TRENDS IN PRINTED INTELLIGENCE

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Printed intelligence consists of components and systems that extend the functions of printed matter beyond traditional visually interpreted text and graphics, and perform actions as a part of functional products or as a part of wider information systems. VTT is investigating and developing enabling technologies for printed intelligence, electronics and optics and their applications, with a vision that 'electronics and functionalities from inks', manufactured by printing like R2R (roll-to-roll) 'continuously running' methods, enable cost-efficient integration/embedding of simple intelligence everywhere. Advances in material technologies have been an important driver in these developments. Instead of evolutionary replacement of traditional paper- and printing-industry products or information and communications technology (ICT)- and electronics-industry products, the development goals are in disruptive new applications, such as interactive and smart packages and shopping environments, disposable diagnostics and bioactive paper, large area sensors for building use and gaming, tag and code technologies for ICT and hybrid-media applications, etc.

Printed intelligence is based on high-throughput application of functional materials onto various, often flexible, substrates. These materials provide the printed product with functionalities based on, for instance, biotechnology, chemistry, optics, optoelectronics and electronics, or combinations of these. The application of these materials is carried out via cost-efficient manufacturing processes, such as contact printing, digital printing, coating, hot embossing, laser processing and combinations of these. The intelligent printed product can act independently on the printed product itself, or it can include, for instance, external power and computing sources, reading devices and supporting information systems. There are many application opportunities for paper-based substrates in this field, even though there are several challenges set by the higher demand of the printed materials and the final applications.

Extensive research has been conducted worldwide since the 1990s, focusing on enabling technologies for printed and/or organic electronics. Examples of possible application fields for organic and printed electronics are shown in the OE-A Roadmap for organic and printed electronics applications (Figure 1) by Organic Electronics Association (OE-A). The possible application areas for printed intelligence have developed to include other functionalities such as chemical, biochemical and optical effects. The developers of these technologies are increasingly looking for new innovations at the intersections of these disciplines, triggering the creation of novel application solutions that can utilize technology from sectors as seemingly unconnected as biotechnology, ICT and electronics.

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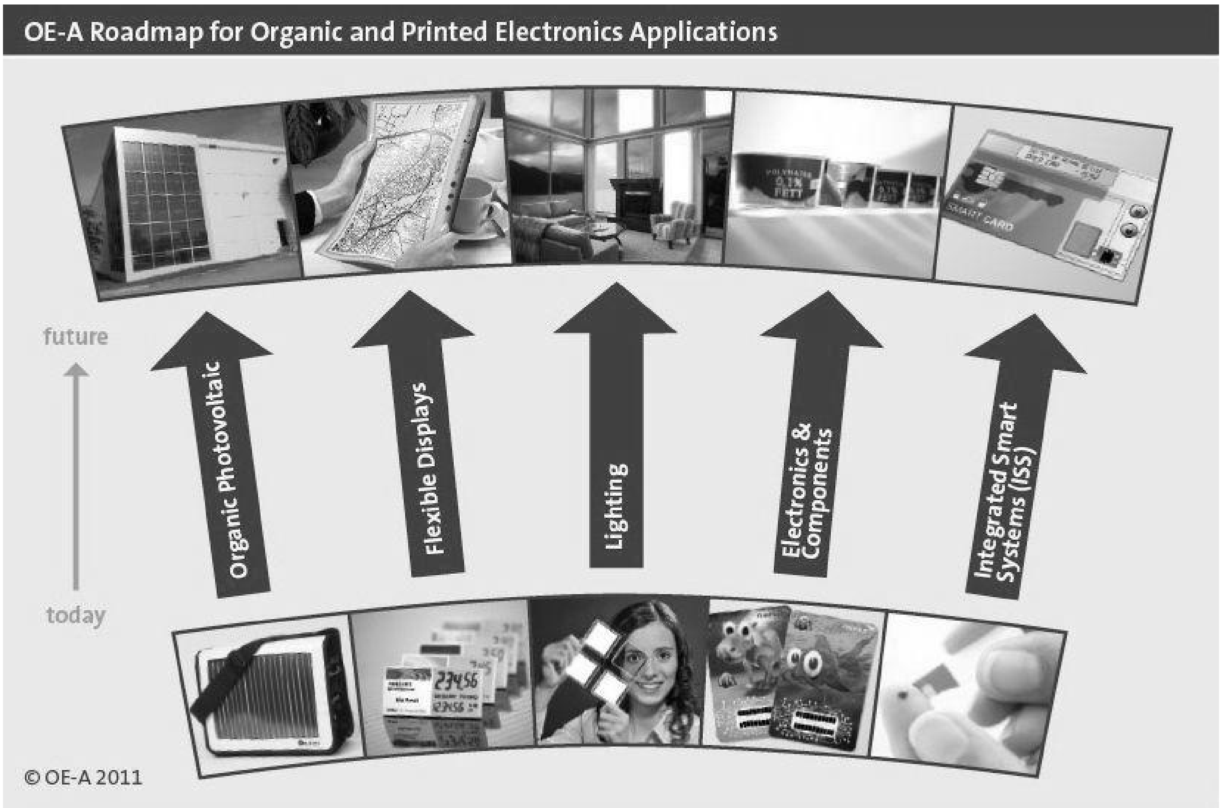

