Chapter 8
Hybrid Integration Technology for Wearable Sensor Systems

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ABSTRACT

Personalized and pervasive healthcare devices help seamlessly integrate healthcare and wellness into the daily life, independent of time and space. Silicon Integrated Circuit (IC) has been used in many advanced healthcare applications due to the compact size and ultra-low power consumption. Meanwhile, printed electronics (PE) is considered as a promising approach enabling cost-effective manufacturing of thin, flexible, and light-weight devices. A hybrid integration of IC and PE provides a new solution for the future wearable healthcare devices. In this chapter, firstly a customized bio-sensing IC is demonstrated, which can detect and process various bio-signals; secondly, the feasibility and performance of using inkjet printing technology as enabling technology has been examined for the fabrication of flexible bio-sensing devices. Finally, a wearable and flexible Bio-Patch is presented by leveraging hybrid integration of PE and bio-sensing IC. In-vivo test results show that the flexible Bio-Patch provides high quality ECG signal comparable with the one gained by bedside ECG machine.

INTRODUCTION

Consistent with the global aging, many countries are facing challenges of elderly care. In the meantime, chronic diseases are becoming the major causes of death (European Commission Eurostat, 2011; Kung, Hoyert, Xu & Murphy, 2008) the prevalence of chronic diseases inevitably increases the total expenditure on healthcare and poses a grim challenge to the current healthcare systems worldwide (Zhang, Yan, & Poon, 2007; Chen et al., 2015). Traditional healthcare and well-being services are usually provided

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within hospitals or medical centers. People with chronic diseases as well as the patients in post-surgery state need continuous monitoring of their health condition, in particular the vital signs, until their health status becomes stable. Patients, as well as their families, also need to collaborate with their physicians to get informed about their status. Until now, most of the monitoring of the health condition of such people is usually accomplished within medical centers or hospital environments. As a result, measurements of vital signs and the corresponding diagnosis are carried out in controlled environments. However, this solution is costly and inconvenient for people with the need of routine checks, since the patients need to visit the hospital on a regular basis. Currently, several trends indicate that the healthcare is gradually moving from institutional care to a growing focus on the individual personalized healthcare at home (Dey & Estrin, 2011; Saranummi, 2008; Yang et al., 2014).

Connected and personalized healthcare help seamlessly integrate healthcare and wellness into people's daily life. Wearable medical or healthcare devices are the key elements that will catalyze the process to enable the paradigm shift from the clinic-centric approach towards a person-centric model. This paradigm shifts focuses on sustainable healthcare aiming to:

- Enable early detection for prompt medical care and healthcare;
- Improve the management of chronic diseases; and,
- Preventive medicine.

The relevance of this change is huge, and healthcare itself, as it can be seen, is changing. The prognosis of several conditions will improve considerably because of prompt intervention; the users will be empowered and more engaged in the management of their disease or even in maintaining their health with a healthy and active lifestyle. Hopefully in many cases this will happen just by wearing certain sensing devices or clothes.

With the developments in biomedical circuits and systems, nowadays, silicon based integrated circuits have shown great advantages in terms of compact size and ultra-low power consumption. As a result, they have been found in many advanced medical and healthcare applications. In the meanwhile, printed electronics is considered as a promising approach enabling cost-effective manufacturing of thin, flexible, and light-weight devices. A hybrid integration of integrated circuits and printed electronics provides a promising solution for the future wearable healthcare devices.

State-of-the-Art of Current Wearable Healthcare Systems

In the last decade, wearable healthcare systems have drawn considerable attention from the research community and healthcare industry as it is pointed out by the numerous and yearly increasing corresponding research and development activities (Pantelopoulos & Bourbakis, 2010; Gatzoulis & Iakovidis, 2007; Lymperis & Dittmar, 2007). A variety of system prototypes and commercially available products have been designed and developed in recent years, with application scenarios of sports monitoring, elder healthcare, infants health monitoring, or smart rehabilitation etc., aiming at providing real-time or near-real-time feedback information regarding users' health condition, either to the users themselves or their family members or to a medical center or straight to a supervising professional physicians, while being able to alert in case of possible imminent health threatening conditions (Fredericks et al., 2015; Bonato, 2005, 2003; Raskovic, Martin, & Jovanov, 2004). A variety of commercially available products have been produced in the course of recent years, which are able to provide real time feedback on the users'