Fraunhofer
ENAS

FRAUNHOFER INSTITUTE FOR ELECTRONIC NANO SYSTEMS ENAS

PRINTED FUNCTIONALITIES

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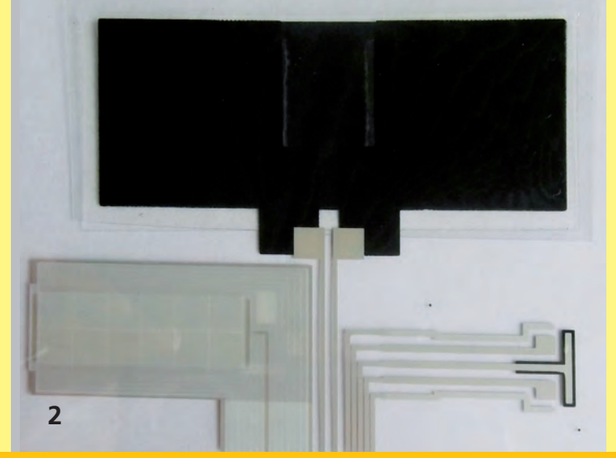

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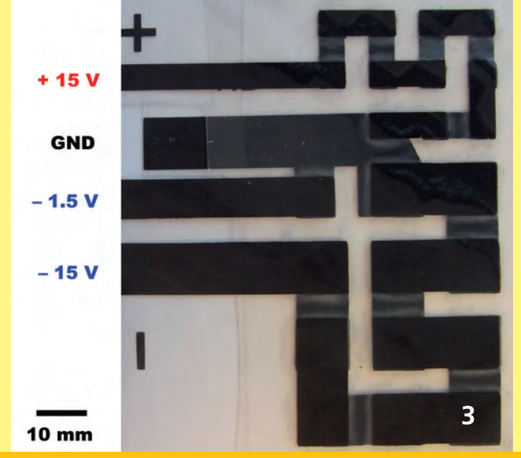
SCREEN PRINTING OF FLEXIBLE ENERGY SOURCES



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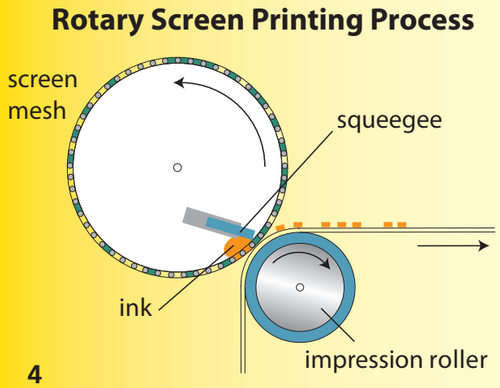

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The particular strength of the Fraunhofer Institute for Electronic Nano Systems ENAS lies in the development of smart integrated systems for different applications. Such systems combine electronic components with nano and micro sensors as well as actuators and communication units. More and more these are autonomous systems with an own energy supply or energy harvester.

Fraunhofer ENAS develops single components, technologies for their manufacturing as well as system concepts and system integration technologies and transfers them into production. That means, the institute offers research and development services from the idea, via design and technology development or realization based on established technologies to tested prototypes.

Smart systems not only unite multiple technologies, they address various application sectors and societal challenges, like a secure energy supply, sustainable transport, sustainable production, and securing of health and wellbeing. They are a key technology looking at industry 4.0, internet of things, smart mobility or smart home.

With this working field Fraunhofer ENAS supports the research and development of many small and medium sized companies as well as large scale industry. Moreover Fraunhofer ENAS has established a strategic network with research institutes and universities in Germany and worldwide.

During the centuries after Gutenberg introduced printing on paper as the technology to distribute information extensively, the printers perfected their technologies to convince the human eye that the well defined cloud of tiny printed color screen dots appears as halftone images.

Therefore, the traditional printing processes gravure, offset, flexo and screen printing as well as the digital printing technologies xerography and inkjet are well developed techniques to transfer ink dots onto fiber based substrates, plastic foil or even sheet metal with a very high precision.

