Загулов Станіслав Русланович
Київський національний університет
технологій та дизайну (м. Київ)
Науковий керівник – викл. Великожон В.А.

FLEXIBLE INTEGRATED CIRCUITS

Introduction. Flexible electronics is a rapidly growing field encompassing a wide range of technologies and applications that spans current consumer applications, such as flexible displays, through to demonstrators and concepts, including sensing textiles and "electronic skin". Flexible thin-film integrated circuits offer lightweight, rugged, conformable and potentially foldable electronic circuits for novel and seamless integration into a wide range of products, creating new uses, adding benefits from embedded electronic functionality and providing technology for the "Internet of Things".

Objectives. The objectives of this research are:

- to investigate proposed flexible circuits;
- to research the market predictions.

Presenting main material. Amongst all potential application areas, the most immediate one is in electronic tagging, for services like product identification, supply chain management, parcel transport, anti-counterfeiting, ticketing, and so on. Electronic tagging devices are 'smart labels' that are read out from a distance through a radio-frequency connection.

Some 50 million smart labels per year, is presently served by silicon based microelectronics devices. Their high cost prevents penetration in a low-end segment where there is a strong demand for (perhaps disposable) flexible smart labels with limited technical performance. Polymer electronics is positioned to satisfy this demand: in-between conventional paper barcodes and high-end silicon devices.

Breakthroughs in flexible integrated circuits were realized in the University of Cambridge with the invention of the polymer light-emitting diode, and in the CNRS Laboratoire des Matériaux Moleculaires with the fabrication of high mobility organic field effect transistors. Philips and Covion have shown the industrial feasibility of polymeric light emitting diodes for applications in segmented displays.

In 2001 the project of Philips and others has realized a number of crucial milestones along the development path towards an industrial plastic electronics technology.

Chemichal synthesis of the precursor polymer poly-thienylene-vinylene. A laboratory process for the synthesis of poly-thienylene-vinylene has been scaled-up to an industrially viable process, yielding kilograms of material. A record value for the mobility for disordered semi-conductors of 5 10^{-3} cm^2/Vs has been achieved.

Reduction of environmental impact. The project has succeeded to replace the toxic solvent meta-cresol with an aqueous formulation of poly-3,4-ethylene-dioxy-thiophene. The chemical composition of polymer devices makes them more suited to standard disposal (combustion or landfill) than their silicon counterparts.

An architecture for flexible polymeric integrated circuits. An industrial technology for polymeric integrated circuits on 150 mm flexible foils was developed. The photochemical process allows feature sizes in the micron range. Vertical interconnect structures allow manufacture of complex circuits in acceptable processing times.

A demonstrator "smart label". A 48-bit code-generator, using 2.5-micron design rule and comprising more than 200 2-Input NAND gates, was demonstrated.

A demonstrator active matrix liquid crystal display. A small 256 grey level active matrix liquid crystal display, driven by polymer transistors, was developed. This is a major step towards "electronic paper" [1].

Organic semi-conducting materials have much lower charge carrier mobility than their inorganic counterparts, such as Silicon and Gallium Arsenide.

Consequently, these materials are not suitable for high-performance, high-speed data handling or computational purposes. Instead, their main application domain will be in relatively simple mass-produced, low-end, low-cost, circuits. Electronic barcode devices for identification (for example in supermarkets or for airport luggage management), flexible displays for personal computers or dashboards, and electronic paper are some of the potential application areas.

Later Pragmat IC has realized Flex IC circuitry printed on plastic film substrates and associated production lines. They made thin-film amorphous metal oxides hosted on polymeric substrates. The technology is available and proven, but cost has been the draw-back. However, that has been changing with chip costs continuing to fall, from $100 each for the 300m/year computer market, through $1-10 for handheld smart devices (50 billion/year) towards the 1-10 US cents range for a potential packaging market (over one trillion units/year), with the company suggesting that "sub cent electronic solutions" can be envisaged [2].

The market is expected to achieve 11% compound annual growth rate between 2018 and 2026, as it is deployed in automotive and healthcare systems, OLEDs and LCDs.

Conclusions. Increased portability is creating new applications, wearable devices, circuitry used in ever-diminishing spaces and some fascinating developments in flexible circuits. Flexible circuitry evolved from being simply wire placement to the development of complex circuits with improved power consumption and faster clock speeds that can perform in contoured placements in mission-critical aeronautical and automotive systems as well as consumer, telecom, healthcare and industrial applications.

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