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Organic microdisplays for ultra-portable digital handhelds

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Organic electronics, or plastic electronics, is a branch of electronics that deals with conductive polymers which are carbon based. Inorganic electronics, on the other hand, relies on inorganic conductors like copper or silicon.

For the past four decades, inorganic semiconductors (Si, Ga, As) and metals (Cu, Al) have been the backbone of the electronics industry. But, if we review the growth of the electronics industry, it is clear that innovative organic materials play a vital role in the performance increase of semiconductors, storage and display at lower costs that we see today. Organic electronic products are lighter, more flexible and less expensive than their inorganic counterparts. These are also biodegradable (being made from carbon). This opens the door to many exciting and advanced new applications that would be impossible using copper or silicon.

However, conductive polymers have a high resistance and therefore are not good conductors of electricity. In many cases, these also have shorter lifetimes and are much more dependent on stable environment conditions than inorganic electronics.

Devices using organic compounds

Some of the major devices that are manufactured using organic compounds are organic thin-film transistors (OTFTs), organic light-emitting diodes (OLEDs) and organic solar cells.

TFTs are transistors created using thin films, usually of silicon deposited on glass. The deposited silicon must be crystallised using laser pulses at high temperatures.

The active layers of OTFTs can be thermally evaporated and deposited on any organic substrate (a flexible piece of plastic) at much lower temperatures. OTFTs are used to design complex architectures like arithmetic logic units and non-linear oscillators, active-matrix displays, chemical sensors and flexible microelectronics.

The structure of an organic semiconducting p-type thin-film transistor with top contacts is shown in the figure.

An OLED is a thin-film LED in which the emissive layer is an organic compound. Conventionally, an OLED has a bottom emitting structure, which includes an opaque metal or metal alloy cathode, and a transparent anode on a transparent substrate enabling light to be emitted from the bottom of the structure usually from the glass side.

Organic solar cells could cut the cost of solar power by replacing the expensive crystalline silicon used in most solar cells with inexpensive organic polymers. What’s more, the polymers...
can be processed using low-cost equipment such as ink-jet printers or coating equipment to make photographic film, which reduces both capital and manufacturing costs compared to conventional solar-cell manufacturing.

**Some organic materials**

*tris(8-hydroxyquinolinate)aluminium (Alq3)*. This organic material is most commonly used for the light-emitting layer of OLEDs.

**Oligothiophene derivatives.** Oligothiophene derivatives bear the styryl (DS-nT) or pyrene (Py-nT) unit as terminal substituent. Thin-film field-effect transistors incorporating DS-nT show high electrical performance, such as mobilities as high as 0.1 cm²/Vs, along with exceptional stability under ambient conditions. Especially, the longer oligomer DS-4T containing the quartethiophene core gives rise to devices that show no decrease in performance after more than 17 months of storage and under continuous operation.

*6,7,13,16-tetrais(alkylthio)quinoxalino[2’,3’:9,10]-phenanthro[4,5-ab]phenazine, TQPP-[SR]₄*. These materials have been synthesised for R=C₁₂H₂₅ and C₆H₁₃ as solution-processable potential charge transport materials for organic electronics applications.

*bis(tri-isopropylsilylethynyl)pentacene (TIPS-pentacene)*. Using this material, solution-processed OTFTs with mobility of about 1.5 cm²/Vs are fabricated. This is the highest mobility reported to date for solution-processed OTFTs.

**Related technologies**

**MEMS.** Polymer-based MEMS are rapidly gaining momentum due to their potential for conformability and other special characteristics not available with silicon microsystems. Polymer-based nano- and micro-devices are flexible, chemically and biologically compatible, and available in many varieties. These can also be fabricated in truly 3-D shapes.

**Nanoimprint lithography.** It is an emerging technology for high-throughput nanoscale patterning. Nano-imprinting uses a hard mould to mechanically deform a polymer material in order to create nanoscale structures, which provides unprecedented resolution and speed in nanopatterning. Due to their compatibility with polymer materials, nanoimprint and its variants find unique applications in polymer-based devices, including organic electronics and photonics.

**Future of organic electronics**

Organic electronics has opened the door for various advancements in technology. Carbon nanotube based transistors will replace Si- and Ge-based transistors in the coming future. Due to its scalability, a large number of devices can be integrated on a single chip. Organic electronic devices will provide an effective solution to pollution by minimising e-waste due to their bio-degradability. Some interesting applications of organic electronics are mentioned below.

**Smart textiles.** Electronic devices can be integrated into textiles to monitor heart-rate and other vital signs, control embedded devices (MP3 players), etc.

**Lab on a chip.** It’s a device that incorporates multiple laboratory functions in a single chip. As the name suggests, it actually enables the functionality of a lab on a miniature device. You can take samples of the substance/component to be tested, sometimes at a remote location or the patient’s bedside in the case of medical diagnostics, and analyse it right then and there.

A lab-on-a-chip can be used in environmental testing to determine, for example, whether there is contaminated water or harmful chemicals in the air. These devices could have multiple applications in medical diagnostics too.

**Portable compact screens.** Micro-displays have the potential to create new opportunities for ultra-portable digital appliances and entertainment products. All that remains to be done is fine-tuning of silicon circuitry designs for the best performance and mechanical integration of colour filters for full-colour capability.

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Prabhat K. Mishra, member of IETE and lecturer in DJCET, Modinagar, has research interest in nanotechnology, VLSI technology and automation. Sahaj Saxena, pursuing M. Tech. from Indian Institute of Technology, Roorkee, has a deep interest in organic electronics, nanotechnology and analogue devices.