ELECTRICAL CHARACTERIZATION OF HYBRID METAL-POLYMER NANOWIRES

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In the recent years, many studies have been devoted to the characterization of low-dimensional structures. Organic and hybrid organic-inorganic nanomaterials are at the heart of the emerging field of nanotechnology. Among them, organic nanowires (NWs) and nanotubes are promising components for a wide variety of electronic applications. The fabrication, manipulation, and characterization of such systems are quite challenging.

Here, we investigate the electrical properties of hybrid metal(Au)-polypyrrole(PPy)-metal(Au) NWs from room-temperature down to very low temperature (T ~ 0.5 K). Furthermore, we highlight our strategy for the fabrication of a platform adapted to both electrical and thermopower measurements of NWs.

Segmented composite PPy NWs presenting diameters of 50 [M50], 70 [S70], and 90 nm [M90], with a nominal PPy length between 300 and 1500 nm, were prepared by an all-electrochemical template method described in detail in Ref. [1]. Variable temperature electrical measurements of multiple NWs embedded in the polycarbonate template (samples M50 and M90) are compared to those of the single NW sample S70.

In all samples, current-voltage ($I-V$) characteristics are symmetrical and show no rectification effect. They are linear from room temperature down to T ~ 100 K and nonlinear at lower temperatures. The current-voltage $I-V$ characteristics of sample S70 are given Fig. 1(a). We show that the Mott variable-range hopping (VRH) model provides a complete framework for the understanding of transport in our PPy NWs. In this model, the resistance follows the relation $R(T) \sim \exp(T_0/T)^{1/4}$, where $T_0 = 16a^3/k_BN(E_F)$, k_B is the Boltzmann constant, a is the localization length, and $N(E_F)$ is the density of states at the Fermi energy. The VRH plots are shown Fig. 1(b) and are used to extract T_0. To estimate the localization length in our samples, we performed low-T magnetoresistance measurements. The plot of $ln[R(B)/R(0)]$ with respect to the magnetic field (B) for sample M90 is given in Fig. 1(c). Data fits the wavefunction shrinkage model developed by Shklovskii and Efros [2]. From this model, we deduce a localization length of about 1.5 nm in our samples and, thus, calculate $N(E_F)$.

We reveal here our strategy for the fabrication of devices designed to perform both electrical and thermopower measurements of single NWs. These devices essentially consist of two platinum electrodes on top of two 80 nm thick silicon nitride (Si_3N_4) membranes. On each membrane, we pattern a platinum resistance serving as thermometer and heater, respectively. Membranes are supported by 1 µm wide and 240 µm long Si_3N_4 beams. A close-up view of the two membranes is given Fig. 1(d).

References:
[1] O. Reynes *et al.,* J. Electrochem. Soc. **152,** (2005) D130.
[2] B.I. Shklovskii and A.L. Efros, *Electronic Properties of Doped Semiconductors*, Springer, (1984).

Figure:

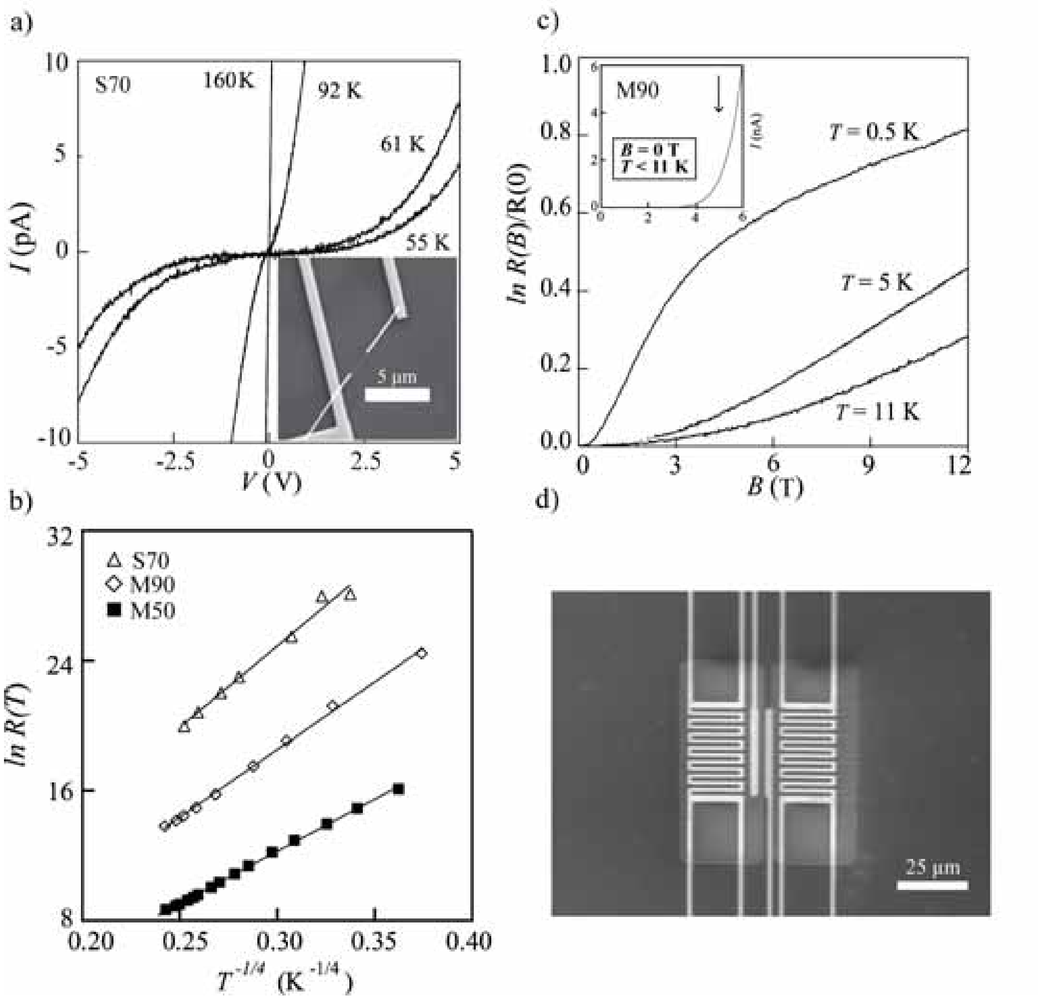

Fig.1 (a) *I−V* characteristics of sample S70. (b) VRH plots for samples S70, M90, and M50. The solid lines are fits to the data. c) Variation of *ln[R(B)/R(0)]* with *B* at indicated *T*'s for the sample M90. Inset: Below *T* = 11 K the *I−V* curves are indistinguishable. (d) SEM image of the device for thermopower measurements.