ANALYSIS

Organic electronics: Europe builds TOLAE portfolio to address markets

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Europe through Horizon 2020, the EU’s latest and largest research and innovation programme, is investing heavily in the translation of thin, organic and large-area electronics (TOLAE) from the lab to the market in a push to build on its research accomplishments and drive economic growth. To discover more about this flexible materials platform and to examine Europe’s plans to commercialize the technology, Benjamin Skuse speaks to representatives from four major projects—LOMID, ROLL-OUT, LUMENTILE and PING—and shares his analysis with the journal Translational Materials Research (TMR).

The commercialization of liquid crystal displays (LCDs) catapulted Southeast Asia to a position of dominance in the display sector. More recently, organic light-emitting diode (OLED) displays for smartphones and TVs have entered the market in flagship devices. Lighter, brighter, thinner and more responsive, OLEDs have taken screens to a new level of performance, but the potential for organic electronics reaches much further into multiple markets and Europe is keen to seize this opportunity for growth, as we shall discover.

TOLAE

Coined by the European Commission in one of four photonics-related Horizon 2020 calls in 2014, thin, organic and large-area electronics (TOLAE) is a catch-all term for cutting-edge organic electronics with increased functionality and strong prospects for commercialization. Belief in the potential market for organic electronics is high. In 2014, the first full year of H2020, TOLAE received one-third of all photonics project funding provided through the programme. Thirty-six project proposals were submitted to the 2014 call and nine received funding (see table 1) totalling €37 million, but the investment doesn’t stop there. Materials for the manufacture of photonic and OLED devices are the subject of two major calls in 2015 and another TOLAE call is planned for 2016 with an estimated budget of €20 million.

Building blocks

The European Commission’s faith in TOLAE technology stems from a combination of market potential and signs that key building blocks are in place. ‘Within Europe there are companies—such as Solvay (Belgium), Merck (Germany), Novaled (Germany) and Genes Ink (France)—producing the raw materials needed for TOLAE systems,’ explains Thibaud Le Séguillon, CEO of Heliatek and Photonics21 board member. ‘In many ways, Europe is really leading these technologies—the challenge is to drive TOLAE systems to commercialization. The principal issues are well known to the community—reliability, manufacturability and performance—and projects are designed to address these areas to open up a wealth of applications.

TOLAE offers a platform for creating advanced products that could penetrate myriad markets, including textile, automotive, health, paper, plastic, advertising and construction industries. What’s more, TOLAE-enabled products are expected to drive the merging of real and digital worlds: ‘TOLAE devices could fulfil the requirement for abundant, efficient, sustainable electronics for Internet of Things (IoT) applications,’ explains Himadri Majumdar from the VTT Technical Research Center of Finland and Principal Investigator on Horizon 2020 project ROLL-OUT. Otherwise known as the Internet of Everything, the IoT involves connected objects feeding data to networks for analysis of how machines, systems, economies and human behaviour function. Such data are extremely valuable to businesses, countries and regions capable of harnessing and interpreting this information.

To ensure a good match between the project outcome and the needs of the market, programmes encourage a high level of industry engagement. ‘Already there is a strong market pull for our project’s results,’ reports PING.
In fact, the project is organized and coordinated by Cartamundi, the end-user company. Similarly, ROLL-OUT’s direction is governed by its industrial partners: ‘Our approach from the very beginning was to allow the industrial partners to define the scope of the project according to their needs,’ adds Majumdar. ‘The industrial partners proposed new business ideas and the goals of the project, and we provided them with possible technological solutions based on the competences of the research partners.’

Collaboration and coordination

Every project funded under the 2014 TOLAE call has a consortium consisting of academic and industrial partners, often representing the entire value chain. The involvement of multiple stakeholders—from researchers uncovering new materials and fundamental aspects of TOLAE technologies through to SMEs and large companies poised to scale up and commercialize breakthrough results—will help projects navigate the so-called valley of death. But deep collaboration among stakeholders with varying degrees of technological, business and communication acumen can pose other difficulties. ‘Language, distance, background and culture can all be barriers to a good collaboration,’ explains LOMID Principal Investigator Beatrice Beyer from the Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology (FEP) Germany. ‘Overcoming these barriers sometimes needs a degree of empathy and patience. The best way to mitigate such difficulties is to choose the consortium and personnel carefully.’

Shared goals go a long way in keeping multiple stakeholders aligned. ‘Enthusiasm for a new idea makes people strive for their best, but effort alone can be wasteful if it is not supported by coordination and insight,’ comments LUMENTILE Project Manager Cecilia Trovati. ‘To act jointly, we carefully weigh each action and new direction, and feel that the multidisciplinary expertise in our team is more a resource than an obstacle, once a common ground is found on the main objectives.’

