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EDITORIAL

Emerging Thin-Film Transistor Technologies and Applications

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Thin-film transistors (TFTs) have radically transformed the way we think and interact with electronics and they are now a mainstay of almost every aspect our lives from personal use to big industries, healthcare, security and beyond. It is hard to overstate the importance of TFT technologies in modern day electronics and their broader societal impact. TFTs have single headedly created a new electronics industry that deviates significantly from the traditional form of small chip-size, monolithic silicon electronics. This rapidly expanding technology strand, often referred to as *large-area electronics*, has traditionally relied on established semiconductor technologies, but the past decade has witnessed the emergence of a library of new materials for an increasing range of applications in different technology sectors.

The mass deployment of TFT-based electronics in our daily lives kick-started with the commercial proliferation of flat panel liquid-crystal displays (LCDs), by enabling the realization of large-area driving backplanes. We are now witnessing similar devices being applied to latest display technologies, such as organic light-emitting diodes (OLEDs), for applications in televisions, computers, smart phones, to name but a few. These ubiquitous displays, in tandem with touch sensing capabilities, have given rise to a unique human-machine interface that most likely will keep dominating our lives for years to come, re-defining the way we work, shop, and interact with each other. As large-area electronics continue to advance, the research on TFTs becomes more elaborate and divergent, extending to new materials, device concepts, manufacturing processes and integrated systems that offer improved performance and more functionalities, ultimately leading to new markets.

This Special Issue entitled "*Emerging Thin-Film Transistor Technologies and Applications*" attempts to consolidate key recent developments in the broader area of thin-film transistors with focus on fundamental properties of emerging materials, from organic semiconductors to metal oxides, from quantum dots to hybrid perovskites, and their integration in innovative new devices that interact with light or biological systems. The issue collates reviews and progress reports that discuss the past, present and future of TFT technologies along with several original contributions.

The charge transport mechanism in the semiconductor channel plays a crucial role on transistor performance, ultimately determining the success of the technology. Park and co-workers (article number 201904545) review important developments in high mobility organic polymer semiconductors, while Podzorov *et al*., reports (article number 201903617) original research on the influence of grain boundaries on the elusive Hall Effect observed in a handful of polycrystalline organic semiconductors. The role of contact resistance and other nonidealities together with possible mitigation strategies, are reviewed by Jurchescu *et al*., (article number 201904576) and the device physics of ideal and non-ideal TFTs is described by Liu *et al.*, (article number 201903889). Xu *et al.*, (article number 201904508) discusses the methods for precise extraction of the charge carrier mobility in organic transistors, while Cho *et al.*, (article number 201904590) focuses on summarizing recent progress in understanding the bias stability of organic TFTs.

Several review articles focus on the design and performance aspects of various TFT technologies. Klauk *et al.*, (article number 201903812) discusses the importance of material characteristics and device design for gigahertz (GHz) organic transistors, while Caironi *et al.*, (article number 201907641) presents recent progress towards solution-processed GHz organic TFTs. Leo *et al*., reviews the promising branch of vertical organic transistors (article number 201907113), while Wakayama *et al.*, (article number 201903724) discusses the operating principles and recent progress of organic based antiambipolar transistors and their applications.

Importantly, a substantial part of the issue is dedicated to multifunctional TFTs. Device concepts covered include, hybrid perovskite phototransistors (Yan *et al*., article number

201903907), quantum dot light-emitting transistors (Loi *et al*., article number 201904174), organic light-emitting transistors (Namdas *et al.*, article number 201905282), thin-film light-emitting transistors (Zaumseil *et al.*, article number 201905269), optically switchable organic polymer transistors (Samori *et al.*, article number 201907507), and biosensor transistors (Torsi *et al*,. article number 201904513).

Fabrication and integration of TFTs on conventional rigid substrates is well established, but transferring the technology to mechanically flexible, bendable, or even stretchable substrates, presents additional challenges. Gelinck *et al.*, reviews recent advances in image sensors (article number 201904205), and Ko *et al*., discusses recent attempts to mimic human skin with flexible electronics (article number 201904523). Ng *et al.,* reports on the use of flexible pressure sensors for physiological signal monitoring (article number 201905241), while Kim *et al.,* describes the use ionic tactile sensors for human-interactive technologies (manuscript number 201904532).

Finally, different approaches for tackling the economic and technological challenges associated with emerging TFTs technologies, are also covered. Anthopoulos *et al*., reviews the use of photonic processing as a viable route for scalable, cost-efficient manufacturing of metal oxide electronics (article number 201906022), while Frisbie *et al*., reports original work on low-voltage ZnO transistors and circuits (article number 201902028). Lastly, Noh *et al.*, (article number 201904588) and Kim *et al*., (article number 201904632) review the advances on printable semiconductors for TFT backplanes for OLED displays, and low-temperature solution processed metal oxides TFTs for flexible electronics, respectively.

By highlighting many of these exciting recent developments in the field of TFTs, as well as the challenges currently faced by this technology, we hope to provide researchers with a broader picture of the current state-of-the-art while at the same time inspire further interactions between scientists from relevant, and not only, disciplines. We are grateful to Dr. Jos Lenders, deputy editor of *Advanced Functional Materials*, for proposing the idea of a special issue on this topic as well as all authors and editorial staff for their sincere contributions and help, respectively.

Authors' Biographies

Thomas D. Anthopoulos is a Professor of Material Science and Engineering at King Abdullah University of Science and Technology (KAUST) in Saudi Arabia. He received his B.Eng. and D.Phil. degrees from Staffordshire University in the UK followed by postdoctoral appointments at the University of St. Andrews (UK) and Philips Research Laboratories (The Netherlands), before joining Imperial College London (UK) from 2006 to 2017. His research interests are diverse and cover the development and application of innovative processing paradigms and the physics, chemistry, and application of functional materials.

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