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PREFACE

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Guest Editors

Yong-Young Noh[1], Yong Xu[1], Mario Caironi[2] and Thomas D Anthopoulos[3]

[1] *Dongguk University, Korea*
[2] *Istituto Italiano di Tecnologia, Italy*
[3] *Imperial College London, UK*
E-mail: yynoh@dongguk.edu, xu.yong@dongguk.edu, mario.caironi@iit.it and t.anthopoulos@ic.ac.uk

Printed electronics is steadily gaining recognition as an important branch of the future semiconductor industry since it enables manufacturing of large-area, flexible, environmentally-friendly and low-cost electronic devices, and has the potential to fulfill the constantly increasing demand for active-matrix displays, solar cells, sensors, memories, radio frequency identification (RFID) tags and integrated circuit (IC) applications. Despite tremendous effort, mass commercialization of printed electronics technology for these applications is still facing numerous challenges. This special issue, therefore, aims to provide a wide and up-to-date overview on the subject by systematically addressing the most relevant aspects related to printed electronics, covering printable functional materials, manufacturing processes, devices and practical applications.

Thin-film transistors (TFTs) are one of most interesting subjects in printed electronics and the central building block of various integrated circuits. They can be fabricated by various printable semiconducting inks, such as organics, metal-oxides, carbon nanotubes and even silicon. TFTs represent a central topic of this special issue. Sun *et al* review unidirectional coating technologies for organic TFTs, which offers an answer to the methodology required to gain control of the molecules' orientation and packing motif in the solid state, thus achieving high-quality organic semiconductor films. Choi *et al* review the latest developments in n-type polymer semiconductors, which provide a timely solution to printed complementary circuits necessitating both p-type and n-type organic semiconductors with comparable performance. Liu *et al* investigate the role of high-LUMO-level polymers in solution-processed n-type organic TFTs, showing that, despite common thinking, if adopted as a dielectric modification layer or charge injection layer they may not cause severe instability and can even improve performance. Their results afford insights into device processing as well as fundamental understanding of charge trapping effect in organic TFTs. Lin *et al* review organic vertical TFTs, often regarded as a 'solid-state vacuum tube', as a path to boost the driving capability at low supply voltage. The operating principle, fabrication techniques, and strategy for performance enhancement, in particular the increase of the on/off ratio, are discussed. Mandal *et al* review printed organic TFT-based ICs, including aspects of printable semiconductors, printing techniques, printed devices and a wide variety of printed ICs, thus providing a good overview of printed circuitry and related issues. Compared to organic TFTs, amorphous metal-oxide semiconductor-based TFTs have demonstrated numerous advantages in terms of mobility, off-state current, and processability for integration. Gelinck *et al* succeeded in the realization of non-volatile, re-addressable memories on large-scale flexible substrate, where IGZO TFTs are used for both logic control and, by including P(VDF-TrFE) as a ferroelectric gate dielectric, memory cells. The fabricated TFTs show high yield and the resulting memories are able to operate well. Solution-processed metal-oxide TFTs offer an interesting and very promising path towards roll-to-roll manufacturing, yet they often exhibit inferior performance compared to their vacuum-processed counterparts. Ahn *et al* review the recent developments of solution processes for oxide TFTs, including compound selection, precursor preparation, annealing techniques and circuits, thereby proposing a route for high-performance printed oxide TFTs. Carbon nanotubes (CNTs) are another appealing candidate for printed TFTs, for their excellent processability, great mechanical properties, and wide spectrum of electrical properties. Zaumseil reviews the fundamentals of single-walled CNTs (SWCNTs) and the corresponding applications in printed (opto-)electronic devices and ICs in which semiconducting and metallic SWCNTs are used for the active layer and the electrodes, respectively.

Resistive random memory (RRAM) and solar cells are fast growing markets for printed electronics. Wu *et al* find that indium diffusion from an ITO electrode is responsible for the ON-state filamentary conduction in RRAM with ITO/active layer/InGa structure; on this basis, a general approach for obtaining a memory effect with a variety of active materials is derived. Their detailed study gains insights into the operating principle of RRAM and provides clues in designing printed RRAM. By means of simulations, the theoretical study by Wang *et al* indicates that a suitable optimization of planar perovskite solar cells with Cu_2O as a hole-transporting layer should yield an efficiency of over 13%, hence providing guidance for the development of high-performance perovskite solar cells incorporating Cu_2O via printing.

From a completely different viewpoint with respect to the solution-based processing paradigm, Taylor reviews vacuum thermal evaporation, which has been much underestimated for roll-to-roll production of large-area electronic circuits. He shows that vacuum thermal evaporation is not only compatible with roll-to-roll production but can also deliver superior performance with respect to the solution-processed counterparts. While not generally accepted under the concept of 'printing technology', continuous vacuum technology offers plentiful opportunities to be explored in the future, especially by complementing most widely accepted printed electronics approaches where the latter struggle to achieve an acceptable level of performances.

We sincerely believe that this special issue is a timely publication and can help to shine a bright light on this emerging field of future electronics.

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