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News Release

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BMBF Project "Polytos2: Printed Organic Circuits and Memory" successfully completed

- **Consortium of ten partners from science and industry creates the basis for the future development of innovative organic electronics applications**
- **Development of new semiconductor polymers with high charge carrier mobility as well as other organic materials for producing printed transistors and circuits**

Darmstadt, Germany, September 2, 2014 – After two years of intense collaboration with nine other consortium partners Merck KGaA, Darmstadt, Germany, the consortium leader, has successfully completed the Polytos2 project funded with a sum of EUR 4.8 million by the German Federal Ministry of Research and Education (BMBF).

Within the scope of this project, Merck KGaA, Darmstadt, Germany, developed new semiconductor polymers with high charge carrier mobility as well as other organic materials for producing printed transistors and circuits and designed for organic electronics applications. Printing machines specifically developed to meet the properties of such materials enable easy, low-cost printing of the electronic components onto plastic films. As the properties of these innovative components differ completely from those of conventional components based on silicon technology, this will open up totally new applications.

One example are smart labels, which are equipped with a temperature sensor and intended for use in food monitoring. Also readers designed specifically for organic

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electronics have been developed, as well as software solutions that make it possible to read and efficiently handle logistic and product-related data. This has created the basis for the future development of novel organic electronics applications at InnovationLab in Heidelberg.

A main focus of the project was on establishing a foundry at InnovationLab in Heidelberg. This is a modular system consisting of standard circuit elements that makes it possible to find tailored solutions for specific product requirements quickly and efficiently.

Apart from Merck KGaA, Darmstadt, Germany, the following companies and institutes participated in the project: BASF SE, Heidelberger Druckmaschinen AG, Mannheim University of Applied Sciences, Pepperl + Fuchs GmbH, PolyIC GmbH &Co. KG, Robert Bosch GmbH, SAP AG, TU Darmstadt, Heidelberg University, and University of Mannheim. Associated partners were InnovationLab GmbH and VARTA Microbattery GmbH.

Polytos2 was the follow-up project of Polytos. This three-year project was successfully completed in February 2012 and was also funded by the BMBF as part of the “Forum Organic Electronics” Rhine-Neckar excellence cluster.

Further information on the project partners:

BASF SE
Within the scope of the Polytos2 project, BASF researchers have developed new, small-molecule-based, n-type organic semiconductors for the fabrication of solution-processed, field-effect transistors. The formulation of the small molecules as well as the configuration of the transistors have been adapted in order to achieve transistors with high charge-carrier mobility as well as high electrical parameter homogeneity. In collaboration with the project partners, the InnovationLab laboratories have succeeded in developing a gravure printing process with highly homogeneous printing results. Further information on BASF SE can be found at www.basf.com.

Heidelberger Druckmaschinen AG
As part of the consortium, Heidelberger Druckmaschinen AG upscaled the fabrication processes from laboratory scale to a rotary press suitable for industrial production. In the Polytos2 cooperation project, this was an important prerequisite for future commercial utilization of fabrication processes for the foundry. The printing of high-precision conductor structures for organic circuits with conductive nano-inks was a key basis for this. Further information on Heidelberger Druckmaschinen can be found at www.heidelberg.com.

Mannheim University of Applied Sciences

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Mannheim University of Applied Sciences participated with the Institute for Design of Integrated Circuits (Prof. Giehl) in the Department of Information Technology. Here, two measuring stations for the electrical characterization of printed organic transistors were set up and serial measurements were conducted in order to obtain statistical distributions of transistor parameters. The measurement results provided approaches for improving the materials as well as the printing process for production. Based on the results, parameters could also be obtained for manual calculations, computer simulations and Monte Carlo simulations. Transistor and circuit simulation models could also be extended to include the influence of parasitic effects such as leakage flux. This laid the foundation for the design of robust circuits. Comparisons were made between simulated circuits and measurements, which demonstrate the usability of the models. These models were implemented in commercial design systems and used in a course during the winter semester 2013/14 at Mannheim University of Applied Sciences. Creating the layout of the individual printed layers of the process was also implemented. This fulfilled the prerequisites for the professional development of applications. Further information on Mannheim University of Applied Sciences can be found at www.hs-mannheim.de and www.inftech.hs-mannheim.de.

Pepperl + Fuchs GmbH
The sensor labels developed in this project can be read and evaluated using a reader developed by Pepperl + Fuchs. The reader is designed to meet the specific requirements of printed organic electronics and offers excellent transmission performance as well as extensive and flexible setting options. This makes it a convenient tool for further developing new organic circuits. Further information on Pepperl + Fuchs can be found at www.pepperl-fuchs.de.