The department Printed Functionalities capitalizes on these experiences and focuses on printing technologies and processes for the manufacture of printed products which do not solely address the human visual sense. These products will be equipped with functionalities beyond color, e.g. electrical conductivity and semiconductivity, optimized porosity or even electric power. With these functionalities they will be able to perceive their surroundings and their own state, save these data and communicate them via computer networks with other members of the “Internet of Things”. We expect a growing number of printed functionalities which in many applications will be supplemented by silicon based micro and nano systems, developed in the Fraunhofer ENAS labs as well.

The key for suitable industrial manufacturing equipment for these “printed smart objects” is the interdisciplinary development of complex inks, manufacturing processes and machine systems with integrated digital fabrication technologies.

In the department of Printed Functionalities traditional and digital printing processes are employed to manufacture this kind of new printed products, taking advantage of the additive character of the printing technologies and their high productivity. These printing technologies with the focuses drop-on-demand inkjet, gravure and screen printing are under further development in cooperation with Technische Universität Chemnitz and industrial partners to meet all the requirements of challenging applications.

Printed Thin Film Battery

Small-sized electronic devices are more and more integrated in our daily life. Most of these new products require energy sources with high flexibility in regard to thickness, geometrical shape, voltage, capacity and weight. Applying the appropriate functional materials onto flexible substrates using printing technologies will open promising opportunities to integrate e.g. batteries into ductile products.

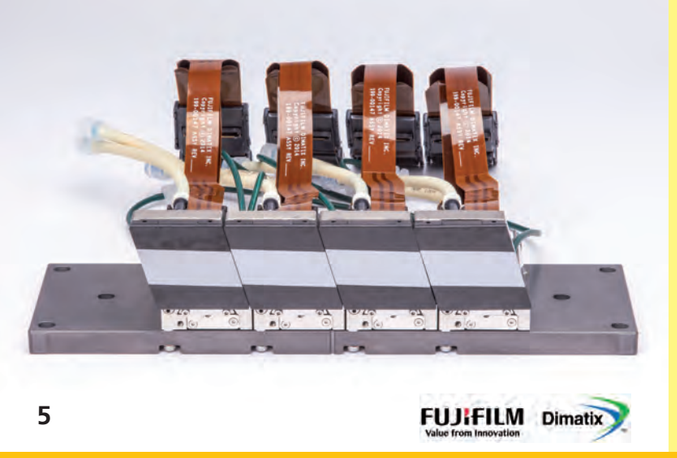
One of the main research areas of the department Printed Functionalities is the printed thin film battery developed in close cooperation with the Digital Printing Group of the Technische Universität Chemnitz (TUC) and industrial partners.

These printed battery cells exhibit a nominal voltage of 1.5 V, are typically 0.8 mm thin and weighs about 1 g. The single cells can be chained easily therefore printed batteries with voltages that are multiples of 1.5 V are built easily. The batteries are made from flexible plastic foil which allows manufacturing them in a roll-to-roll printing process. All the materials used are readily available, inexpensive and without environmental risks as they are free of mercury or other toxic materials. The latter properties stand for easy end-of-life treatment without special recycling logistics.

The highest profile in the media reached the printed battery when the New York Times Magazine listed this battery among the top five technology achievements of the year 2009. Furthermore, the nongovernmental Responding to Climate Change organisation (RTCC) accredited as an official observer to the United Nations Framework Convention on Climate Change (UNFCCC) selected the printed battery for its 2010 report. This report was presented to the United Nations Climate Change Conference in Cancun, Mexico, in December 2010.

Project results based on our battery technology have been awarded twice by the OE-A as “Best Publicly Funded Project Demonstrator” @ LOPE-C 2013 and LOPEC 2014.

