Bioengineered Textiles and Nonwovens – The Convergence of Bio-miniaturisation and Electroactive Conductive Polymers for Assistive Healthcare, Portable Power and Design-led Wearable Technology

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Abstract: Today, there is an opportunity to bring together creative design activities to exploit the responsive and adaptive 'smart' materials that are a result of rapid development in electro, photo active polymers or OFEDs (organic thin film electronic devices), bio-responsive hydrogels, integrated into MEMS/NEMS devices and systems respectively. Some of these integrated systems are summarised in this paper, highlighting their use to create enhanced functionality in textiles, fabrics and non-woven large area thin films. By understanding the characteristics and properties of OFEDs and bio polymers and how they can be transformed into implementable physical forms, innovative products and services can be developed, with wide implications. The paper outlines some of these opportunities and applications, in particular, an ambient living platform, dealing with human centred needs, of people at work, people at home and people at play. The innovative design affords the accelerated development of intelligent materials (interactive, responsive and adaptive) for a new product & service design landscape, encompassing assistive healthcare (smart bandages and digital theranostics), ambient living, renewable energy (organic PV and solar textiles), interactive consumer products, interactive personal & beauty care (e-Scent) and a more intelligent built environment.

Keywords: Textiles, non-wovens, electroactive polymers, responsive hydrogels, microfluidics, fashion design, printing.

1. Introduction

The emergence of novel materials with advanced functional features, similar in provision to the equivalence of low performing silicon logic & memory, over the next 3 to 7 years, will enable us to almost completely renew our perceived use of textiles, fabrics and polymer surfaces, in a range of human centred applications. In particular, the enabling process integration will be afforded by printable sensors, detectors and delivery systems. These are the technological kernel of ambient life systems – and also include the ultra large area solar cells (portable power) and printable light. New material properties and characteristics will allow designers flexibility in how to 'imagineer' and implement products, devices & integrated systems, functional and beautiful, improving our quality of life. This can only happen, if the new materials world integrates with the innovative design world, opening up new product functionalities and options. Historically, it is worth considering how & why this could occur and is it capable of significant acceleration in the future. The development of the physico-chemical and aesthetic properties of materials used to be collaboration between the arts and sciences. The potential benefits for renewing / reviving such a vibrant culture are great, in particular, the unifying concept of ambient life applications, with the 'citizen at the centre' of functional, beneficial technology [1,2].

The materials problems of the cultural industries, typically concerning a combination of cultural, sensory, environmental, performance and communication characteristics and properties, are crucial to the growth of these industries and intellectually demanding, for example: materials for 'intelligent walls or polyvalent surfaces' that can modify their properties through sensing human interactions & emotions [3].

From materials in the form of 'dots, lines and surfaces' to fabrics, textiles, assistive healthcare products, renewal energy and an interactive and intelligent built environment, we will see a revolution in the use of flexible, lightweight responsive and even emotionally responding materials created by the everyday tools of the creative product designer. Beyond this will be 3D supramolecular structures and macro

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structures, created through self assembly and rapid prototyping respectively, especially when created with semi-conductive polymers with high mobility and with some degree of reasoning. The key to this emergence of useful intelligent surfaces is four fold [4]:

i. New electro / photo / bioactive functional materials;
ii. Familiar physical form transformations;
iii. Free form experimentation;
iv. MEMS integration into 'sense-analyse-actuate-deliver' systems and devices.

2. The Rise of Intelligent Materials

Conjugated, conductive polymers were discovered in the late 70's by Heeger et al. Shortly after this, light emitting polymers were developed at the University of Cambridge by Prof. Friend et al. These two materials events, due to the interest in material properties at the micro and nano scale, have given rise to a functional materials revolution to equal microelectronics and biotechnology (Figures. 1 and 2).

3. OFED Functionality in New Materials and their Processing Technology

OFEDs are a genuine attempt at using a molecular engineering approach to create a renewable energy platform. Achieving low cost manufacturing is essential to ensure maximum penetration of OFED technology into general power applications. Solution processed OFEDs attract, as it is now possible to envision a high throughput R2R printing process or R2R multilayer, thin film co-extrusion process which can make large area OFEDs at low cost. Possible techniques for relatively large pixel (low definition) printing are screen, gravure or flexography. Nevertheless, even with ultra low cost printing of the organic layers of the OFED device, high device performance typically still requires integration with one or more high vacuum process steps for electrode formation during device manufacture. This adds complexity and reduces throughput relative to a pure printing or deposition process and hence limits the ultimate low cost potential. It is thus highly desirable to develop an OFED manufacturing process that does not ultimately require any vacuum process steps.

The heart of the design paradigm for solution processable OFEDs technology lies therefore in adding as much functionality as possible into the active organic materials and then to use these materials in device structures with as few active layers as possible, in contrast to vapour phase processing strategies which has progressed by exploiting multi layer device designs with simpler small molecule materials. Scaling solution processable technology for large area organic power will need the development of new solution based processes of materials specifically optimized to improve inherent adhesion between the organic active layers at lamination interfaces. How to do this systematically requires a deep knowledge of the behaviour and characteristics of both polymeric and small molecule organic semiconductors [5].

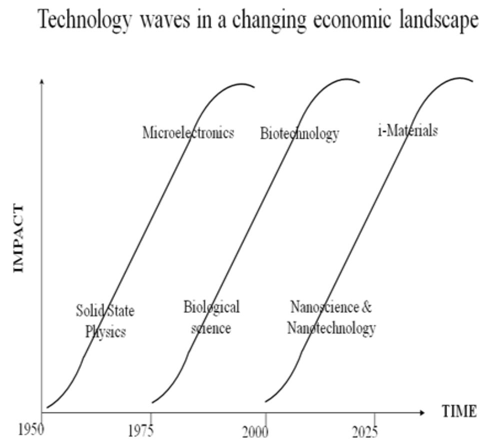

Figure 1 Technology waves in changing economic landscape.

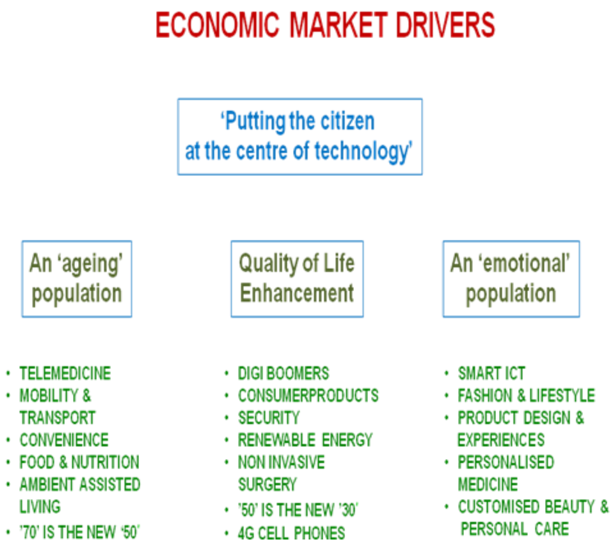

Figure 2 21st century economic market drivers.