DOI: 10.1017/S1431927605508092
Microsc Microanal 11(Suppl 2), 2005

In-situ Electrical Characterization of Nano-Interconnect Structures in the FIB

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The dual beam Focused Ion Beam (FIB) system provides unique capabilities such as nano-lithography and nanostructure fabrication using FIB chemical vapor deposition. The formation of electrical interconnects by FIB is of particular interest [1-2]. Equipped with nano-manipulators, the system allows us to directly measure the properties of nanostructures in-situ. In this paper, we present results on the in-situ electrical characterization of nanoscale test structures fabricated in the FIB.

A FEI Dual Beam Nova NanoLab 200 equipped with five gas injection sources for deposition and etching was used for this study. This FIB is also equipped with a Zyvex F100 nano-manipulation stage, which includes four independent manipulators with 10 nm positioning resolution (Fig. 1(a)). The four manipulators can be fitted with either sharp whisker probes for electrically probing samples or microgrippers for manipulating nanostructures as small as 10 nm. Fig. 1(b) shows gold contact pads used as electrical test structures for this study. A 100 nm thick gold thin film was deposited on insulating SiO_2/Si substrates through a shadow mask to fabricate "dog-bone" looking structures (90μm×6μm).

For electrical studies, a small gap of about 100 nm in width was first created by FIB Ga ion beam etching, as shown in Fig. 2(a). This provides electrical isolation between two-terminal contact structures. In-situ electrical I-V measurements were made on this structure with nano-manipulators connected to a Keithley 4200-SCS system. Fig. 2(b) shows I-V characteristics of the structure before and after the electrical isolation. The as-deposited gold contact pads exhibit a good electrical conductivity. The measured electrical conductivity of the electrically isolated structure fabricated by FIB is negligible and is well within the noise level of the measurement system (inset in Fig. 2(b)), indicating no significant metallic Ga contamination across the isolated contact structure. This also indicates that the substrate electrical conduction is negligible. Nanoscale interconnect structures were then fabricated by FIB CVD deposition of Pt, as shown in Fig. 3(a). The FIB deposited Pt nanointerconnect has a geometry of 500×200×200 nm^3. The measured I-V characteristic of the Pt nanointerconnect is shown in Fig. 3(b), showing a good Ohmic behavior. The in-situ measured resistivity is approximately 220 μΩ·cm, which is higher than pure bulk Pt (10.6 μΩ·cm) [3]. However, the measured resistivity is consistent with previous studies [4]. Ex-situ electrical measurements were also done on the same nanointerconnect structure, resulting in minimal differences. Therefore, the measured resistivity is attributed to the FIB CVD process related defects such as co-deposited carbon contamination and disordered Pt microstructure. The contact resistance may also contribute to the total resistance. Our results demonstrate the feasibility of nano-patterning, deposition, and electrical probing all in-situ. This approach will work for complex interconnect integration of nanoscale materials and devices.

Reference:

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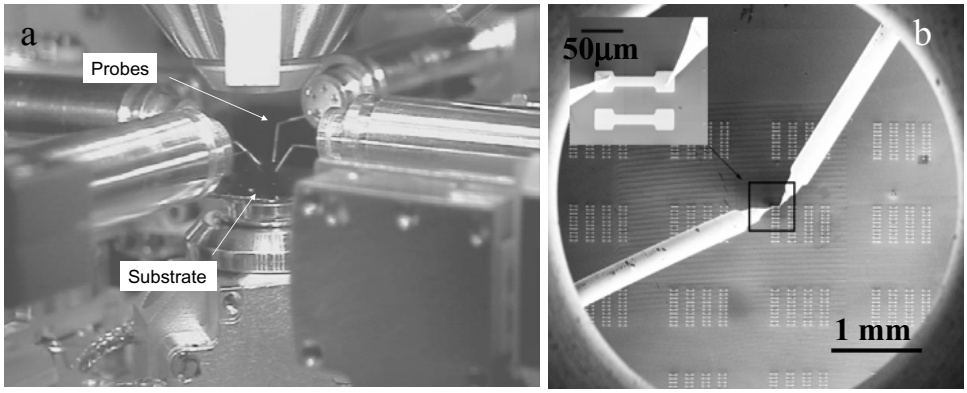

FIG. 1. (a) The Zyvex F100 Nanomanipulator in the FEI Nova NanoLab 200 Dual beam FIB/SEM. (b) SEM image of W probes and gold “dog-bone” electrical test structures.

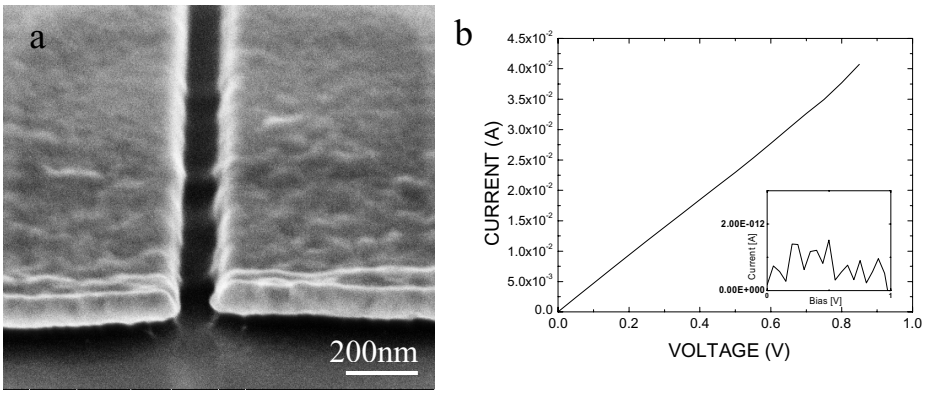

FIG. 2. (a) SEM image of the isolated two-terminal electrical test structure fabricated by FIB. (b) Current-voltage (I-V) characteristics of the gold “dog-bone” test structure. (Inset) I-V curve of the isolated structure, showing negligible electrical conductance across the junction. Note the difference in current scale.

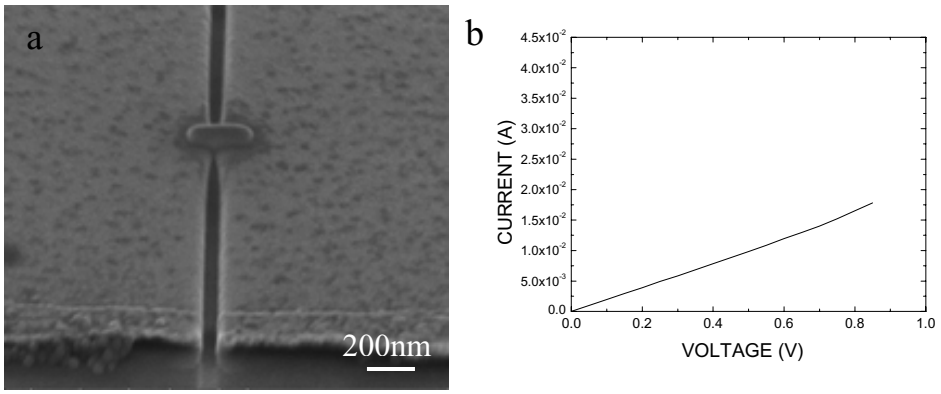

FIG. 3. (a) SEM image of the Pt nanointerconnect fabricated by FIB deposition of Pt. (b) Current-voltage (I-V) characteristics of the nanointerconnect structure shown in (a), showing good Ohmic behavior.

https://doi.org/10.1017/S1431927605508092 Published online by Cambridge University Press