Fig. 1: Demonstrator of SIMS
Fig. 2: 3 components without cover (see 1)
Fig. 3: +/- 15 V printed battery
Fig. 4: Rotary screen printing process



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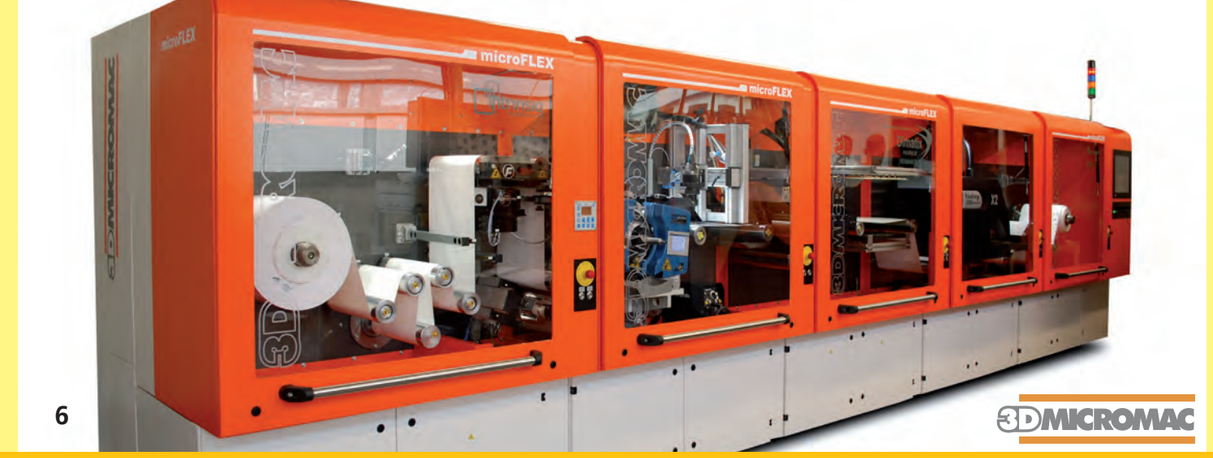

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Radio Frequency Identification Technology (RFID)

In addition to microsystems technology and consumer electronics, Radio Frequency Identification technology (RFID) is one of the focal areas in the field of Printed Functionalities. Especially the development of printable antennas, adapted to the dedicated dielectric environment of the tagged item and attached to regular silicon RFID chips, will contribute to the single item tagging of different objects – either of our everyday's life or as members of industrial supply chains – remarkably. In order to characterize the communication quality of these printed RFID tags an electromagnetic shielded measuring environment without any reflections is definitely needed. Such an environment – an anechoic chamber – was built by Fraunhofer ENAS in 2009.

One of the major aims of the department Printed Functionalities is to foster the development of customized and low cost printed antennas for various and sometimes critical dielectric environments including metallic objects and liquid containing casks. An anechoic chamber is one of the essential equipment to master the appropriate R&D challenges. With these experiences and the available top notch equipment ENAS is ready to serve interested R&D partners from institutes and industry.

Hybrid Roll-to-Roll Manufacturing System

Printing functional material is only one process step within the workflow process. Therefore we started the development of a machine concept on basis of the 3D-Micromac AG modular machine concept microFLEX™. This machine enables us to embed new processing technologies as they become necessary either inside the already existing machine or by adding just another module. The web width is up to 30 cm and the web speed up to 20 m/min (dependent on the process parameters).

The current machine consists of: unwinding, web guide roll, optical mark detection, rotary screen printing, inkjet printing, LED UV curing, IR heating, photonic sintering and rewinding. For the inkjet printing a close cooperation with Fujifilm Dimatix is established. For the photonic sintering a Novacentrix® PulseForge® 3200 module is installed in the machine.

Substrates as PET foil or paper has been used to manufacture printed antenna systems as well as conductive patterns based on e.g. silver or copper inks. At the end of the process the printed and cured/sintered structures are rewound. The functionality of RFID transponders built from copper patterns has been demonstrated.

