STENCILLED CONDUCTING BISMUTH NANOWIRES

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Bismuth nanowires (NWs) have been intensively studied in recent years due to their unique electronic transport [1] and thermoelectric characteristics[2]. Highly crystalline NWs with small diameters are obtained using electrochemical growth, but positioning them precisely on a substrate and providing good metallic contacts to them is difficult. With the bottom-up approach of using e-beam lithography and physical vapor deposition to pattern Bi NWs by lift-off, this issue is circumvented, but several disadvantages also exist: the wires resistivity is up to 20 times higher compared to that of bulk Bi[1], and the wires' thickness and width are limited by the lift-off process[3].

Here we present the physical (Fig. 1, 2) and electrical characterization of Bi NWs fabricated for the first time using stencil lithography. The stencil wafer is aligned and clamped to a wafer pre-patterned with Ti/Au contact pads. Bi is then deposited through nano-apertures located in the 100 nm-thin SiN stencil membranes. As the Bi is evaporated, it accumulates on the stencil, leading to the gradual clogging of the apertures[4]. Thus in a single deposition step the thickness of the individual wires across the wafer can be varied, depending on the apertures' width and amount of Bi deposited (Fig. 3).

The current vs. voltage characteristics of the NWs are linear at room temperature (Fig. 4a). We show that the conductivity of wires with dimensions as small as 35 nm x 140 nm x 2.6 μm is a factor of 3 higher than that of wires fabricated using lift-off[1] and is independent of the wire dimensions (Fig. 4b). Electrical conduction mechanisms are investigated through transport measurements at low temperatures.

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2 A. Nikolaeva, T. E. Huber, D. Gitsu, and L. Konopko, Physical Review B **77**, 10 (2008).
3 S. Farhangfar, Physical Review B **76**, 4 (2007).
4 O. Vazquez-Mena, G. Villanueva, V. Savu, K. Sidler, M. A. F. van den Boogaart, and J. Brugger, Nano Lett. (2008).

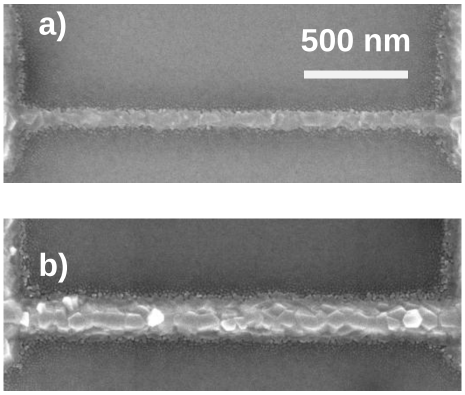

FIG. 1. Scanning electron micrographs of 2.6 μm long Bi NWs desposited on SiO_2 at the same time with widths of a) 100 nm and b) 260 nm.

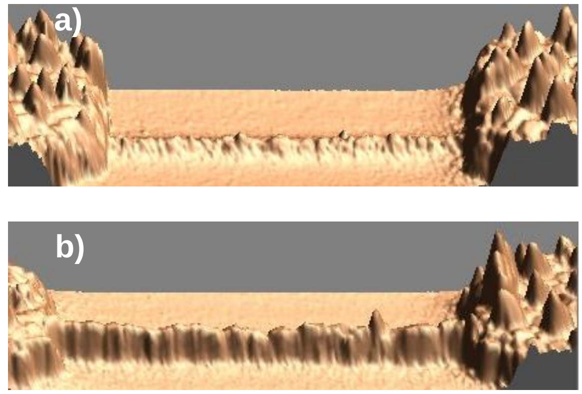

FIG. 2. Atomic force microscope images of the NWs from Fig. 1, illustrating the change in NW thickness a) 20nm and b) 95 nm as a function of width due to the stencil aperture clogging.

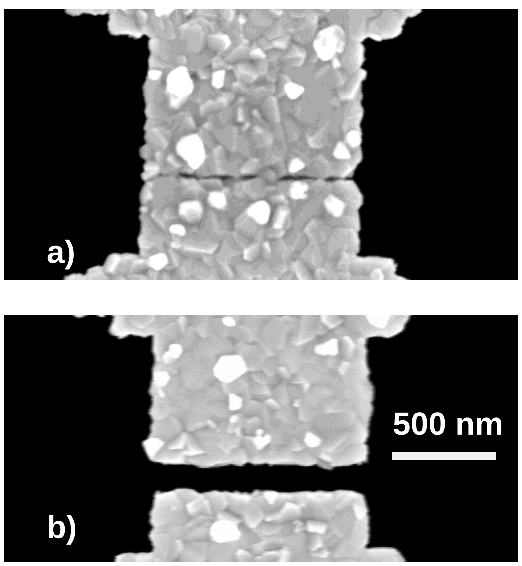

FIG. 3. Scanning electron micrograph of 1 μm long stencil apertures of a) 90 nm and b) 200 nm widths after the deposition of 90 nm Bi, where one can see the narrower one is clogged faster than the wider one.

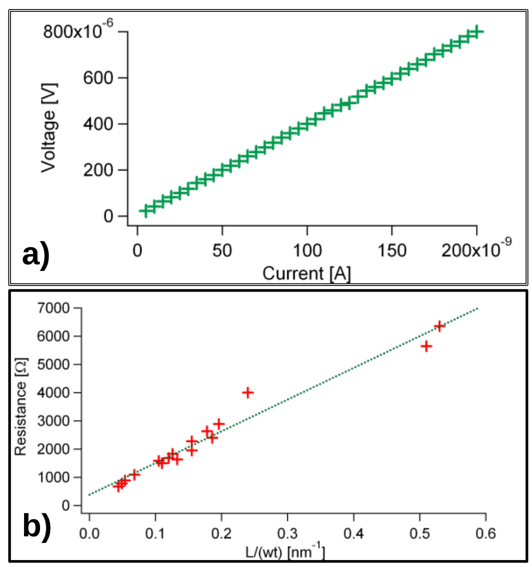

FIG. 4. a) Current vs. voltage curve of a 40 nm x 130 nm x 2.6 μm Bi NW, and b) plot of Bi NWs resistances vs. the ratios of their length L to the product of their width w and thickness t. The resistivity extracted from a linear fit is 1.2 x 10^{-3} Ωcm.