Resistance of Nanoparticles Embedded Electrospun Nanofiber

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ABSTRACT

Electrospinning produces nanofibers with diameters ranging from 200-500 nm under 10-20 KV at 10-20 cm distances, and if these nanofibers were composed of polymers like PVA or PVP, they are usually nonconductive with resistances too larger to measure on ordinary meter. One way to change the conductivity of nanofibers is to add nanoparticles. We produce Fe_3O_4 nanoparticles with polyols method, and mix these diameters ranging from 20-50 nm nanoparticles with PVP into electrospinning process on a double knife edge receptor set up. We found the current between the two knife edges of 0.005 g of nanofibers and nanoparticles is around 20 nA at 50 V bias, and based on estimations of nanofiber diameter and number, the resistance of each individual nanoparticles containing nanofibers can be estimated.

Keywords: electrospinning, nanofibers, nanoparticles, resistance, thin film field effect transistor

1 INTRODUCTION

Electrospinning [1] is an easy method to manufacture nano-size fibers with the pulling force induced by the applied electric field. General trend is higher voltage and longer spinneret to collector distance leads to thinner fiber, while denser solution leads to thicker fiber. Most electrospun nanofibers are of 200-500 nm diameters, and smaller diameters are possible with very high voltage. Electrospun nanofibers have been applied in air filtration, isolation film in Lithium battery, and scaffold for enhanced tissue growth on wounded skin.

New ideas for nanofiber include serving as vehicle for drug in active drug release (ADR), or a medium for dispersing semiconductor materials to form network type thin film field effect transistor (TF-FET). In ADR, nanoparticles are used as the substrate for drug coating, and then the nanoparticles are either enclosed inside the nanofiber, or attached on the surface of the nanofiber, and transport to designated locations inside human body. The release of these nanoparticles can be achieved by magnetic resonance induced heating, or by DC current heating between the two ends of the nanofibers from implanted power source. For the latter case, knowledge of the resistance of nanoparticle doped nanofiber would be interesting.

In TF-FET, nano-semiconductor materials like carbon nanotube or Si nanowires are grown on pre-patterned metal electrodes to form a network like connections. This kinds of 2D networks from 1D nanostructures form a better conductivity connection than single nanowire, and relief oneself from the daunting challenge of aligning multiples of nanowires to the electrodes. However, this still requires CVD process, which is challenging for some of the proposed flexible substrate materials.

Electrospinning represent another low temperature and low cost solution to network forming. Nanoparticles or CNTs can be mixed with solution in an electrospinning process, and electrospun onto designated areas by shadow mask technique, and then the solution materials can be vaporized by mild heating to leave the nanomaterials behind, or simply use the nanofiber network as thin film current path. For this, the DC resistance of such nanofiber is of interest.

We report here the resistance measurement of electrospun nanofibers containing Fe_3O_4 nanoparticles. Nanoparticles containing solution is electrospun onto a two-knife collector, and then measure its resistance. Section two describes the two-knife electrospinning set up; section three is the preliminary results, and then the conclusion.

2 TWO-KNIFE COLLECTOR ELECTROSPINNING

Figure 1 depicts the two-knife electrospinning set up. Two knife blades of 2x5 cm are placed parallel to each other with a distance of 1 cm on a stand made of insulator material, and then the collector is placed under a conventional syringe electrospinning stand.

A syringe containing mixture of 2g of magnetite nanoparticles and 3g of polyvinylpyrrolidone (PVP) in 9g of alcohol solutions are used. The solution is first stir and heated at 95 ℃ for 30 minutes, and placed in ultrasound for 30 minutes to achieve uniform dispersion. Magnetite nanoparticles were produced with polyols method. The electrospinning process was conducted in a very short period (~ 1 minute) in order to have small amount (0.005g) of nanofibers present. The applied voltage was 10 KV, and the spinneret to collector distance is 6 cm. After electrospinning, the whole knife collector is moved to a probe station, and the two knifes serve as electrodes to measure the resistance between them. A Kethley 237 high voltage precision meter is used in this measurement. Figure 2 is a TEM picture of a typical nanoparticle distribution inside the nanofiber. We can see the nanoparticles are not rich enough to form a continuous alignment.