Table 1. Major TOLAE projects funded through H2020 (Jan 2015–Jan 2018).

<table>
<thead>
<tr>
<th>Project name</th>
<th>EU contribution (EURO)</th>
<th>Focus</th>
<th>Website</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOMID(^a)</td>
<td>4.0 million</td>
<td>Larger area, high-resolution, flexible OLED microdisplays for use in VR and other applications.</td>
<td><a href="http://cordis.europa.eu/project/rcn/194152_en.html">http://cordis.europa.eu/project/rcn/194152_en.html</a></td>
</tr>
<tr>
<td>ROLL-OUT(^a)</td>
<td>3.7 million</td>
<td>R2R fabrication to bring autonomous TOLAE devices to mass markets.</td>
<td><a href="http://cordis.europa.eu/project/rcn/196624_en.html">http://cordis.europa.eu/project/rcn/196624_en.html</a></td>
</tr>
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\(^a\) Further information can be found in the main text (see—Projects in detail).

项目参与者Alexander Mityashin，项目管理Thin-Film电子的imec。‘事实上，该项目是由Cartamundi，终端用户公司。同样，ROLL-OUT的方向是由其工业合作伙伴：‘我们的方法从一开始就允许工业合作伙伴根据他们的需求来定义项目的范围。’Majumdar。‘工业合作伙伴提出了新的商业想法和项目的目标，并提供了可能的解决方案，基于研究合作伙伴的专长。’

合作与协调

每个2014 TOLAE项目都有一个由学术和工业合作伙伴组成的联盟，通常代表整个价值链。研究人员在发现新材料和TOLAE技术的各个方面的过程中，以及通过中小企业和大公司来推动商业化和陌生化结果——将帮助项目穿越所谓的死亡地带。但是，不同背景、文化和沟通能力的各个合作伙伴之间的深度合作可能会产生其他困难。‘语言、距离、背景和文化都是阻碍良好合作的障碍，’LOMID首席研究员Beatrice Beyer来自德国Fraunhofer有机电子、电子束和等离子体技术研究所（FEP）解释。‘克服这些障碍有时需要一种同情心和耐心。最好的方式是选择联盟和人员仔细。’

共享目标是一个长期的保持多个合作伙伴保持一致的方式。‘对新想法的热情使人们为之奋斗，但如果没有支持协调和洞察力，仅凭努力本身就会徒劳无益，’LUMENTILE项目经理Cecilia Trovati评论。‘要共同行动，我们必须仔细权衡每个行动和新方向，并感觉到我们的团队的跨学科专长是更多资源而不是障碍，一旦找到了共同的基础。’

呼吁行动

这些研究需要的许多TOLAE技术已经对市场有了影响。今天，为欧盟是解决容量和从小型生产转为大型商业规模运作的焦点。‘工业界在采用新技术过程中面临的最大问题是TOLAE，’Majumdar (VTT)。Mityashin (imec) 同意：‘这是一个鸡和蛋的情况。这项技术可以在成本上变得具有竞争力，但要实现这一点，就需要付出一个行业才能满足的成本。’

将基础研究与开发和规模化通过学术界与工业界的合作在Horizon 2020允许政府和工业界分享财务负担，并推动创新。

Oriol Jimeno来自KIM全球在西班牙是LUMENTILE的项目沟通负责人。他指出，该项目存在一种迫切性。‘我们不能等太久，设计师将看到其他的机会。’
object or platform.’ And Europe isn’t the only player. Competitors outside the EU are also pushing the envelope, which needs to be factored into the strategy. ‘Clearly Asia, and mainly Korea and Japan, are extremely active in the organic electronics research domain,’ points out Le Séguillon (Heliatek). Far from panic though, the overwhelming feeling coming from the European TOLAE community is calm determination. The EU is committed to creating hi-tech employment and believes that TOLAE can provide this. Importantly, funders appear to recognize that this kind of technology and functionality is going to take time to reach its full potential, and the EU is ready to support TOLAE into the future.

Projects in detail

Large cost-effective OLED microdisplays and their applications (LOMID)

Involving eight European partners, consisting of research organisations, companies and project management consultants, LOMID is a three-year, €4 million project that aims to develop flexible, larger area, high-resolution OLED microdisplays and, in parallel, cheap manufacturing processes that yield acceptable numbers of defect-free displays for commercial purposes. The OLED microdisplays will consist of a thinned CMOS backplane chip for flexibility addressing a top-emitting organic layer sequence (OLED). These subsystems will then be encapsulated and combined with a colour filter prior to mounting the chip on a printed circuit board.

