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Cost-effective and strongly integrated fabric-based wearable piezoelectric energy harvester

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ABSTRACT

Fabric-based wearable electronics are becoming more important in the fourth industrial revolution (4IR) era due to their connectivity, wearability, comfort, and durability. Conventional fabric-based wearable electronics have been demonstrated by several researchers, but still need complex methods or additional supports to be fabricated and sewed in clothing. Herein, a cost-effective, high throughput, and strongly integrated fabric-based wearable piezoelectric energy harvester (fabric-WPEH) is demonstrated. The fabric-WPEH has a heterostructure of a ferroelectric polymer, poly(vinylidene fluoride-co-trifluoroethylene) [P(VDF-TrFE)] and two conductive fabrics via simple fabrication of tape casting and hot pressing. Our fabrication process would enable the direct application of the unit device to general garments using hot pressing as graphic patches can be attached to the garments by heat press. Simulation and experimental analysis demonstrate fully bendable, compact and concave interfaces and a high piezoelectric d_{33} coefficient (-32.0 pC N^{-1}) of the P(VDF-TrFE) layer. The fabric-WPEH generates piezoelectric output signals from human motions (pressing, bending) and from quantitative force test machine pressing. Furthermore, a record high interfacial adhesion strength (22 N cm^{-1}) between the P(VDF-TrFE) layer and fabric layers has been measured by surface and interfacial cutting analysis system (SAICAS) for the first time in the field of fabric-based wearable piezoelectric electronics.

1. Introduction

With the tide of the fourth industrial revolution (4IR), the wearable devices combined with the internet of things (IoT) have become a vital part of our daily life. The trend of the wearable electronics is moving from small electronics to directly embedded ones [1–5]. In this respect, fiber and fabric-based electronics have many advantages such as high wearability, ventilation through pores, and high durability by weave structures [6]. In addition, the fibers and fabrics are more highly conformable to curved surfaces on human bodies rather than planar flexible devices. These features make textile-based electronics suitable for future wearable electronic applications.

The conductive fabrics can be directly applied to fabric-based wearable electronics. They have been made by coating, spinning, printing, plating, and injecting the electrode materials [6]. The coating, spinning, and printing processes, such as dip coating, electrospinning, and screen printing, are simple and fast. The plating process, such as magnetron sputtering, enables the fast and uniform deposition. Along with the conductive fabrics, the fiber and fabric-based wearable electronics have recently been fabricated by packaging, surface mounting, screen printing, conductive nano-coating, and self-organizing technologies to integrate electronic functions to textiles and improve their performance and functionalities [7]. In the applications, prior research used e-textiles wearable electronics as transistors [7], sensors [8], supercapacitors [9], and energy harvesters [10,11]. For example, Lai et al. demonstrated a conductive thread-based triboelectric textile-nanogenerators for human self-powering and sensing [12]. Ning et al. developed fabric-based triboelectric nanogenerators for

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