AG NANOWIRE-BASED NANOCOMPOSITES FOR INTERCONNECTS OF FLEXIBLE/WEARABLE ELECTRONICS

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Key Words: Ag nanowire, nanocomposite, interconnect, flexible, wearable.

With the recent increasing interest in wearable/stretchable electronics, there are concentrated efforts to develop a material system for flexible/stretchable interconnects that can endure severe mechanical deformations. The most widely used strategy to fabricate stretchable interconnects is to form polymer composites by embedding conductive fillers such as metal particles or metal nanowires into the elastomeric polymer matrix. The conductive fillers can form a percolated network in the polymer matrix, which enables the polymer composites to serve as conductors. Because of the elastomeric properties of the polymer matrix, the composites could withstand mechanical strain while maintaining the conductive properties until the percolation in the network of the conductive fillers is lost below the critical percolation threshold above which conduction can start. The volumetric deformation of the polymer matrix under severe mechanical strain causes disconnection of the percolated network, which results in the degradation of conductivity. Since the loss of percolation is highly dependent on the mechanical properties of the polymer matrix, the development of a stretchable polymer matrix that is high compatible with the conductive fillers is urgently needed.

There are several candidates for the stretchable polymeric matrix such as poly(dimethylsiloxane) (PDMS, and Ecoflex (a type of platinum-catalyzed silicone). PDMS showed a high stretchability of ~200% and good chemical stability, and is thus widely used for substrates of stretchable interconnects. However, solution coating on PDMS is difficult due to its highly hydrophobic surface that required additional surface treatment to modify the surface property, thus limiting its use in multilayer-structured electronic devices. Ecoflex is the emerging material for stretchable electronics and is known to withstand a tensile strain of more than 700%. In addition, the ease of tuning the colors from transparent to saturated colors as well as its biodegradable characteristic makes it an attractive candidate for wearable electronics. However, the large elastic mismatch of Ecoflex with other organic/inorganic materials used in electronics adversely affects the reliability of devices that require moderate stretchability. Different polymers show different mechanical and chemical properties; thus, selecting an appropriate polymer matrix for specific applications is key to the development of stretchable electronics. In this regard, increasing the available material options for the stretchable polymer matrix is necessary, especially for wearable electronics that have a large variety of applications and these applications determine the required properties of the materials used for each device. For example, the polymer strip for wristbands needs a relatively higher modulus than that for the electronic devices applied to elbows. However, the choice for stretchable polymer-matrix materials used for stretchable interconnects is limited.

In this study, we explored the application of a trimethylolpropane formal acrylate (TFA)-based polymer matrix as a potential candidate stretchable substrate for stretchable electronics. The UV-cured TFA films were highly transparent and were able to withstand a tensile strain of ~100% (Figure 1), which is suitable for wearable electronics where the human motion generates ~75% strain. To show the suitability of the TFA films for stretchable interconnects, Ag nanowires were embedded on the surface of the TFA films using a well-known peeling off process. The efficient transfer of the Ag nanowires to the polymer matrix is important to prepare highly transparent and conductive stretchable interconnects. For this, special treatments such as the self-assembled monolayer (SAM) treatment is typically required to change the surface of the base substrate hydrophobically. However, with the TFA resin, the Ag nanowires could be successfully transferred from the glass substrate without a special surface treatment, which enabled easy fabrication and cost reduction. In addition, the elastomeric TFA matrix was attachable to polymeric substrates such as polyethylene terephthalate (PET) and glass substrates, which make it a promising candidate material for the substrates of patchable devices. Such possible applicability of TFA for stretchable substrates was systematically studied by characterizing the optical, electrical, and mechanical properties, which are presented in this paper. In addition, the potential application of the stretchable supercapacitor using the TFA/Ag nanowire interconnects as the current collector is demonstrated.

Figure 1 Photo of tensile test of TFA/Ag nanowire composite