Figure 1. OE-A Roadmap for organic and printed electronics applications. Forecast from existing devices towards future applications for the five clusters discussed in this roadmap.[1]

In the Strategic Research Agenda for Organic & Large Area Electronics (OLAE) in Europe, OLAE is perceived as a disruptive technology that will change the way we live, consume, work and play. OLAE will enable next-generation information technology, energy, healthcare, entertainment and advertising industry solutions to meet the demands of large end-user markets. In the future, OLAE will provide significant societal benefits in the form of more effective usage of materials and energy and added functionality of products. It will enable new cost-effective products for healthcare and well-being, in particular for changing demographics[2]. Development of technology is entering the stage where the first products can be introduced into the market, but long-lasting developments are still needed in order to turn the disruptive visions into reality (Figure 2).

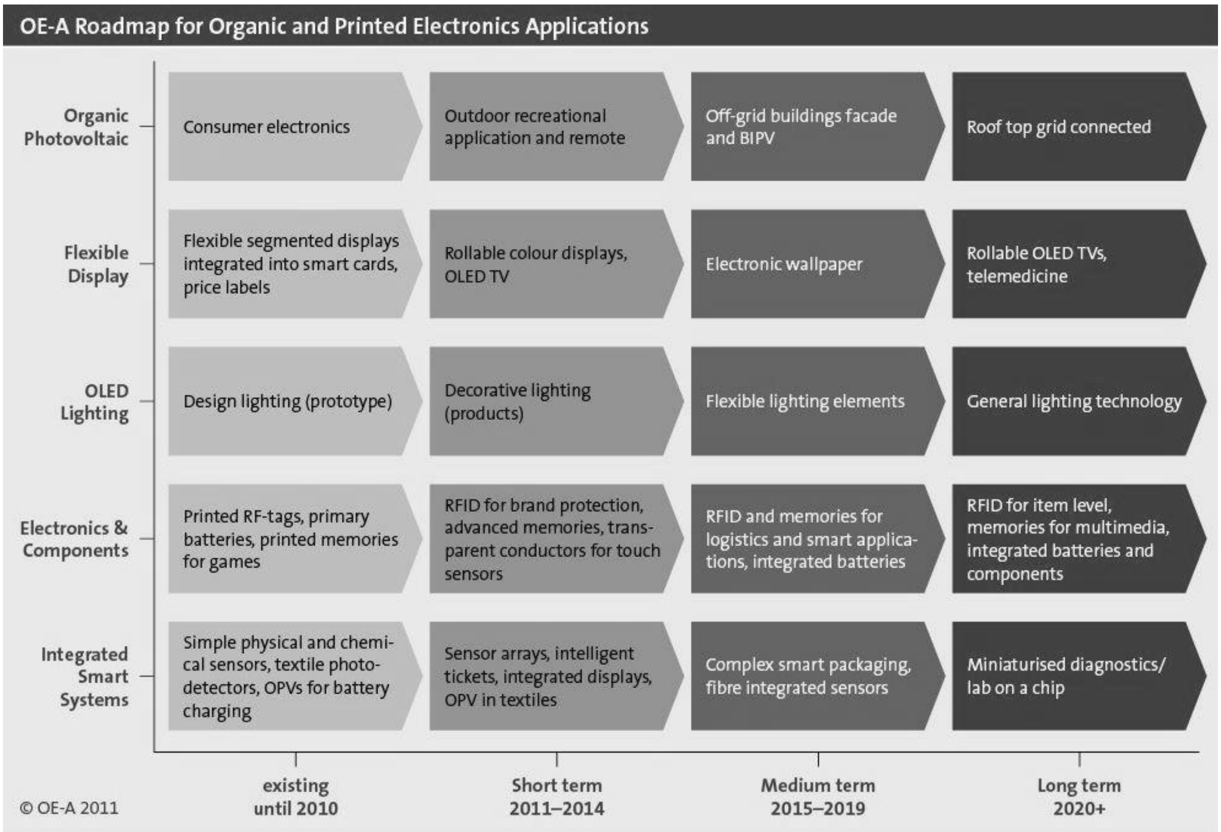

Figure 2. OE-A Roadmap for Organic and Printed Electronics Applications.[1]

Printed electronics and intelligence is a technology-intensive industry in its early stages, and it is undoubtedly very excited about the future prospects of its printed components, thin-film layers, etc. These developments have largely been driven by technical research institutions and the R&D departments of companies. The visions of the industry have therefore also been technology-heavy, and the developments have come predominantly from technology push. There have unfortunately been only a few product developers, and the end-market requirements (specification data sheets) that the industry has been trying to satisfy have therefore perhaps, in parts, been too strongly influenced by well-known and established technological component benchmarks.

IDTechEx reports that 60% of the companies they have profiled for Printed, Organic & Flexible Electronics Forecasts are components providers, 27% materials providers and 10% production-machinery and know-how providers[3]. Only 3% make products or perform integration. In the same IDTechEx profile, the market for printed & potentially printed electronics in 2012 is calculated to be $9.4 billion, consisting mostly of vacuum-processed OLED (Organic Light Emitting Diode) displays on glass ($4 billion) and mostly vacuum-processed photovoltaics ($2.6 billion). Only 6% of this market is currently produced on a non-rigid substrate. This market is forecasted to grow into a $63.3 billion market by 2022, with 45% in printed solutions, including 33% on a flexible substrate.

