Three reasons why investing in Printed Electronics might be worth wile to explore strategically for the Dutch Printing Industry

Current situation of the Printing Industry

The print market is currently facing another plummet due to digitization and over capacity. Although some predictions for 2014 forecasted that the decrease of the market would stop and the market would stabilize, volume has again dropped. This forces Printers to look for other markets in order to ensure growth. The strategic plans of many bigger Printers have set targets to reach sales in new markets. At the moment, most Printers new market focus is on markets outside of Europe. However, with digitization in those regions also growing, it would be wise to consider growth in markets outside the current industry.

Figure 1. Use of mobile devices in emerging countries

Printed Electronics is a chance for Printers

Printed Electronics essentially refers to a collection of technologies that leads to very thin, flexible, and low cost electronic devices. The devices, as the name suggests, are made largely by additive manufacturing technologies, such as printing.

This new market, which uses traditional printing methods to create electronics, is rapidly developing. Currently we are witnessing the emergence of new electronic products that either contain printed components or that are fully printed. And these are only the top of the iceberg: many electronic products are not yet printed, but have a strong potential for large volume manufacturing based on printing processes. Among the promising fields of application are intelligent packaging, OLED lighting, flexible touchscreens and solar cells, and disposable diagnostic devices, to name a few.

We believe that printing electronics as a printing company, could be a chance for Printers to build a sustainable business in a growing market for several reasons: 1) it is an investment in a superior and cost efficient technology, 2) Printers have the basic technology and competence and 3) it is a much needed chance to grow in a promising market. We are aware that this would mean a diversification strategy in terms of Ansoff, which is the most risky of strategies. We therefore propose a thorough, structured process to come for Printers to a well-considered and supported strategy proposal.

Printed Electronics: a bit more in depth

Other names than Printed Electronics that are often used to describe similar technologies are 'flexible electronics', 'large area electronics' and 'organic electronics'. Currently the most used name to describe the ensemble of technologies is Thin, Organic and Large Area Electronics, abbreviated as TOLAE. This name is also adopted by the community and the European Commission.

Traditional electronics are typically built on rigid printed circuit boards (PCB). Although the name suggest otherwise, lithography is the most important manufacturing technology. Chips and other components are integrated onto this by soldering. The result is highly functional but relatively thick product.

In contrast to this, TOLAE focusses as much as possible on additive manufacturing processes such as printing to realize the desired electronic functionality. In these processes, materials are typically deposited on low cost flexible substrates like plastic foil (polyesters) and paper. Only when and where needed are traditional components and chips being integrated. The use of flexible materials and thin layers not only results in flexible devices but it also opens up the possibility of roll-to-roll (R2R) manufacturing.

The advantages over traditional electronics are in form factor (the product becomes more flexible), in functionality (doing things that otherwise would be impossible) and in reduction of cost for large area and mass manufacturing (use of low cost materials and the ability to do R2R manufacturing).

Figure 2. prototype of a temperature sensitive coffee cup with Printed Electronics (Holst Centre 2014)

Historically TOLAE evolved from the discovery of organic light emitting diodes (OLED) and organic photovoltaic cells (OPV) (solar cells). For decades, research has primarily focused on the development of better materials to improve efficiency and lifetime of devices. In the last 10 years or so, the research community has shifted its focus towards the manufacturing processes themselves to enable industrialization and application in a variety of products. In an effort to trying to materialize the promise of large area and cost effective manufacturing, research institute Holst Centre (TNO) has invested heavily in equipment for the manufacturing of OLEDS and OPV. Most often, the processes involve printing and coating technologies, combined with classical thin film techniques such as sputtering, vapor deposition and lithography.

The market for Printed Electronics

Although the Printed Electronics industry is still in its early stage, it is expected to revolutionize both traditional printed products and electronics. It opens up opportunities for thin, light-weight, flexible and environmentally friendly electronics and electronic components, which can be directly integrated in low cost printing processes. Therefore printers as well as traditional electronics manufacturers are monitoring the technological advancements in Printed Electronics with great interest.