Inkjet-Technikum

The Fraunhofer ENAS department Printed Functionalities and the Digital Printing Group of the Technische Universität Chemnitz (TUC) are equipped with most modern digital and traditional printing systems forming the digital Inkjet-Technikum. The installed digital printing equipment is made by leading companies such as Fujifilm Dimatix and XAAR. However, the equipment not only includes inkjet technology but also the integration of this technology into traditional printing systems. The combination of inkjet, gravure and/or screen printing and laser based patterning and conversion techniques in the ENAS labs results in hybrid-printing systems and highly flexible digital fabrication machinery as part of the equipment of the Inkjet-Technikum. It is under ongoing development in close cooperation with leading industrial machine builders and it is open to use by interested R&D partners.

This Inkjet-Technikum does not only allow joint projects with partners but also provides a chance for all size of companies to take first steps into the field of printed electronics and digital fabrication without the need of risking own investment. Furthermore, interested partners are welcome to do training on certain pieces of equipment.

We offer the following services:

- precise deposition of liquid processible materials to form layers with defined properties, utilizing printing technologies
- specific employment of inkjet techniques for resources-saving, additive material deposition
- printing-workflow development to optimize the manufacture of new functionalities
- material and layer characterization: viscosity, surface tension, morphology, electronic properties, layer zoning, layer interaction
- SEM & EDX analysis
- tactile surface profilometry
- development of innovative components for specific applications based on printing technologies, e.g. flexible energy/battery systems
- tailoring of applications employing printed batteries
- printing of conducting patterns, e.g. as antennas or electrodes
- design, simulation, printing and measurement of customized antennas.

Our development partners:

Fig. 5: FUJIFILM Dimatix SAMBA™ Printbar

Fig. 6: microFLEX™ machinery (3D Micromac)

Fig. 7: Integrated Novacentrix PulseForge® 3200 module

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Drucker nutzen heute sehr zuverlässige Technologien für die Herstellung hochwertiger Druckprodukte, mit denen fast ausschließlich der visuelle Sinn des Menschen adressiert wird. In Zukunft werden die Druckprodukte über die Farbigkeit hinaus weitere Funktionalitäten besitzen, mit denen sie z. B. ihre Umgebung wahrnehmen und mit Computernetzen kommunizieren können. Der Schlüssel für die Verfügbarkeit geeigneter industrieller Produktionsanlagen für diese gedruckten „Smart Objects“ liegt in der interdisziplinären Entwicklung von komplexen Druckstoffen, ihrer Applikation in Fertigungsprozessen und Maschinensystemen unter Einbeziehung neuer, digitaler Fertigungstechniken.

Radio Frequency Identification (RFID)

Die Entwicklung von RF-Komponenten für Low-Cost-Radio-Frequency-Identification-(RFID)-Anwendungen im Ultra-High-Frequency-(UHF)-Bereich ist ein Schwerpunkt der Abteilung Printed Functionalities. Im Besonderen wird an der Optimierung gedruckter Transponder-Antennen für komplexe dielektrische Umgebungen gearbeitet. Diese auf Druckprodukte gedruckten Antennen werden mit einem Silizium-Chip verbunden und ermöglichen als optimierte Low-Cost-RFID-Transponder die drahtlose Identifikation von Objekten auch in schwierigen dielektrischen Umgebungen.

Hybride Fertigung

Für die Realisierung industrietauglicher Herstellverfahren auf flexiblen Substraten wurde am Fraunhofer ENAS ein hybrides Fertigungssystem auf Basis eines Rolle-zu-Rolle-Aufbaus installiert. Hiermit ist es in der derzeitigen Ausbaustufe möglich, mittels Sieb- oder Inkjet-Druck Materialien ortsaufgelöst auf ein flexibles Trägersubstrat (bis 30 cm Bahnbreite) aufzubringen. Eine UV- oder thermische Nachbehandlung ist in der Anlage genauso möglich wie die Sinterung von Precursor-Materialien mittels eines photonischen Sinterprozesses. Somit lassen sich hier beispielsweise Metallschichten aus Silber oder Kupfer herstellen, die für Leitbahnen oder Antennensysteme nutzbar sind. Andere Tätigkeiten an der Maschine adressieren den Bereich der gedruckten Elektronik.

