Industrial Printing Beyond Color

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Abstract

During the development of today's industrial printing technologies traditional press makers and printers gained a number of abilities and competences which will help to extend their scope beyond printed products which only address the human visual sensory nerve.

For example, printing an appropriate pattern with an ink which generates on a substrate the functionality electrical conductivity gives the opportunity to print electrical circuitry or antennas for RFIDs. Adding further patterns with functionalities like semi conductivity and electrical insulation opens routes to print e.g. organic field effect transistors OFETs and LEDs.

The paper outlines the extension of traditional graphic technologies into new fields of industrial printing and will discusses opportunities, challenges and limitations of industrial printing systems for printing electronic devices.

Today's Printing Technologies

During the 500 years since the Man of the last Millennium Johannes Gutenberg initiated the process of printing, printers and printing press makers constantly developed more and more refined methods which convince the human eye to recognize a well defined ensemble of screen dots as a perfect halftone image.

Printers and press makers gained important knowledge and acquired abilities to facilitate placing screen dots / image elements at a minimum size of 5 µm with a reproducible dot positioning < 70 µm and back-to-front registering < 200 µm for 1 Million copies. It is even possible to meet these specs at printing speeds up to 15 m/s (paper velocity) at paper widths beyond 2 m, printing on endless paper web or paper sheets and on a broad variety of substrates. These data apply to the traditional industrial printing technologies Gravure and Lithographic (Offset) Printing.

The development of the non-impact printing technologies Electro Photography (liquid or dry toner based) and Ink Jet are also driven by the intention to convince the human eye seeing a halftone image although the image actually consists of an ensemble of dots of different colors.

Summarizing, it is obvious that today's printing industry deals only with the generation of the *functionality color* on substrates with typical properties of paper, plastic and metal or compounds of these materials, because today's printed products generally addresses the visual and haptic senses of humans.

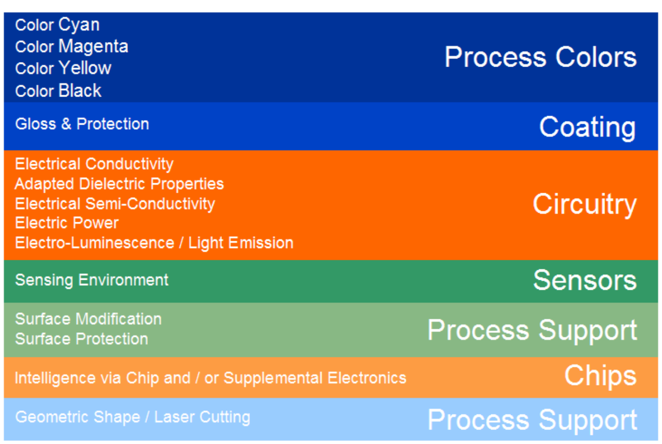

Figure 1. Traditional and future functionalities manufactured by printing

Polymer Electronics as Part of Emerging Printed Products

Analyzing the future requirements of printed products, for example of being elements of automated supply chains or highly secure medication systems, it is evident that the products made on an industrial print production line have to have more functionalities than just merely color. Figure 1 summarizes different groups of functionalities of future printed products.

The functionality *Process Color* is generated by transferring a colored ink to the substrate dot wise. In any case the ink has to be optimized for a designated printing technology. The setting of the rheological properties of these inks, determined by the chosen printing process, allows almost all possible low prized solutions to be used, as long as the targeted color fits the standards.

Contemplating other functionalities included in Fig. 1 it becomes obvious that the number of applicable materials to set the rheological properties of an ink is seriously limited. E.g. UV curable inks used to generate the functionality *Gloss* can only be composed from materials which neither inhibit the photochemistry nor the polymerization itself. Considering the optimization of those inks which will generate in multilayer arrangements the functionalities of Electrical Circuitries, the material scientists are facing a rather narrow window of opportunities to combine the targeted functionality of the printed element and the required rheological properties of an appropriate ink.

Nevertheless, mass printing technologies including the non-impact ones will enable a new field for print applications and subsequently a new market: *low end electronics* (see fig. 2). A variety of new products, which will not meet the top-notch specs of silicon electronics, but will be manufactured on flexible substrates, at low production costs, under ambient conditions and in very large quantities, typical for printing lines. And these manufacturing details are illustrating the potential of low end electronics becoming a value adding part of printed products.