PolyIC GmbH & Co. KG
As part of the funded project Polytos, new automated design methods, circuit design concepts and application scenarios for printed smart labels were defined and investigated by PolyIC in cooperation with project partners. For the targeted Polytos foundry concept, a fundamental objective was to enable circuit design between partners beyond corporate boundaries. Therefore, PolyIC developed their own manufacturing process layout rules, which were also used by the project partners for their designs. These comprised digital and analog circuit blocks that have been combined to form complex functions. In addition to digital circuits, in particular circuit designs based on analog technology were also developed using the new design methods. One result of the development is a 3-bit flash ADC (Analog-Digital Converter) with 106 transistors. All designs were built and tested by PolyIC with polymer semiconductors using photolithographic prototyping techniques. With the project partners, who represent a large part of the value chain of RFID-based sensor systems, application scenarios were investigated. This work resulted in specifications that can be used for the future development of printed electronics. Overall, an important basis for new methods in printed circuit design as well as in the development and specification of RFID-based sensor systems was established in the course of the project. Further information on PolyIC can be found at www.polyic.com.

Robert Bosch GmbH
Robert Bosch GmbH focused on production process optimization for component fabrication and reliability. Both aspects form the basis for implementation in new applications. Both the participating institutes and the industrial partners collaborated closely to find new solutions in this interdisciplinary field. In particular, the estimations of reliability are the prerequisite for the successful market launch of products based on organic electronics. Here, new insights were gained, which expand the understanding of organic electronics in an industrial setting. Further information on Robert Bosch can be found at www.bosch.com.

SAP AG
Within the scope of the project, SAP investigated applications and software solutions for handling smart label data. Besides the design of a platform for evaluating smart label data, the focus was on exploring methods for secure and high-performance data management as well as concepts for locating data distributed across the supply chain. In addition, application scenarios for smart labels were designed and investigated for their economic benefit. Here the main focus was on applications across multiple supply chains for tracking and monitoring temperature-sensitive goods. Further information on SAP can be found at www.sap.com.

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TU Darmstadt
Represented by the Institute of Printing Science and Technology (IDD), Department of Mechanical Engineering, and the Microelectronic Systems Research Group (MES), Department of Electrical Engineering and Information Technology, the TU Darmstadt covered both the printing process development and characterization of finished devices as well as the buildup of the foundry. Based on the work from the first funding phase, the printing processes for constructing organic field-effect transistors were developed at the IDD and were transferred to a printing machine developed at the IDD specifically for organic electronics. At the MES, the transistors fabricated at the IDD were characterized and used to construct the first simple circuits. Besides analyzing process-related influences, further circuits specifically realizable through printing processes were designed and complex analog circuits were simulated. Further information can be found at www.idd.tu-darmstadt.de and www.mes.tu-darmstadt.de.

Heidelberg University
For the Polytos project, at the Kirchhoff Institute for Physics (KIP) of Heidelberg University thin-film analysis was performed using infrared optical spectroscopic ellipsometry and atomic force microscopy with the aim of optimizing the component fabrication processes with regard to the homogeneity and stability of organic semiconductor layers. Further information on Heidelberg University and the KIP can be found at www.uni-heidelberg.de and www.kip.uni-heidelberg.de.

University of Mannheim
Under the subcontract of SAP AG, the University of Mannheim developed a pattern-based library based on complex application cases for the observation and long-term analysis of supply chains. The library was tested for its usability within a prototype implementation. In addition, best practices were developed for use of the library in follow-up projects. Further information on the University of Mannheim can be found at www.uni-mannheim.de.

About Merck KGaA, Darmstadt, Germany and EMD Chemicals

Merck KGaA of Darmstadt, Germany, is a leading company for innovative and top-quality high-tech products in the pharmaceutical and chemical sectors. Its subsidiaries in Canada and the United States operate under the umbrella brand EMD. Around 38,000 employees work in 66 countries to improve the quality of life for patients, to further the success of customers and to help meet global challenges. The company generated total revenues of € 11.1 billion in 2013 with its four divisions: Biopharmaceuticals, Consumer Health, Performance Materials and Life Science Tools. Merck KGaA of Darmstadt, Germany is the world's oldest pharmaceutical and chemical company – since 1668, the name has stood for innovation, business success and responsible entrepreneurship. Holding an approximately 70 percent interest, the founding family remains the majority owner of the company to this day.

EMD Chemicals is a North American subsidiary of Merck KGaA of Darmstadt, Germany. Worldwide there are two separate companies that bear the name "Merck", the original Merck KGaA from Darmstadt, Germany, the oldest pharmaceutical and chemical company in the world, and the pharmaceutical company Merck & Co. in the United States. The rights to the name and trademark MERCK in North America (USA and Canada) lie with Merck & Co., the former U.S. subsidiary, whereas Merck KGaA, Darmstadt, Germany, operates in North America under the umbrella brand EMD and EMD Chemicals. In the rest of the world, Merck KGaA,

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