> ***"Printed and Flexible Electronics could end up a larger market than today's semiconductor market … 20 years from now ($300+ B)."***
>
> *Ragu Das*
> *CEO of IDTechEx*
>
> *(2010 Interview)*

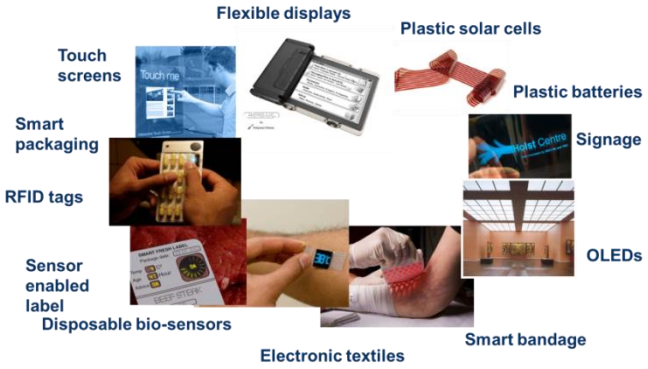

Figure 3: Applications of Printed Electronics (Holst Centre 2013)

Already the first applications have reached the market: mass printed passive ID cards for ticketing or toys, flexible batteries used in smart cards, and RFID-tags with printed antennas have been around for several years. More recently Organic Photovoltaic (OPV) and Organic LED (OLED) lighting products have been introduced, and e-paper price labels have become commercially available and installed in stores. See figure 3 for applications.

IDTechEx find that the total market for printed, flexible and organic electronics will grow from $16.04 billion in 2013 to $76.79 billion in 2023. The majority of that is OLEDs (organic but not printed) and conductive ink used for a wide range of applications. On the other hand, stretchable electronics, logic and memory, thin film sensors are much smaller segments but with huge growth potential as they emerge from R&D.

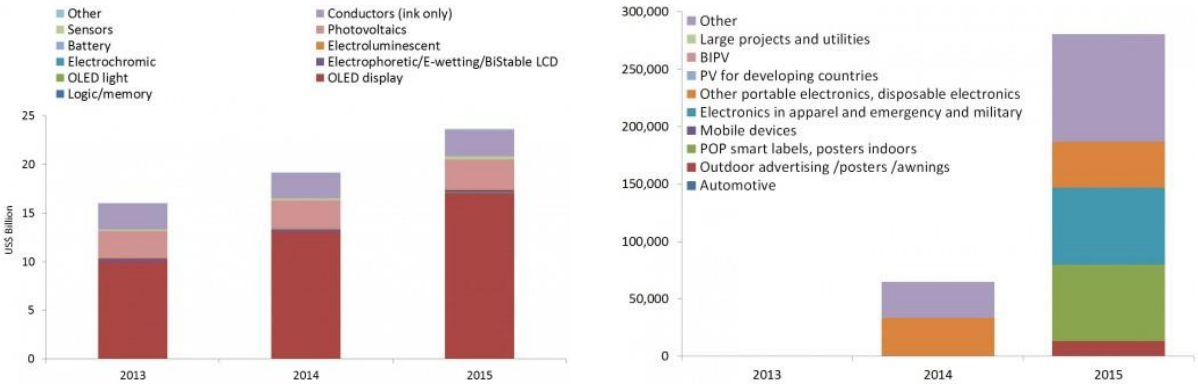

Figure 4: The Market for Printed and Potentially Printed Electronics in 2015 (IDTechEx, 2013)

Prototypes of products that have been shown recently include packaging products (note that the price level of these products is strongly depended on the added functionality) and wearable health monitoring devices. The market for products with hybrid electronics is currently in the developing stages where especially SME companies are looking into the integration of the technology into existing products.

The pictures in this paper show some of the product prototypes that can be achieved using the hybrid electronics approach (all developed by Holst Centre). Figure 2 shows a cup with an inkjet printed circuit that monitors the temperature of the contents of the beaker giving feedback via some mounted LEDs. Figure 5 shows a first iteration of a wearable health monitoring device based on a 5 layered Printed Electronics circuit made with screen printing. The last picture, 8, shows a screen printed food monitoring label with integrated thinned chips. The trends in this area are towards more flexible, thinner, stretchable and conformable systems.