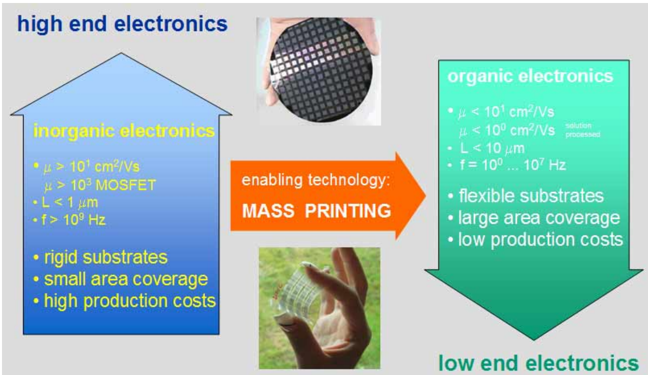

***Figure 2**. Mass printing technologies enabeling low cost electronics*

Figure 3 compares the integration level and manufacture productivity of traditional, high end microelectronics and the printed low end electronics, which will be a value adding part of traditional printing products. Although the productivity of the IC and MEM's fabrication is fairly low compared to the organic electronics fabrication employing printing technologies, the manufactured devices excel with high end specs which are closely related to the small feature size resp. the high integration level.

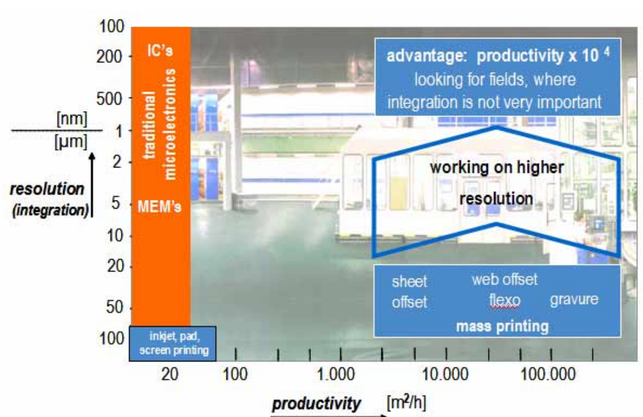

***Figure 3**. Mass printing technologies enabeling low cost electronics*

On the other hand figure 3 proofs that the integration level of printed organic electronics will be limited due to the given resolution limits of the printing technologies. Therefore the performance of this new kind of electronics will be far below the high end electronics. But the fabrication productivity for print technology based electronics is 4 orders of magnitude higher, which will remarkably support the mass wise spreading of organic electronics as a part of printed products..

The Printing Systems

Figure 4 shows a summary of the well established printing technologies in the Graphic Arts Industry. In Electronics Fabrication today only Screen Printing is broadly applied and Ink Jet Technology starts to be used for marking purposes. The major industrial printing technologies for future printed products will be gravure, offset, flexo and inkjet. Each of the technologies has its strengths and weaknesses. But all of them are true additive systems in contrast to the established subtractive etch technologies usually employed for the production of electronic components.

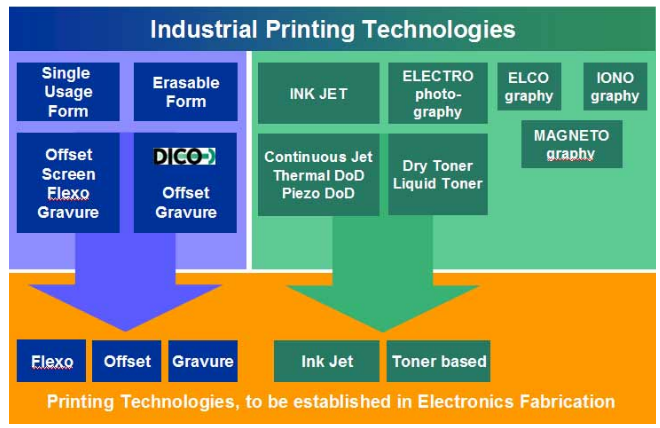

***Figure 4**. Established mass printing technologies and their migration into electronics fabrication*

Gravure stands for a straightforward inking system consisting of an ink pan, a pan roller and a doctor blade. The form cylinder carries the engraved cells which are filled by the inking system; their content is transferred to the substrate in the printing process and contributes to the printed image. It is important to know that the manufacture of the form cylinder and the change over time to set up the press for a print job are very time consuming and expensive. Therefore, under economic considerations gravure printing is suited for jobs with a very high number of copies to be printed or extremely high quality applications. But the simplicity of the inking unit and the ink transfer pointing to a high potential of gravur technology for printing the new functionalities.