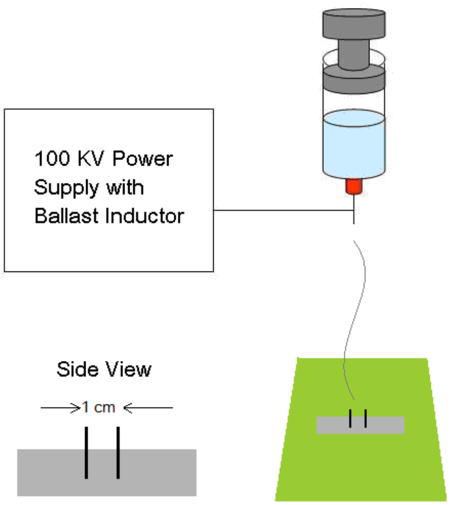

Figure 1: Two knife electrospinning set up.

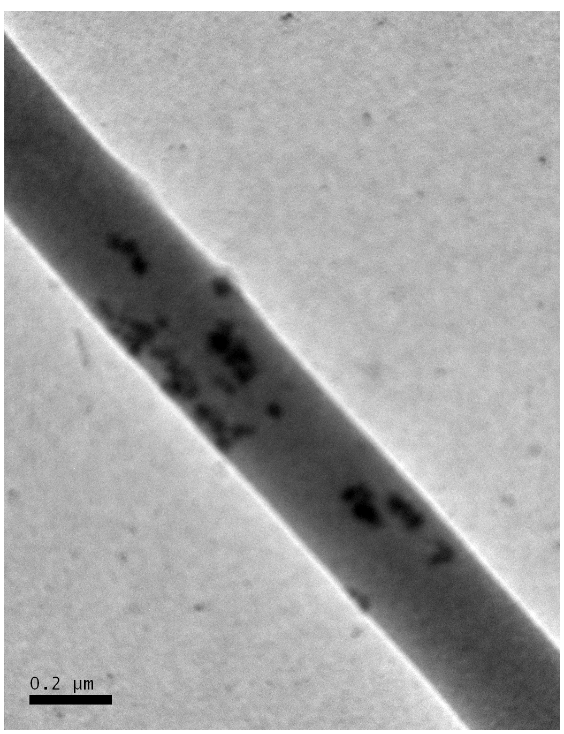

Figure 2: Electrospun nanofiber containing magnetite nanoparticles.

3 RESULTS

The electrospun nanofiber network under short electrospinning time appears sparse and a bit parallel to each other, with some intersection in between. It is difficult to measure the resistance of this nanofiber network because they are very fragile, a small vibration or air blow cause fluctuations in current measurement, and the nanofibers weaken soon. Several attempts were made to try to measure the resistance of the formed nanofiber networks, and figure 3 is a preliminary result. It means the resistance is about $2.5 \times 10^{10}\ \Omega$.

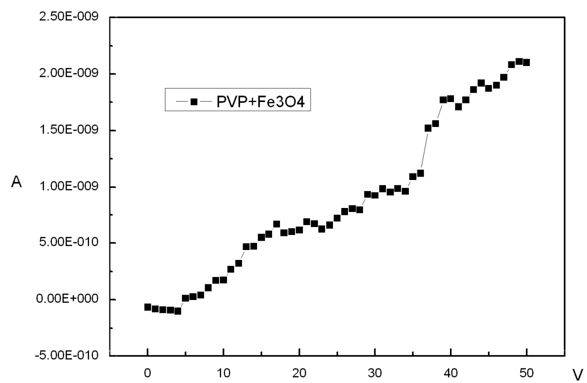

Figure 3: The I-V curve of resistance measurement.

The increase weight of PVP (density $1.2 g/cm^3$) and Fe_3O_4 (specific gravity 5.17-5.18) together is 0.005g, and since they were pre-mixed in 2:3 ratio, the PVP is 0.003g (assuming alcohol all evaporated). Assuming the average diameter of the nanofiber is 200 nm, then a 1 cm long PVP nanofiber would weights about 1.5×10^{-9}g, which means there were about 1.9×10^6 nanofibers present in this measurement. Therefore the measured resistance would be the parallel resistance of all these nanofibers if they are perfectly aligned and electrically separated from each other.

4 CONCLUSION

The nanoparticles in the nanofibers were not sufficient enough to form a continuous path for electron path, plus the fact that Fe_3O_4 is not a good conductor, therefore adding these nanoparticles did not change significantly the conductivity of nanofibers. However, this experiment does provide rare data on actual electrospun nanofiber resistance measurement.

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