Flexible and Wearable Electronic Devices; Market Forecasts 2015 -2025

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ABSTRACT

Wearable technology mainly concerns devices and apparel that aim to afford integrated electronic functionality in a wide range of products; from glasses and headphones to arm, wrist, leg and footwear, skin patches and even jewelry, the device business is already large, at over $14 billion in 2014 according to IDTechEx research. It also has the largest number of big brands involved, such as Apple, Accenture, Adidas, Fujitsu, Philips, Reebok, Samsung, SAP and Roche behind the most promising new developments.

However, truly disruptive new technology, in the form of e-textiles and even soft robotics, will also begin to establish major sales in a few years' time and fashion, industrial, commercial and military applications will burgeon as a consequence.

This paper will focus on the detailed study of the activities of over 1200 organizations (consumer electronics companies, apparel companies, healthcare companies, but also research and academic institutes) actively developing wearable devices. It will describe their activities, areas of focus, growth areas as well as particular challenges in commercialization.

1 INTRODUCTION

Wearable technology -or wearables for short- popularly covers clothing and wearable accessories that incorporate advanced electronic technologies that afford them a wide range of functionalities. Broadly speaking, wearables can be divided into two overarching categories:

a. Apparel & textiles: electronics and electric integral in or distributed through apparel including clothing, rucksacks, bandages, etc. This is still an emerging market.
b. Devices: Discrete electronic and electrical hardware sold on its own as bodywear. Glasses, headgear, footwear, even skin patches and accessories such as handbags with electronics mounted on them qualify. This will be the main market for the next decade. [1]

So far, most wearable technology products are derivatives of mobile phones, PCs, cameras, wristwatches, headphones, conventional apparel, including jewelry, medical instruments or RFID devices. This is bound to change in later years as advances in the technology tool kits will allow for unobtrusive integration of electronics into textiles/fabrics for clothing, thus affording additional functionalities to apparel that has been traditionally considered simple, mundane in its usage scenarios.

In addition, changing consumer behavior has led to an observed market trend, as consumers have come to expect more functionalities from ordinary objects they habitually utilize in their everyday lives. This alone is one of the most significant drivers for further innovation in the field of wearables, enabled by advances in allied technologies (e.g. conductive inks for printed devices, plastic electronics on flexible substrates, etc.). Insight on this topic and the associated challenges will be offered in a later section of this paper.

In section 2 we will focus on statistical research conducted by IDTechEx on over 1,200 organizations that are actively developing wearable electronic devices, which aimed to identify the most popular parts of the body for which wearables are being developed and why.

2 WEARABLE DEVICES ON DIFFERENT PARTS OF THE HUMAN BODY

Figure 1 [1] outlines the major market sectors that wearables address, alongside the position on the body that the devices are placed on, as categorized by IDTechEx. Some devices are being developed specifically to address one of the market sectors but in some cases, it is difficult to choose only one market which is being addressed by a device: for instance, although activity trackers seem to be fully geared towards fitness & wellness, many devices integrate activity tracker functions alongside infotainment ones (the iWatch from Apple being one of the most prominent examples), in some cases they are also

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fashion accessories (Italian eyewear designer Luxottica having announced a multiyear collaboration with Intel on wearables) etc. This also explains why "medical/healthcare, fitness & wellness" constitute a single category in IDTechEx research, as, increasingly, the functions for each sector are provided in one device.

The most popular wearable devices in 2015 are wrist worn and ear worn. There is good reason for this: mostly derived from headphones and electronic watches, devices that are largely commoditized by now and were commercialized decades ago, the form factors are familiar to potential adopters, albeit with augmented functionalities. This leads to easier consumer acceptance and a clearer path to commercial success but also fewer requirements for new design rules as developers can build upon existing platforms.

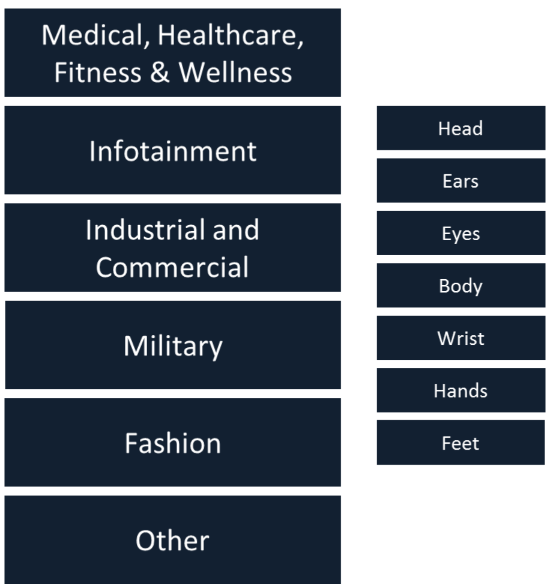

Figure 1: Market sectors addressed by wearable technology and position on the human body devices are worn. [1]

2.1. Wrist worn devices

Fitness based bands and smartwatches are a very attractive market, as they address major modern health issues such as the obesity epidemic, without requiring FDA approval following lengthy and expensive clinical trials. Although beneficial at first, the lack of government mandated approval can also lead to faster commoditization of the more basic types of devices so that can affect the relationship between unit volumes and corresponding revenues.