In case of *Offset* the form manufacture and the change over process of the press are fast and inexpensive. On the other hand both, the dry and the wet offset are based on sophisticated equilibrium processes on highly optimized form materials, requiring expensive inking and dampening units which are limiting the formulation opportunities of suitable inks for printing the new functionalities.

Finally, in case of *InkJet* the corresponding head technology will also limit the formulation capabilities of suitable inks, but the achievable resolution at industrial printing speeds is improving and is getting closer to the industrial requirements. And, because the ink supply system does not need the large amount of ink in the reservoirs (compared to gravure and offset inking systems), this technology should have a bride future in printing of small amounts of expensive functional inks. Additionally, Ink Jet applications have the potential of printing variable data.

Today the printing industry starts facing the challenge of manufacturing highly complex printed products which are requiring the print-application of expensive functional inks. The choice of the printing technology per printed functionality depends on the printability of the functional ink. For example, it will be unpromising to print a moisture sensitive material using wet offset. The key to build an industrial (inline) production system for future printed products will be found in highly modular machinery with absolute variability regarding printing and drying technologies. Press makers call these systems *Hybrid Printing Systems*, consisting of a machine base of standardized automation, data electronics, a regular workflow system, and defined interfaces

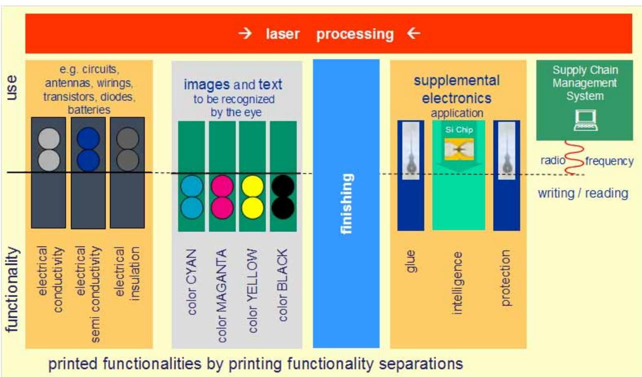

Figure 5. *Conception of a modulare printing system, e.g. for upcoming packaging applications*

which allow the user to “knob-in” the printing technology he needs for a given functionality. Figure 5 shows a conception of this kind of printing system.
The development of the different specialized printing units requires a close partnership of the ink maker, substrate maker and press maker because, other than today, future partners will not be able to optimize their components without mutual coordination.

The Future

Globally, a broad variety of approaches to print new functionalities with established printing technologies can be observed. But the basic challenge is still to merge the known visual and haptic functionalities and at least some of the new printed functionalities in *one* printed mass product.

Recently polymer electronics activists have opened a new dimension in the field of printed electronics: appropriate products are now available in lots which need the pallets used for product handling in the press rooms of the graphic arts industry since years…….

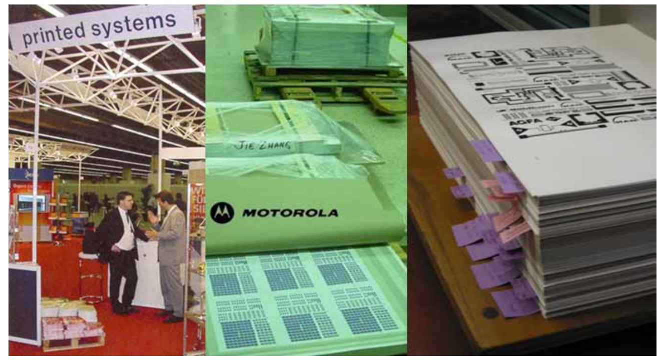

Figure 6. *Printed products with new functionalities starts filling regular pallets*

Author Biography

Reinhard R. Baumann received his Diploma in physics from the Leipzig University of Germany (1976) and his PhD in chemical physics from Leipzig University of Technology (1985). His research interests focused on areas of Physical Chemistry and Electrical Engineering of organic materials for polymer electronics at the University of Bonn and the IBM Almaden Research Center in San Jose / CA. In 1999 he joined the MAN Roland Group and held differerent management positions there. Since 2006 he is Professor for Digital Printing and Imaging Technology at the Institute for Print and Media Technology of the Chemnitz University of Technology in Chemnitz / Germany.