Fabrication of Schottky diode and electrolyte-gated transistor using spray-printed ZnO at low-temperature as the semiconductor material

Gabriel Nogueira, Rogério Morais, Douglas Vieira, Maykel Klem, Neri Alves
São Paulo State University, School of Technology and Science, Presidente Prudente, Brazil

Spray-printed technique have attracted interest among others well established printing processes due to their simplicity and low-cost implementation, enabling the ease fabrication of electronics devices. An important fabrication step is the semiconducting layer. Zinc oxide (ZnO) is one of the most successful inorganic semiconductor due to their abundance, low-cost, facility to form nanostructures and large bandgap. Between all the possible application of ZnO as the semiconductor, Schottky Diode (SD) [1] and Electrolyte-Gated Transistor (EGT) [2] are two devices that stands out. However, less attention has been paid to the SDs and the EGTs fabrication using ZnO by spray-printing technique. Here, we deposited the ZnO ink by a low-temperature processes using a low-cost airbrush and manufactured a SD and an EGT using the sprayed ZnO as the semiconducting material.

We formulated suitable ink to spray-coating technique by dispersing AgNW and ZnO nanoparticles (both from Sigma-Aldrich) in ethanol. In our homemade spray-coating system, the airbrush can move in a linear way above the substrate, where we can easily control the thickness by setting the number of layers. To the fabrication of the SD, we made the bottom electrode by printing the AgNW onto glass substrate. Next, the ZnO was sprayed forming the semiconducting layer onto the AgNW electrode. To finish the diode structure, aluminum (Al) electrodes were evaporated on top of ZnO film. After, we fabricated the EGT. We used a glass substrate covered with patterned ITO (from Ossila) to act as the source and drain electrodes. For the active layer, the ZnO ink was sprayed onto these electrodes. To finish the transistor structure, the ion gel film and the top gate electrode were stacked onto the ZnO.

AgNW electrodes showed the sheet resistance and the transparency (550 nm) of 10 Ω/sq and ~98 %, respectively. Figure 1a shows the expected current rectification for the ZnO/AgNW Schottky contact, achieving the rectification ratio of 1.4x10^3. Applying the Cheung' method, were calculated an ideality factor (n), series resistance (Rs), and barrier height (φb) of 1.58, 1.3x10^6 Ω, and 1.07 eV, respectively. Figure 1b shows the low-voltage transfer curve for the ZnO transistor. The calculated transistors parameters as Ion/Ioff ratio, turn-on voltage (Von), and mobility (μ), are of 1000, -0.5 V, and 0.33 cm²V⁻¹s⁻¹, respectively. In conclusion, the ZnO was successful applied as the spray-printed semiconductor material in both SD and EGT. The low-cost manufacturing process proposed here has a great potential to large area and flexible electronic devices.

References

Acknowledgement - The authors would like to thank FAPESP (Proc. 2018/02037-2), INEO, and POSMAT.

Figure 1. ZnO-based devices: (a) Current vs. Voltage curve for the Schottky diode (SD). (b) Transfer curve for the electrolyte-gated transistor (EGT).