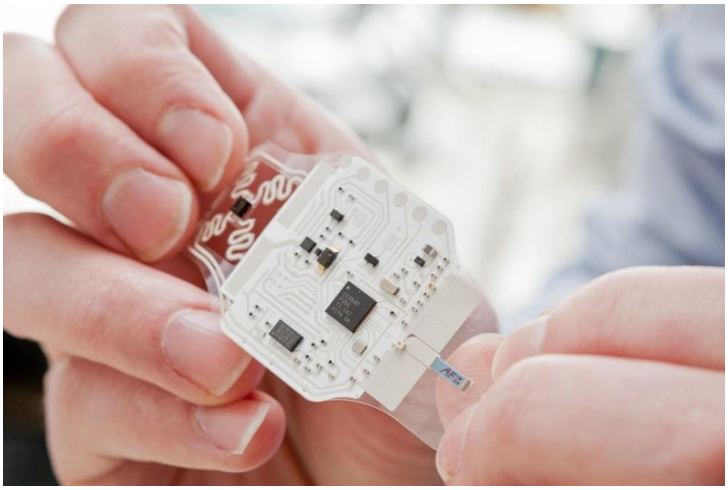

Figure 5. five layered printed circuit in a wearable health monitor (Holst Centre 2014)

Technologies used

Techniques used for printing electronics are a mix of traditional printing techniques with additional process steps.

Screen printing (both flatbed and rotary) is the most mature and most widely used printing technique for conductive structures because it delivers the highest conductivity tracks, it's fast, low cost and gives good reproducibility. Conductive, silver filled inks are widely available in the electronics industry today. Gravure and flexographic printing are also being used. These techniques deliver better resolutions compared to screen printing, at the cost of more expensive inks. This style is especially suited for very large volumes of products where low and medium conductivity is allowed. Inkjet printing of conductive structures is an upcoming technique. It has the advantage that it is digital and therefore very attractive for small batches and very short lead times. The inks are extremely expensive, but material consumption is relatively low.

The substrates used for the printing of electronic circuits are typically polyesters, although other plastics have also been used. For inkjet printing special types of paper are available which provide very high quality results. The most important requirement for substrates for circuit printing is the thermal stability. It should be mechanically and dimensionally stable at least 100°C and preferably at higher temperatures.

Recent developments have been mainly in the quality inks and in the resolution and the registration (multilayered printing) of the printing processes. For instance, the typical line width used in screen printed circuits has gone down from 1 mm to 100 µm, allowing for de application of much more advanced electronics.

Some products typically consist of many ultra-thin layers that have to be printed or coated at very high precision and homogeneity. Since the aim is to do this in a continuous, roll to roll (for OLED and OPV) way, the developed printing and coating processes have to be extremely reliable and robust.

After printing, the conductive inks need to be cured and/or sintered. There are many types of inks available. For low end inks drying or UV curing may be sufficient, but for medium and high-end application heat curing is a must. Traditionally this is done with hot air in ovens. Typical curing temperatures and times are 150-200°C

and 15 min. Therefore, drying/curing conductive circuits at a large throughput will require lengthy ovens (in the order of 150 m at 10m/min). A new development in this field is photonic sintering technology. Intense pulsed light is used to much more efficiently dry, cure and sinter the conductive circuits. The typical processing times can be reduced to mere seconds, thereby reducing the length of the line considerably. This technology is currently marketed by a number of companies. As an example, at Holst Centre, because of this technology a thermal oven could be replaced by a machine taking only 1m as shown in figure 7.

Apart from the manufacturing of printed electronic circuits, the current state of the art allows for the printing of a number of other components such as resistors, capacitors, inductors, piezo-electric elements etc. In order to realize more complex electronic products, hybrid solutions are currently being pursued. Chips, LEDs and other components are being assembled onto the conductive circuit using conductive adhesives. The reliability of these integrated solutions is approaching that of the traditional soldered electronics.

As stated above, the preferred printing technology is screen printing (fat bed or rotary). Flexographic and gravure printing are possible but will result in limited design freedom. Inkjet printing will be especially useful for prototyping small batches. UV or air curing is possible for low end applications but thermal and/or photonic curing is mandatory for more demanding applications. A curing device should be invested in in those cases.

The need of a clean room production area, as shown in figure 7, depends on the product-market combination chosen. Products requiring printing or coating at very high precision and homogeneity need to be produced in a clean room production area. Other, less demanding products, can be printed in normal clean surroundings.

Figure 7. Holst Centre's R2R print line with rotary screen, inkjet stations and photonic curing unit (box in the middle).

Needed competence and partners
In all cases time and competence will have to invested in the development of the printing processes. Especially multilayer printing and registration may require extra attention because the requirements are typically much more challenging than in “normal” graphic work. In fact the most important difference with graphical work is that not the looks but the functionality is most important.

Apart from these printing related topics, it is important to realize that an important role is fulfilled by the system and electrical designers at the front end and an integrator at the back end of the process. Printing is only part (but an important one) of the trajectory.