‘Distinct application scenarios require very high information content in a small area—much higher than standard display technology can achieve,’ explains LOMID Principal Investigator Beatrice Beyer from the Fraunhofer FEP, Germany. ‘There was a clear need to increase pixel density and area that prompted LOMID’s formation, in particular for virtual reality (VR) applications (e.g. for design, art, remote medical interventions) and other scenarios such as visual prosthetics (bionic eyes).’

However, significant challenges remain before such applications can be realized. Although a much less severe problem than for lighting applications using roll-to-roll production methods on polymer substrates, OLED displays still suffer from relatively short operating lifetimes, compounded by the fact that VR applications require high brightnesses. To tackle this and increase device lifetime, the LOMID project is exploring transparent pre-encapsulation technologies to be applied during production with very low water vapour and oxygen permeation rates. ‘We also aim to design a cost- and power-efficient OLED stack that achieves an appropriate performance/lifetime compromise,’ adds Beyer.

Realising the desired colour purity and a fast enough display refresh time (to avoid flicker and lag) are also on the consortium’s list of aims, but the greatest hurdle concerns production: ‘Our biggest challenge is to keep the display yields high enough that the devices are affordable!’ emphasises Beyer. ‘Display yield’ refers to the number of fully functioning displays that can be sold compared to the ones which cannot. Unfortunately, this number typically scales with the display area, mainly due to defects introduced by particles during manufacture.

The ambition is to produce the first functional displays by Autumn 2016 and to have products on the market in 2018 or earlier through partner companies XFAB, Microoled, Limbak 4PI SL and University of Oxford spin-off Va-ST Ltd.

High-performance, flexible, AUTOmnomous systems manufactured with unique, industrial ROLL-to-roll equipments (ROLL-OUT)

ROLL-OUT is a three-year ~€3.5 million project that intends to create a multi-purpose technology for thin, large-area, high-performance, smart and autonomous systems. These high-efficiency flexible autonomous systems will comprise integrated circuits (ICs), sensors and electronics for packaging, automotive interiors and textile industries. Involving five research and five industrial organisations, the project will develop novel, hybrid, moderate-temperature, roll-to-roll (R2R) processes.

Primarily a question of combining several different TOLAE components that have been developed over the years into an autonomous system, ROLL-OUT aligns with one of the near-term objectives of TOLAE technologies for Horizon 2020 in that the final product will be a hybrid device: ‘Hybrid integration combines printed electronics and conventional silicon-based electronics,’ illuminates Himadri Majumdar from the VTT Technical Research Center of Finland and Principal Investigator on ROLL-OUT. ‘In ROLL-OUT, the silicon chips are assembled on a plastic substrate, whereas interconnects and some passive components are printed.’

In brief, oil-based, polymeric films like polyester (PET), polyimide (PI) or polyethylene naphthalate (PEN) will form the thin, flexible, large-area substrates. Then, metal-oxide transistors and circuits will be created using unique R2R methods. For the thin-film transistors, insulator and semiconducting layers will be fabricated on the substrate using R2R sputtering and R2R atomic layer deposition (ALD). ALD may also be used to create barrier layers in order to protect electronic components from the elements. Metallic interconnects for the different components integrated into the systems will be screen printed. Finally, non-toxic, environmentally friendly, high-density storage, printable batteries, memory components and large-area pressure and temperature sensors will be added to complete the pilot autonomous systems.
Key challenges for the consortium include optimizing the performance of the indium-free, high-performance transistors that will be used to create the circuits; combining and improving multiple R2R manufacturing technologies to fabricate the high-performance electronic circuits on flexible substrates; and, finally, delivering the cost-effective, highly functional autonomous systems on large-area, flexible substrates that can be applied in real-world products.

‘We are combining components manufactured in different locations, following different standards,’ explains Majumdar. ‘Matching component requirements and performances for the optimal performance of the autonomous system is a considerable challenge, and will keep us busy over the next 36 exciting months.’

Already the partners are, individually, looking for and/or have acquired additional funding for work similar to ROLL-OUT. The consortium also intends to follow-up ROLL-OUT with further industrialization-orientated projects in the future.

**LUMinous ElectroNic TILE (LUMENTILE)**

LUMENTILE is a three-year ~€3 million project focused on providing a disruptive new construction element to designers and architects. Each tile will be made of glass or ceramic with embedded large-area and organic electronics. ‘This is the first time someone has tried to embed electronics into ceramics or glass for a large-scale application,’ states Project Coordinator Professor Guido Giuliani from the University of Pavia. ‘The luminous tile will include structural materials, solid-state light sources and electronic chips.’