A wide range of devices is already available on the market today, and companies making wrist based wearables for the medical/fitness & wellness sector are the largest individual category according to IDTechEx research. The wide range of products is accompanied by a wide range of business models, for instance:

a. Mi band by Xiaomi, China. Retails at ~$13. Represents a range of basic wrist worn devices, quickest ones to be commoditized, addressing the market demand for high volume/ low cost devices.
b. Fitbit flex by Fitbit, USA – Retailing for ~$100. One of the more popular activity trackers, at a mid-level price point.
c. GOQii life band by GOQii, USA – Available initially only in India for 7000 Rupees (~$114), the company is currently offering the activity band in the USA as well, alongside a 12-month fitness plan (at $99/year). The business plan is aiming to further the use of the device and analysed data, making it more of a fitness/lifestyle companion.
d. Adidas miCoach by Adidas, Germany. >$400, this device is at a higher price point but as a fully integrated fitness trainer it is aimed at performance athletes.
e. At higher price points but addressing wider consumer markets, are devices from consumer electronics giants such as Apple and Samsung, which aim to integrate infotainment, fashion and fitness/welness functionalities. In addition, following in the footsteps of their predecessors, these devices aim to become as indispensable as cell phones & smartphones, by weaving into the fabric of everyday life of consumers, becoming "status symbols" for younger generations but also offering sleek designs and cutting edge technologies.

2.2. Ear worn devices

The ears are the second most popular individual body part for the placement of wearable tech. This is the case, even when excluding the $8.7 billion market for simple electronic headphones. [1]

Beyond the market for simple, chorded, electronic headphones, the most popular ear based wearable is the Bluetooth-enabled wireless headphone. However, some of the most interesting developments come about from the incorporation of different sensors within headphones. A particular example is the incorporation of heart rate monitors into headphones. Early prototypes of these products from many of the most obvious players in the field suffered from poor reliability and performance, so many have turned to companies such as Valancell to provide their sensors. Companies like this -that have invested strongly in research and building IP for reliable sensors and other components for wearables- are likely to be big winners as wearable tech hits the mass market over the next few years.

3 FLEXIBLE ELECTRONICS: TOOLKIT OF ALLIED TECHNOLOGIES FOR WEARABLES

Flexible electronics, commonly incorporating printed and organic electronics in their definition, will lead to significant cross-fertilization given the alignment of a lot of the requirements for both types of technologies. Products and prototypes developed commonly integrate conductive inks, printed Sensors, flexible energy storage, displays and thin film transistors (TFTs) deposited on flexible substrates etc. Having currently commercialized rigid displays on flexible substrates (termed "rigid plastic", in order to differentiate from fully flexible devices) LG and Samsung lead the developments in the consumer electronics segment, and with well-defined paths of technology transfer to wearables that become less obtrusive, and later on more integrated in fabrics, will result in a significant market for flexible electronic devices. For instance, flexible OLED display shipments are expected to reach 86.2 million units globally in 2020, up from only sample volumes in 2015, according to a recent IDTechEx report entitled "OLED Display Forecast 2015-2025: the Rise of Plastic and Flexible Displays". [2]

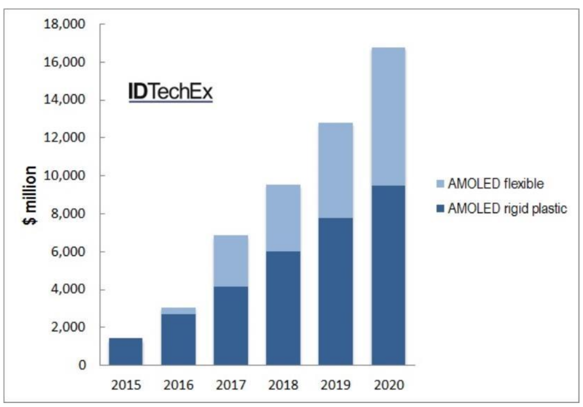

Figure 2: Rigid plastic and flexible OLED display revenue forecast to 2020. [2]

The report projects that market revenue for flexible OLED displays in wearables will grow to $2.9 billion during the same five-year period, a significant percentage of a $7 billion market as shown in figure 2. [2]

4 CHALLENGES AND BARRIERS TO COMMERCIALIZATION

As with all emerging electronic technologies, there are challenges that hinder fast proliferation of new wearable products. Some of the more significant ones are outlined below.

