Extremely stretchable nanotube transistors

Taishi Takenobu
Dept. of Applied Physics, Waseda University, Shinjuku 169-8555, Japan
Tel.:81-3-5286-2981, E-mail: takenobu@waseda.jp

Flexible and stretchable electronics are attracting considerable attention as the next-generation functional electronics because it is believed that in future many electronic assemblies on rigid substrates will be replaced by mechanically flexible or even stretchable alternatives. This is a consequence of the ambient intelligence vision where the citizen carries along more and more electronics systems, near the body, on or even inside the body. These systems must be light weighted, must preferably take the shape of the object in which they are integrated, and must even follow all complex movements of these objects, explaining the need for stretchability. Typical examples are implants, intelligent textile, portable electronic equipment (e.g. mobile phones), robotics, car electronics, etc. Very recently, this is not just concept anymore and smart watches, such as Apple Watch, Galaxy Gear and Sony SWR50, are already in the market. Now, it is strongly required to establish technological basis of future stretchable electronics. Although Si and organic materials have been playing the main role in these research fields, in this study, we would like to show you the considerable potential in single-walled carbon-nanotube (SWCNT) films.

Firstly, we investigated the mechanical properties of SWCNT films. As the results, we clarified that the resistance degradation due to mechanical strain is approximately 1% per 1% strain. This is much smaller than normal rigid materials, such as Si, and it suggest that SWCNT film is one of the promising materials for stretchable electronics.

As the next step, we fabricated stretchable SWCNT transistors. We have already established the simple method to fabricate high-performance SWCNT film transistors using the enriched semiconductor SWCNT [1,2] and one of the solid electrolyte dielectric materials, ion gel [3,4]. These semiconducting SWCNT transistors hold carrier mobility of more than 100 cm^2/Vs and on/off ratio of 10^4-10^5 [5,6]. Based on this method, we fabricated SWCNT transistors on flexible plastic substrates and stretchable poly(dimethylsiloxane) (PDMS) substrates. Very importantly, SWCNT films on plastic substrates are very stable and their resistivity was almost constant under the curvature radius of less than 100 μm and 100 times cycle test. We have tested mechanical strain dependence of SWCNT transistors on thin plastic/PDMS substrates and devices revealed the stable operation up to strain of 70 %. Moreover, for future logic circuits, we demonstrated CMOS-like inverters using the SWCNT films and ion gel.

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