The seven partners—made up of research organisations, tech and traditional companies, and knowledge transfer experts—have ambitious aims for the tiles: ‘The digital signage and show industry is highly interested in the video tile, where a single tile will be a pixel of a gigantic video screen,’ enthuses Giuliani. ‘We are talking of permanent video installations larger than 40 × 60 m without need for specific maintenance.’ Looking at other adopters of the technology, LUMENTILE members envisage designers and architects exploiting the intrinsic ability of the device to display lights, colours and images for both exterior and interior design and lighting. Not only could the tiles be used in and outside shopping malls, airports and skyscrapers, but also for simple household illumination, where ambitious colour and video effects would be replaced by a focus on luminous efficiency and ease of installation.

To deliver a product that meets such revolutionary ambitions will require technical hurdles to be surmounted. First, suitable structural substrates, luminous layers and outer materials will need to be identified that provide high-quality optical properties while standing up to potentially harsh environmental conditions: ‘For example, for floor or road applications the outer material must combine optical, structural and durability properties,’ explains Giuliani. A prototype tile had been constructed prior to the project’s formation and now scaling up manufacture is a major focus—developing a technology and fabrication process that can yield large quantities reliably, repeatedly and at a reasonable cost will provide the backbone needed to commercialize the luminous tile.

Currently analysing technical solutions for the subsystems, it is expected that before the project’s end several prototype walls or floors will have been installed and that a production process capable of being quickly implemented by manufacturers will have been created. ‘If all of this goes to plan, commercialization will start a few months after the project’s end,’ concludes Giuliani.

**Printed intelligent NFC game cards and packaging (PING)**

A three-year € ~ 3.5 million project involving one SME, three industrial partners and two research institutes, PING’s ambition is to develop flexible, fully integrated indium-gallium zinc oxide near-field communication (NFC) tags seamlessly embedded into printed objects, such as packaging, game cards and stickers, and printable substrates, such as paper, cardboard and plastic. Products born from the project should enable the identification and interaction of printed objects through standard NFC reading devices, which include smartphones.

Already embedded in many Android and Apple devices, NFC is a short-range, low-power communication technology that is expected, for example, to replace contactless credit card payment systems with contactless mobile payment. PING’s innovation will be to make the tags ultra-thin (25 μm) and flexible, meaning NFC technology can be introduced at lower cost and without substantial changes to product dimensions or mechanical characteristics. ‘Moreover, development of one-time programmable memory (PROM) will enable additional NFC tag functionality,’ adds Alexander Mityashin, Project manager for Thin-Film Electronics at imec, and PING project participant. As a consequence, PING scientists will explore integrating sensing (temperature, light, humidity, etc) and interactions (display, sound, etc)—functions that the team believes to be feasible and will offer significant added value.

Potential examples include product packaging in supermarkets. NFC tags could track products from production to consumption, and offer customers information such as price, provenance, shipment, storage temperature, freshness, nutritional values and recipe suggestions, all through the interaction of the tag with their smartphones. Further, scanning individual products would become a thing of the past; customers would simply pass through a detector with their shopping, which would register all products.
'The NFC tag will come in the form of a thin plastic substrate, within its surface lies a metal antenna and a thin fully flexible chip,’ Mityashin elucidates. The novelty of this design lies in its flexibility. Because the transistors that make up the chips are ultra-thin and layered into a stack, a bending radius of 1 mm results in a minute strain on the overall chip.

Key to delivering on their ambitions is the development of standardized, low-cost and high-volume manufacturing techniques, requiring designs to be aligned with established mass manufacturing processes. Furthermore, the basis underlying the technology comes from an innovative radio frequency identification (RFID) circuit developed in Seventh Framework Programme (FP7) project ORICLA: ‘NFC is a special form of RFID, with specific protocols to respect, which is significantly more challenging for our technology,’ explains Mityashin.

However, once these challenges have been tackled Mityashin sees a significant market for PING’s innovations: ‘Europe has many companies, particularly SMEs, which can develop products and services enabled by our technology,’ he says. ‘They are interested in the Internet of Things, which is an increasing market and a huge opportunity for Europe.’

Biography

Benjamin Skuse¹ is a science writer and editor with experience in the mathematical modelling of optical and photonic systems. After earning a BSc in Mathematics and PhD in Applied Mathematics at the University of Edinburgh, he completed an MSc in Science Communication at the University of the West of England. He then worked for IOP Publishing and Research Media Ltd—a science and research communication agency—before embarking on a freelance writing career.

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