Thermoplastically Shaped Wearable Medical Devices

B. Plovie, *Member, IEEE,* S. Dunphy, K. Dhaenens, S. Van Put, B. Vandecasteele, F. Bossuyt, *Member, IEEE,* and J. Vanfleteren, *Member, IEEE*

***Abstract*— Compact and highly-integrated wearable medical devices can improve patient comfort and device performance. Many barriers exist to achieving this, one of them being the current standard electronic manufacturing practices; this especially applies to circuit board technology. In this paper, we demonstrate a technique to integrate the circuit board within a 3D thermoplastic device shell, allowing the creation of light-weight ergonomic devices with improved functionality. At the same time the device is completely encapsulated; greatly enhancing user-safety and resistance to environmental factors. Possible applications range from wearable health monitoring systems, to improved medical imaging hardware (e.g. surface coils for magnetic resonance imaging), and intuitive user-interfaces.**

I. Introduction

Wearable electronic devices typically consist out of a plastic shell clamped around a circuit board. This cheap, highly-scalable, one-size-fits-all approach has greatly served consumer electronics; providing a good starting point. However, this approach typically fails to conform to the user's body, nor are the fabricated devices flexible. An ideal method would hermetically seal the circuit board within a free-form thermoplastic shell with the desired mechanical, electrical, and chemical properties; preferably using proven, reliable, easily-available, and cost-effective technology.

II. Thermoplastic Devices

Flexible circuit board (FCB) technology provides a suitable starting point, offering the flexibility required – through careful structuring of the substrate – with an excellent reliability track record. Borrowing from existing stretchable circuit technology, we attach the FCB to a rigid carrier board, and cut it into spring-shaped interconnects (meanders) and islands carrying the reflow soldered components.

The circuit board is transferred into the polymer using vacuum lamination. A thermoplastic polymer is laminated on top, adhering to the circuit and releasing it from the carrier board through shear forces generated by a mismatch in thermal expansion between the carrier and polymer. To protect the components during vacuum press operation a silicone foam rubber press pad is used. This lamination process is repeated to add additional encapsulating layers.

*The work reported here was carried out in the frame of the European Commission (EC) funded project FP7-TERASEL (Contract Nr. 611439).

B. Plovie, S. Dunphy, K. Dhaenens, S. Van Put, B. Vandecasteele, F. Bossuyt, and J. Vanfleteren are with the Centre for Microsystems Technology, 9000 Ghent, Belgium. All authors are associated with imec vzw and Ghent University. (phone: +32 9 264 66 04; e-mail: bart.plovie@imec.be; jan.vanfleteren@imec.be).

Thermoforming gives the device its final shape. This is achieved by clamping the encapsulating thermoplastic sheet, with the embedded FCB, past its glass transition temperature. The sheet is pressed against a mold with the desired shape, and retains its shape after cooling down.

Fabrication of the device as a flat FCB, embedding it within a thermoplastic polymer of choice, and thermoplastic deformation to the desired shape provides an attractive alternative to the conventional approach, achieving many of the proposed objectives.

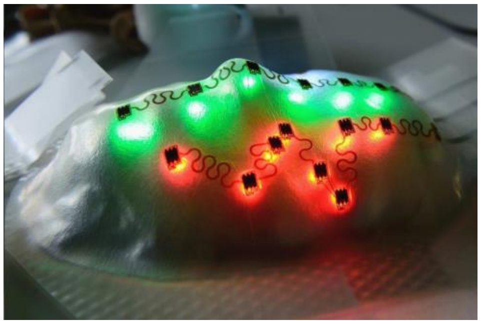

Figure 1. Wearable electronic device made to fit a user's face, in cooperation with JasnaRok. (Source: Fashion Hackday 2016)

III. Applications

The primary application of this technology is the fabrication of light-weight intricate form-fitting devices, as shown in Fig. 1. By using a wide range of polymers in combination with tightly integrated electronics it enables a wide range of applications; for example, made-to-measure sensor head caps, intelligent prosthetics providing touch and temperature sensitivity, and non-planar imaging detectors.

Acknowledgment

The authors wish to thank Manuel Seckel (TU Berlin), Jürgen Günther (FNT), Lionel Tenchine (IPC), and Joachim Verhegge (ACB nv) for their valuable input and assistance.

References

[1] J. Vanfleteren, M. Gonzalez, F. Bossuyt, Y.-Y. Hsu, T. Vervust, I. De Wolf, M. Jablonski, "Printed circuit board technology inspired stretchable circuits," *MRS BULLETIN*, vol. 37, pp. 254-260, 2012.

[2] Bart Plovie, Yang Yang, Joren Guillaume, Sheila Dunphy, Kristof Dhaenens, Steven Van Put, Björn Vandecasteele, Thomas Vervust, Frederick Bossuyt, Jan Vanfleteren, "Arbitrarily Shaped 2.5D Circuits using Stretchable Interconnects Embedded in Thermoplastic Polymers," *Advanced Engineering Materials*, pp. 1700032, 2017, ISSN 14381656.