry (equipment and materials) as well as the user industries (e.g. transportation, telecommunication, mechanical engineering):
- Local production can answer these needs a lot better than geographically-removed production (and design) in terms of faster reaction to changes, acceleration of the innovation process, and differentiation . Production of advanced displays in Europe focusing on customised products provides a real opportunity for the enhancement not only of the European advanced displays industries as such, but to larger sectors of the European economy.

It has to be emphasised that a strategic investment into displays and organic electronics that will have the desired effect cannot be taken by private or national funding alone. This must be a concerted effort driven by the European Commission, and should be handled as it is in the Far East, in a coordinated and integrated way to remove investment barriers.

Fundamental risks for Europe if we do not proceed proactively

From the discussion above, a number of fundamental risks for European RTD and industry become clear:

- The long term trend to the integration of products and devices means that more and more functions are integrated into displays, which typically evolve over time for larger size and visual bandwidth. If Europe has no influence on the display, then it can have little control over the devices that get integrated onto it and gradually **will get squeezed out of the value chain**.
- **World-class researchers** may choose a different country outside the EU to conduct their research in the field of organic electronics and advanced displays; the EU position in this area will be significantly weakened and Europe will lose this technology in the mid-term future to Asia and the US
- Asian FPD producers are sourcing more and more components and materials locally. By increasing vertical integration, production costs can be reduced. Korea is already known for this practice, Taiwan is also adopting this cost-saving approach, building large industrial parks for the key component supply industry around their FPD fabs. It can be expected that the **European supply industry will be hit hard** by these aggressive plans if it is not able to offer innovative cutting-edge components on which the FPD manufacturers have to rely.
- The supply industry suffers from **lack of feedback** and lack of references for their products in a functioning mass production. The supply industry delivers almost entirely to Asia, sometimes without getting detailed feedback for improvement of their products. Furthermore, display manufacturers prefer to buy entire production lines rather than buying single components. Without functioning user-supplier relations and without a systems approach in manufacturing, the supply industry will disappear.
- CRTs have been mass produced in Europe. With the replacement of CRTs by FPDs, the industry is moving to markets where CRTs are still today "top of the list", but will probably not be in the future. Without an investment into new display production, Europe will **lose an entire industry sector**.
- Without the possibility of creating turnover in current technologies like displays, there will be more and more **problems generating enough private capital** for the reinvestment into new technologies in this sector.
- Without continuity in funding, private and public, the investments of the past (e.g. from 5th and 6th framework programmes) will be at stake.

Conclusion and recommendations for actions

The above discussion immediately leads to the following conclusions and recommendations:

Using Europe's strengths...

European companies have excelled in making and developing products that are really designed for use by people, especially when compared with the technology driven design seen in parts of Asia. Human factors, sustainability and environment protection have always played a higher role in Europe than elsewhere. European RTD and an innovative and yet competitive materials and supply sector in the displays area are of high value and need to be strengthened beyond FPDs for the next-generation smart displays.

As a possible route to success, we may leverage Europe's outstanding capabilities in the field of organic electronics. A multi-billion $ market is foreseen for products based on organic electronics, as was shown in Chapter 2, Figure 7. Most of these applications and products, including smart display technologies, are new. Organic electronics do not replace an established technology, rather they have the opportunity to develop in their own market segment. Display systems involving these new technologies, in parallel with innovative silicon- and other inorganic-based electronics will profit greatly.

Combining its strengths in display technology, large area processing and organic electronics Europe can fully enter the stage of display and large area electronics manufacturing. With its strong electronics and printing industries, and deep knowledge-base in organic materials, high-resolution patterning and processing of large-area electronics, disruptive manufacturing systems (including roll-to-roll) on flexible substrates, it is entirely realistic that smart displays and novel applications beyond (e.g. pixellated lighting, photovoltaics, radio frequency identification (RFID) tags, disposable electronics, etc.) could all be manufactured in Europe.

The great advantage of a knowledge-transfer approach is that European core technology would be effectively integrated into end products. Research results and inventions generated in Europe would be integrated into productions manufactured in Europe. This directly leads to a maximum exploitation of research and technology efforts.

...to strengthen the display and organic electronics landscape in Europe

The displays RTD and industry landscape will increasingly have to meet tough competition from outside Europe, putting even its very existence at stake. The build-up of strong clusters has helped Europeans to strengthen their position internationally and even to create unique selling points. However, the enhancement of local production of displays and display systems will help to overcome a number of risks in this area. The move into viable products will be the crucial point for competitiveness in the large area electronics field. The latter will of course also benefit significantly from local production.

Grabbing a major slice of the future world production would be a desirable result of the investment into R&D in Europe, but of course not everything is at stake if this is not reached. However, as seen in the European semiconductor industry, some 10% market share of high-tech production can already secure the competitiveness of the industry and the supply chain.

In order to stimulate such production activities in Europe, excellence in basic research should of course be maintained. However, a much stronger additional focus has to be put on **application driven research beyond demonstrator level**.

As with the Asian TFT-LCD industry or European semiconductor industry, clustering the material and component suppliers around the production facilities (vertically integrated industrial parks) will lead to significant cost reductions, faster time-to-market, and more application driven research activities, as the supply industry has a better access to and better understanding of the problems encountered during the manufacturing process.

Technology platforms and assessment activities yielding full exploitation

Excellence in R&D is essential to ensure that Europe can remain competitive in the long-term. In this respect, the continuing support of R&D through public funding is indispensable together with the availability of world-class researchers and competition between research teams at European level. At the same time knowledge must be translated into innovative processes and products that can improve the competitiveness of the European industry.