4.1. Encapsulation

Further integration into apparel will lead to more stringent requirements from electronics in terms of encapsulation, as components may be sensitive to moisture, water, detergents, use in a variety of environments, etc.

Current solutions in prototypes and early products rely on smart design; integration of removable electronics that can be detached before washing, apparel that doesn't need washing at all, etc. Of course, in order to achieve seamless integration, future electronics will need stringent encapsulation, with some of the encapsulation having requirements for transparency (e.g. displays, solar cells for energy harvesting). Solutions based on plastics coated with transparent metal oxides are already being developed, but also flexible glass is being researched due to its very high sealing characteristics. Other highly flexible encapsulants, high performance sealants and more resilient active electronic materials are also being developed.

4.2. Flexibility & Stretching

Current trends are showing electronics moving to flexible form factors, with the trend expected to quickly expand into wearable applications. In addition, fabric integration will be moving the industry away from discrete electronic devices and towards e-textiles without wires and. Such applications will increase flexibility but also stretching requirements from conductive inks and other active materials integrated into electronic textiles.

DuPont, EMS and others are already showing examples of conductive inks that are stretchable. Already able to reach 50% strain in specific design configuration, DuPont's conductive inks are aiming for an increase of tolerated strain by 20%, while allowing for only 1% increase in resistivity. [3], [4]

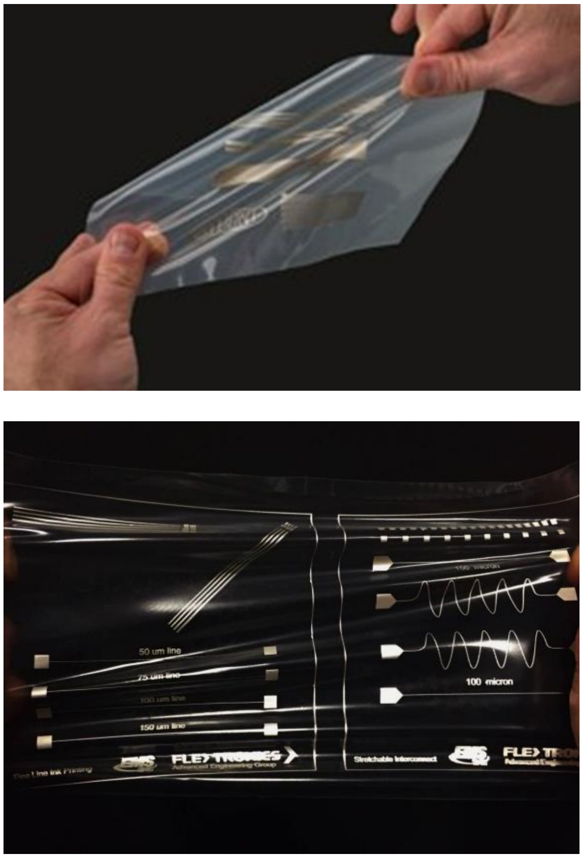

Figure 3: examples of conductive silver ink traces on flexible, stretchable substrates from DuPont (top) and EMS (bottom). Both materials have been tested and retain stable performance over the course of 100 washing cycles. [3], [4]

4.3. Miniaturization

Challenges also appear as electronics with flexible form factors will also need to be miniaturized for integration on products with limited area such as contact lenses, microchips. Significant improvements are required from energy technologies in order to improve performance of "on-board" powering schemes (flexible storage devices, energy harvesters + storage), achieve increased resolutions and maintain performance as dimensions are reducing etc.

4.4. Power

Specifically on the topic of power, the expected ubiquity of electronics, not just due to proliferation of wearables but also due to other overarching trends such as the internet of things means that powering schemes will need to become "greener" if we are to avoid filling up landfills with billions of additional batteries. Allied technologies such as energy harvesting technologies can offer alternatives and are being developed for further integration in future generation of electronics.

5 FUTURE DIRECTIONS: E-TEXTILES IN SOFT ROBOTICS

In later years, we will also see significant impact in sectors such as soft robotics; the intersection between materials, manufacturing and robotics according to Professor Rebecca Kramer. [5] In contrast to traditional robots, which are typically made of rigid metals, circuit boards and motors, my work aims to develop autonomous machines made of all soft materials. Potential applications for soft robotic technologies include (1) search-and-rescue robots that are impact resistant and can deform to squeeze through cracks and crevices to aid in natural disasters, (2) wearable technologies such as fabrics and skins that can give proprioceptive feedback to the wearer or assist with motions and prolong endurance without restricting the natural mechanics of motion, (3) human-machine interfaces that utilize compliance to embed safety at the material level, (4) more robust electronics that accommodate high-strain applications and are less sensitive to vibrations, and (5) surgical tools that match the compliance of human tissue and pose lower-risk during invasive procedures. The main concept that is explored is the use of responsive systems that react automatically to changes in their environment (material intelligence), which will reduce the complexity of robots overall.

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