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# MEMS-Based Electrical Testing of IBID Carbon and Tungsten Wires

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The ability to electrically characterize micro- and nano- scale structures has been a limiting factor for advancements in the field of ion beam induced deposition (IBID). In the past, deposits have been electrically characterized utilizing *in situ* two- and four- point probe measurements; however differences in types of depositions and substrates introduced a plethora of variables [1-3]. Presented here is a new approach using an *in situ* MEMS-based electrical testing technique to determine whether as-deposited IBID tungsten (W) and carbon (C) wires formed Ohmic contacts to a silicon nitride ($Si_3N_4$) substrate. Further materials characterization was performed to determine sheet resistivity, elemental composition, and structure of the as-deposited wires.

Briefly, the Aduro platform (Protochips, Inc., Raleigh, NC) is a MEMS-based substrate consisting of silicon, gold pads, and an electron transparent 0.5 mm x 0.5 mm x 50 nm thick $Si_3N_4$ membrane (Figure 1). The $Si_3N_4$ membrane supports four micrometer-sized Au electrodes where W and C IBID wires were created utilizing a Hitachi NB5000 (Figure 1 inset). A $W(CO)_6$ precursor, 40 kV $Ga^+$ ion beam, 70 pA ion current, 5 µs dwell time, and an interlace 8, a wire (30 µm x 1 µm) was fabricated at a deposition time of 10 minutes. The same deposition conditions were used to create a 60 µm x 1 µm IBID carbon wire using a phenanthrene precursor. Immediately after depositions, *in situ* energy dispersive x-ray spectroscopy (EDS) was performed on the resulting wires (Figure 1). Electrical characterization, similar to four-point probe, was achieved by sourcing variable currents through the outer two Au electrodes, and the voltage was measured across the inner two Au electrodes. Further morphology and chemical analysis was performed on the IBID deposits using STEM/EELS. Atomic force microscopy (AFM) was employed to measure the thickness of deposits (150 nm – 200 nm) and used to calculate the resistivity values, $\rho$, of the W or C wires (Figure 1).

Following extensive studies, results show that the beam deposited W wires behaved Ohmically with an average $\rho$ of 50 µΩ cm, which is only one magnitude difference from bulk W and among the lowest obtained $\rho$ for IBID W wires tested. Carbon wires did not show an Ohmic response and larger $\rho$ ranges between $1.5\times10^6$ µΩ cm and $2.5\times10^9$ µΩ cm were found. The integration of an *in situ* testing platform that can be adapted to many nano-scale beam depositions, in addition to analysis via electron microscopy and spectroscopy, provides the ability to characterize these nanostructures efficiently and thoroughly. [4]

References

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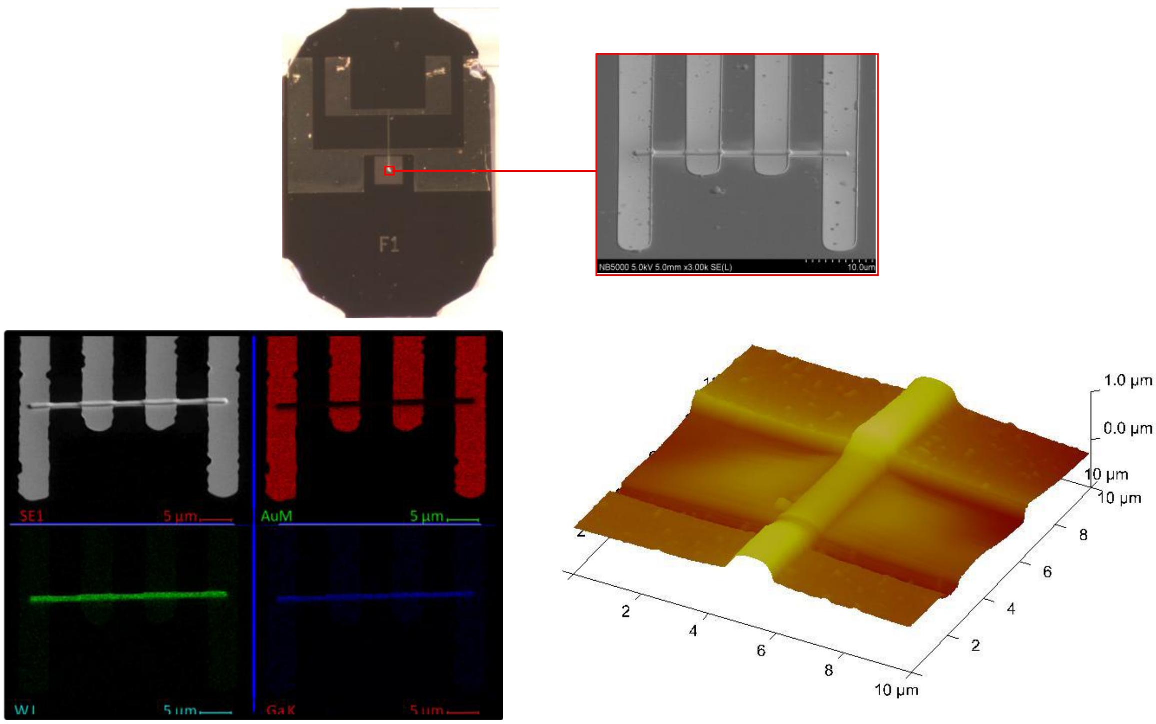


FIG. 1. Protochips Aduro substrate (top left) and FIB-SEM image of the tungsten wire deposit on gold electrodes (inset). EDS and AFM data from a tungsten deposit is shown (bottom left and right).

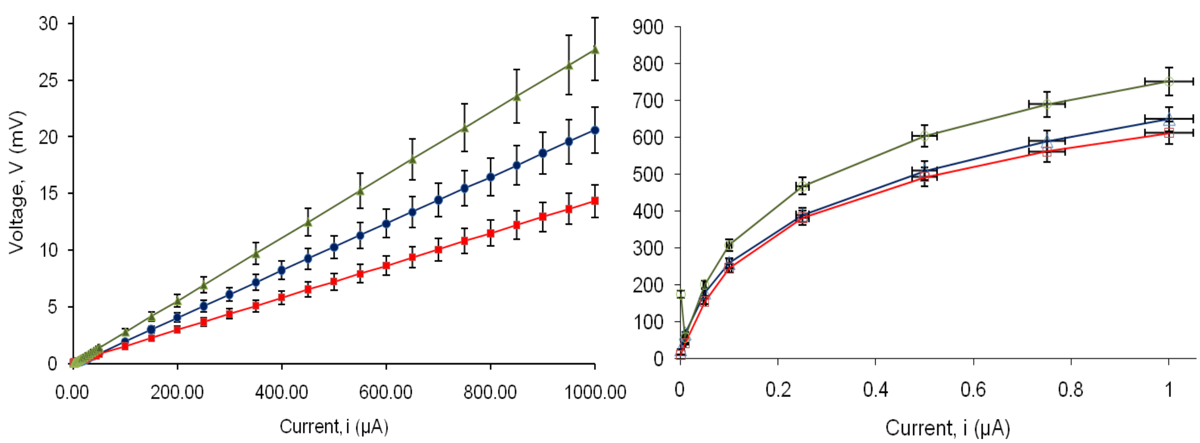


FIG. 2. Example I-V curves of tungsten (left) and carbon (right).

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