The move from demonstrator level to mass manufacture is, however, a step that has become increasingly difficult, especially in the electronics industry.

This is especially true for the supply industry in the displays field. In addition, the suppliers (mostly small or medium sized enterprises) often lack a close feedback-loop to their customers, the producers, both geographical and through ease of access. The share of intellectual property rights is also an issue.

However, state-of-the-art equipment and materials is increasingly crucial for the development of electronics products in general. This is especially true for smart displays and organic electronics, since low-cost fabrication will only be possible through world-class engineering and design. All issues in the value chain need to be addressed with close co-operation and participation between users and suppliers of equipment and materials if high performance and concurrent cost reduction are to be achieved. Only strategic partnerships are yielding productive solutions.

Today, the existing infrastructures do not always meet the requirements of the industry, especially of SMEs. **Technology platforms**, where users and suppliers are working together, "open laboratories" with easy access for industry could effectively contribute to precompetitively mature manufacturing technology. SMEs, in particular, are often undercapitalised and could benefit substantially from such access to accelerate the development process and reduce the "time to market" for viable products.

Specific assessment programmes offer another approach to provide equipment and materials manufacturers with a flexible path to develop and improve their product innovations via strategic partnerships with equipment users. A model for this is the very successful Semiconductor Equipment Assessment (SEA) programme[1] which is a European Community funded activity from the 4th and 5th framework programmes in the area of microelectronics.

The aim of SEA was to **bridge the process innovation – equipment productivity gap**: A gap can frequently arise between process innovation and productivity as the technology rapidly evolves to satisfy the component and system manufacturers' needs. Productive solutions are demanded with higher throughput and performance in terms of process quality, measurement accuracy, yield, equipment reliability, uptime and cost effectiveness[2]. This is currently the case for FPD manufacturing and will sooner or later be the same for organic electronics.

SEA is currently being adapted to the 6th framework programme structure for the semiconductor field. From its success we can fully recommend to **extend assessment activities** like SEA to the smart displays and organic electronics field.

[1] One can say that SEA was one of the programmes that pushed the European semiconductor industry as well as the equipment manufacturers to the world-class position they are in today.

[2] These issues were all focal points in the SEA programme. Projects were typically from 18-24 month duration and phased to evaluate and improve the relevant process, measurement or analytic performance of the equipment followed by productivity and reliability assessments, thus bridging the innovation – productivity gap.

SEA adopted an open and global approach that provided an opportunity for equipment manufacturers to participate in funded programmes with the active involvement of global IC manufacturers. It responded to industry trends and needs and consequently proved to be very attractive to both manufacturers and equipment companies resulting in many successful projects. Dissemination of the results globally was also an inherent part of the programme.

For more information see http://www.sea.rl.ac.uk

Recommendations for actions

This paper is based on the input of **95 individuals from 17 countries**. Major topics addressed by this community towards **smart displays and applications to enable an intelligent environment** were flexible, large area displays, the advancement of 3-D displays, organic electronics, displays with high optical performance, high resolution and low power consumption, with an **integrated systems approach** and with the prospect of being produced in a sustainable manner. There are a number of very **promising opportunities** that can push the industry and ensure that the EU participates in the **enormous growth** of this sector. However, the community faces tough, even growing competition, especially from Asia. There is a **high risk of losing** this important industry if no proactive steps are taken.

We therefore recommend the following actions to be included in the next framework programme of the EC:

- substantially **increase public investment** in displays and organic electronics, in general, in a coherent and coordinated manner by a factor of 2[1] by 2010 bearing in mind the Lisbon and "3%" objective;
- to **increase investment and coordination of R&D to reinforce the industrial exploitation** of displays. Key topics are large area processes and new manufacturing techniques, organic electronics, improved materials, and new device structures for an integrated systems approach. A draft research agenda is given in Annex 1;
- to promote the interdisciplinary education and training of research personnel together with the promotion of a stronger entrepreneurial mindset;
- to facilitate **joint projects with the new EU member countries** in the East and beyond;
- to ensure favourable conditions for the transfer of knowledge and innovation through **technology platforms** and **assessment activities** to ensure that European R&D excellence is translated into wealth-generating products and processes;

The actions described in this paper are in line with the European Councils of Lisbon 2000, declaring the commitment to develop a dynamic knowledge-based economy and society, of Gothenburg 2001, aiming at sustainable development, and of Barcelona 2002, targeting 3% of GDP funding for research.

[1] To be discussed in more detail

Annex.1 Proposed RTD agenda for displays in intelligent environments in FP7

Key points for research and technology development for smart displays in intelligent environments are:

- large area processes and new manufacturing techniques,
- improved materials,
- new device structures,
- for an integrated systems approach
- accompanied by technology platforms for assessment of materials and equipment to foster access of the industry – especially SMEs – to research results, to accelerate the innovation process on the production side and reduce "time-to-market".

This will enable **new displays and applications** including:

- Autostereoscopic and full 3-D multi-user displays
- flexible, large area displays,
- displays with high optical performance, high resolution and low power consumption,
- all-organic displays,
- portable devices with low power consumption and/or autarkic internal power supply,
- organic ICs, RFID-tags
- smart displays, integrating logic, sensors, display, antenna and power supply, organic, inorganic and hybrid.
- large area photovoltaic solar cells

with the prospect to be produced in a sustainable manner on competitive equipment with high yield at low cost.

The **list of important RTD topics** for smart displays and large area electronics has been compiled. However, their prioritisation is still in the making. A consensus view among the contributors will be proposed by June 2005.