One of the big bottlenecks in getting such hybrid systems to market is the lack of integrators, companies that can integrate the printed circuits with traditional electronics and make products with it.

Furthermore, since technology is still being developed in research institutes such as Holst Centre, it is important to work together with research when aiming for the more high end markets such as OPV or OLED. This is true also in a lesser extend for other applications than OPV and OLED, where a knowledge transfer is needed to build up competence, and Printers could take it from there.

Manufacturing of Printed Electronics would be in new markets for Printers. This requires market knowledge which Printers either should build up or gain by hiring sales and marketing people with background in those markets. Being an European industry player with an innovative approach, it should be no problem to attract well qualified personnel.

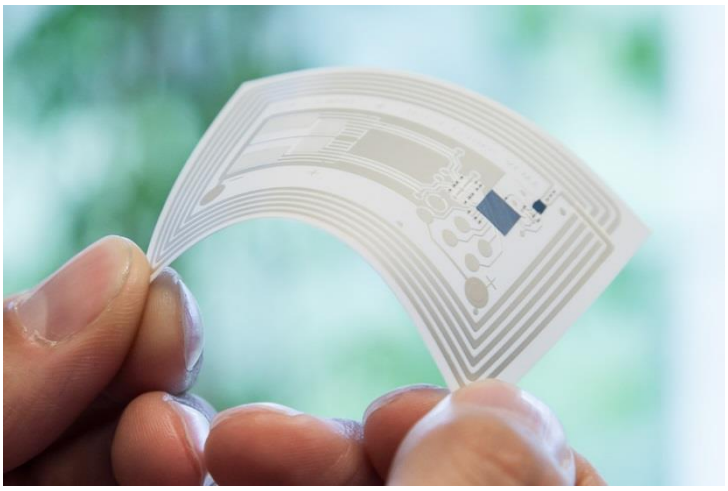

Figure 8. State of the art screen printed fine pitch conductive circuit (50 µm structures) (Holst Centre 2014)

Conclusion

Printed Electronics could be a feasible market for Printers to enter with an estimated of over $76 billion in 2023. This could mean a much needed chance in a growing market enabling Printers to grow further. The advantages over traditional electronics are in form factor, in functionality and in reduction of cost for large area and mass manufacturing, meaning that Printed Electronics has unique value over current technology. With Printers current printing background, Printers should be capable to transform itself into a printing electronics manufacturer. We therefore advice Printers to explore Printed Electronics strategically in a structured and inclusive process.

Steps forward

The prospects for industrial printing such as Printed Electronics are strong in both Western Europe and North America according to Smithers (2014). We are looking for the Dutch print industry to pick up this chance in the market. We realize that a diversification strategy in terms of Ansoff is the most risky of strategies. We therefore propose a thorough, structured process to come to a well-considered and supported strategy proposal.

Holst Centre/TNO has all the state-of-the-art knowledge to support the development of a Dutch electronic printing industry.

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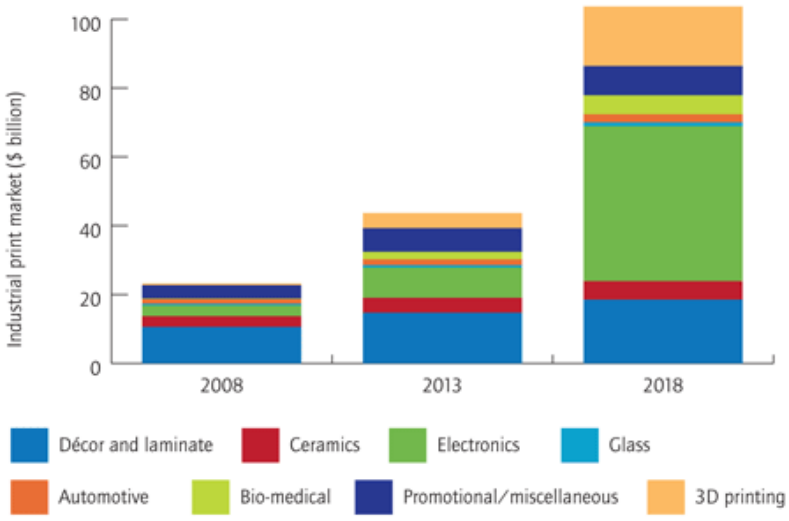

Figure 9. Industrial Printing market by product application 2008-2018 ($ billion) (Smithers 2014)