A starting point for materials development has been the development of functional properties of a material itself. In addition to development of the functional materials to be printed, the substrate materials need to be developed so they are usable in printing and post-processing and still retain functionality in the end-product over the lifetime of the product. According to IDTechEx's survey and forecast, the largest market potential in this emerging technology market lies in OLED and OPV (Organic Photovoltaics) solutions. The organic functional materials currently used in both of these applications are very sensitive to oxygen and moisture, and require a transparent and partially conductive casing. This sets high demands on the barrier and sealing properties of the substrates used for these components.

With current materials, the lifetime of OLED and OPV components is from a few months up to three years [e.g. 4, 5, 6].

In addition to these barrier and transparency requirements, most of the printed organic electronics components require an extremely smooth and stable substrate. This set of demands makes it a challenging task to develop a suitable paper or board to be used as a substrate in these applications with the commercial materials currently available. New material developments, for instance in the field of nanocellulosic materials and films could open up novel opportunities for the forest industry as a supplier of substrates for printed electronics.

Electronics and optics components are often multilayer structures, and the layers need to be uniform and aligned in a reproducible way with a higher accuracy than in traditional printing. The material compatibility of different layers accounts for the functionality of the end product in a similar way as the functionality of a material itself. The register accuracy and reproducibility requirements set new demands for the process control and on-line monitoring equipment as well as for substrate stability and uniformity (across the web, within a roll, from roll to roll and batch to batch).

Paper's natural tendency to wick liquids has attracted several research groups worldwide in starting development of various sensors and/or paper-based diagnostic devices. These developments will potentially lead to multi-billion dollar markets by bringing diagnostic capability to everyday situations as a part of consumer products or their packaging, and by distributing medical and environmental diagnostic testing from laboratories to the point-of-use. A good example of an existing paper-based application is glucose test strips for diabetics' daily use.

Significant progress has been made in the last few years in technology development for printed intelligence, and the performance of the devices enables a first generation of products. However, in order to fulfil the more complex requirements of future generations, further improvement of materials, processes, design and equipment is necessary.[1]

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