Inkjet-Printed Carbon Nanotube Electrodes for Electrochemical Sensor Applications

Ryan P. Tortorich[1], Edward Song[1], and Jin-Woo Choi[1,2]
[1]Division of Electrical and Computer Engineering
School of Electrical Engineering and Computer Science
[2]Center for Advanced Microstructures and Devices
Louisiana State University, Baton Rouge, LA 70803 USA

Printed electrodes offer many advantages over other methods of patterning conductive materials. In terms of electrochemical cells, printing allows for the fabrication of cheap, disposable, and flexible electrodes that can be fabricated on a large scale. Screen printing has become a popular method for electrode patterning [1-3]. Although screen printing provides an easy and simple printing method, the process control is often limited for screen printing. An alternative is inkjet printing which offers an on-demand method for designing and patterning electrodes without requiring a template or screen. A computer generated electrode pattern can simply be printed on a thin film substrate as long as a proper "ink" is available.

In this work, we present a carbon nanotube ink and an inkjet-printed carbon nanotube electrode for sensor applications. For a carbon nanotube ink, it is critical to uniformly disperse carbon nanotubes in an aqueous solution. We slightly modified the reported method of dispersing multi-walled carbon nanotubes in an aqueous solution using polyvinylpyrrolidone (PVP) to make a well dispersed carbon nanotube ink [4]. Surfactant (Tween-20) was added to adjust the surface tension of the carbon nanotube ink. An office HP inkjet printer was modified to print the developed carbon nanotube ink. The cartridge was disassembled and thoroughly cleaned to remove residual materials. The developed ink was then filled into the cartridge.

Prior to printing an electrochemical cell, a test pattern was printed on a transparency film and the sheet resistance of the carbon nanotube pattern was measured. The resistance of the inkjet-printed carbon nanotube pattern was relatively high with single print and, for a better conductivity, multiple prints were necessary. Figure 1 shows the trend of relative sheet resistance with multiple prints, which resembles other reported work on inkjet-printed carbon nanotube patterns [5-6].

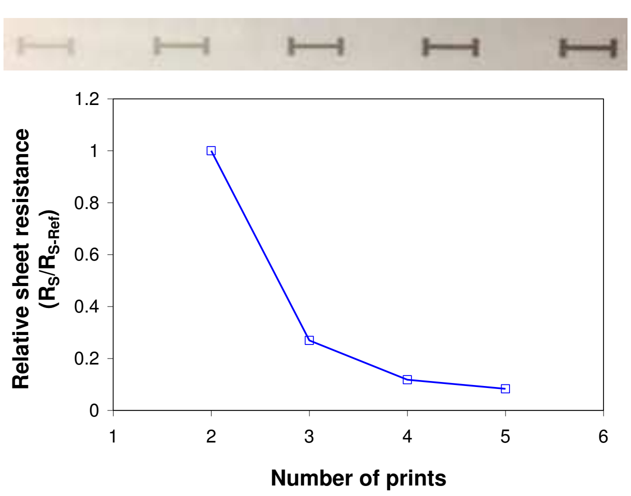

Figure 1: Inkjet-printed test carbon nanotube patterns (from single print to five prints on top) and the measured relative sheet resistance of the test patterns (on bottom).

The carbon nanotube ink needs to be optimized for obtaining a better conductivity of the printed electrode. The concentration of carbon nanotubes in the ink is one of the critical factors. It is clear that higher concentration will be desired to obtain a high conductivity as long as it does not compromise the dispersion of carbon nanotubes. PVP helps dispersion of carbon nanotubes but, once dried, it may hinder electric conduction between carbon nanotubes. The optimization is currently underway to exploit the inkjet-printed carbon nanotube electrodes for an electrochemical sensor application. A sample design of an inkjet-printed carbon nanotube electrochemical cell is shown in Figure 2. With the ease and accuracy of inkjet printing, the presented inkjet-printed carbon nanotube electrodes would provide a promising alternative for large-scale fabrication of cheap and flexible electrochemical cells.

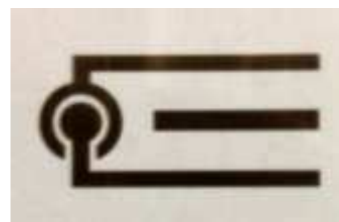

Figure 2: Optical image of sample inkjet-printed (five prints) carbon nanotube electrodes as an electrochemical cell.

References

[1] J. Wang, B. Tian, V. V. Nascimento, and L. Angnes, "Performance of screen-printed carbon electrodes fabricated from different carbon inks," Electrochimica Acta, vol. 34, pp. 3459-3465, 1998.

[2] R. O. Kadara, N. Jenkinson, and C. E. Banks, "Characterisation of commercially available electrochemical sensing platforms," Sensors and Actuators B, vol. 138, pp. 556-562, 2009.

[3] K. C. Honeychurch and J. P. Hart, "Screen-printed electrochemical sensors for monitoring metal pollutants," Trends in Analytical Chemistry, vol. 22, pp. 456-469, 2003.

[4] A. Abera and J.-W. Choi, "Quantitative lateral flow immunosensor using carbon nanotubes as label," Analytical Methods, vol. 2, pp. 1819-1822, 2010.

[5] K. Kordas, T. Mustonen, G. Toth, H. Jantunen, M. Lajunen, C. Soldano, S. Talapatra, S. Kar, R. Vajtai, and P. M. Ajayan, "Inkjet printing of electrically conductive patterns of carbon nanotubes," Small, vol. 2, pp. 1021-1025, 2006.

[6] J.-W. Song, J. Kim, Y.-H. Yoon, B.-S. Choi, J.-H. Kim, and C.-S. Han, "Inkjet printing of single-walled carbon nanotubes and electrical characterization of the line pattern," Nanotechnology, vol. 19, 095702 (6pp), 2008.