Das installierte, flexible Maschinenkonzept ermöglicht die selektive Erweiterung um weitere Prozessschritte wie Laserbearbeitung oder auch andere Druckverfahren, sodass auf dieser Basis das Konzept der digitalen Fertigung (Digital Fabrication) demonstriert werden kann. Der Kerngedanke hierbei ist die vollständig durch digitale Daten kontrollierte Fertigung ohne statische Druckformen bis hin zur Losgröße 1 – und dies bei minimalen Rüstzeiten von ideal 0.

오늘 날 인쇄기를 통한 최적의 결과물 생산을 위해 매우 신뢰성이 높을 기술들이 적용되고 있으며, 인쇄물은 더 이상 시각적 표현만을 목표로 하지 않는다. 가까운 미래에 인쇄물은 단지 색감을 표현하는 것을 넘어 다양한 기능들을 수반하게 될 것이며 인쇄물을 통해 우리는 주변 환경을 인식하고 통신 네트워크와의 소통도 가능해 질 것이다.

이러한 “스마트 사물 (Smart Object)”의 생산을 가능하게 하는 생산설비의 핵심요인은 새로운 디지털 인쇄기술을 활용한 다양한 잉크의 개발 및 생산기술과 설비시스템 개발의 조화로부터 비롯된다.

Radio Frequency Identification (RFID)

UHF (Ultra High Frequency) 분야에 활용이 가능한 저비용 RFID 의 RF 컴포넌트를 개발하는 것이 Fraunhofer ENAS 내 Printed Functionalities 부서의 핵심과제 중 하나이다.

무엇보다 복합 유전체 환경의 인쇄 트랜스폰더-안테나의 최적화된 기술을 개발하는데 중점을 두고 있다. 인쇄방식으로 생산된 안테나의 경우 실리콘 칩과 연결돼 복잡한 유전체 환경 내에서도 무선으로 사물인식이 가능한 최적화된 저비용 RFID-트랜스폰더의 기능을 수행하게 된다.

하이브리드 생산

플렉시블한 기판위에 인쇄가 가능한 생산 시스템을 구현하기 위해 Fraunhofer ENAS 에서는 Roll-to-Roll 기반의 하이브리드 생산시스템을 개발하였다. 이 시스템은 현재 시제품 수준이며 현 단계에서는 스크린 또는 잉크젯 방식을 통해 최대폭 30 cm 너비의 플렉시블한 기판위에 인쇄가 가능하다.

이 시스템내에서는 UV 및 열을 이용한 후처리와 광학 Sintering 과정을 통한 전구체 물질의 소결도 가능하다. 따라서 도체회로 또는 안테나 시스템에 사용가능한 은(Ag) 또는 구리 (Cu) 금속층 제작도 가능해지고 이 외에도 하이브리드 생산시스템은 다양한 인쇄전자 분야에 적용이 될 수 있다. 현재 개발중인 하이브리드 시스템은 레이저 또는 다른 방식의 인쇄방법을 응용해 시스템을 확장해 갈 수 있도록 개발이 되어 있다. 이를 통한 디지털 생산화(Digital Fabrication)가 가능해질 수 있도록 하는 것이 목표이다. 여기서의 핵심아이디어는 디지털 정보를 통해 완벽하게 통제가능한 생산 시스템이 모든 인쇄기판위에 경제적 로트 사이즈 (Lot size) 까지 인쇄가 가능하고 이 모든 과정이 최소 준비시간을 거쳐 진행되는 것이다.

Fig. 8: Illuminated magazine powered by printed batteries (acknowledgement: OE-A)
Fig. 9: Printed flexible batteries with LEDs
Fig. 10: Screen printing pilot production line
Fig. 11: Printed RFID antennas for tagging of packages for metal containers

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Title page:
Roll-to-roll printed copper patterns on paper web