Superconductivity of tungsten-containing carbon nanowires fabricated by focused-ion-beam chemical vapor deposition

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We have demonstrated the superconductivity of tungsten-containing carbon nanowires deposited by focused-ion-beam chemical vapor deposition (FIB-CVD) using the precursor of phenanthrene ($C_{14}H_{10}$) mixing tungsten hexacarbonyl ($W(CO)_6$). Compared with reported merely $W(CO)_6$-based superconducting deposition,[1] the growth rate of deposition from the mixture is superior.[2] This technique facilitates the direct fabrication for the three-dimensional superconducting nanostructures, expanding the applications to high performance superconducting quantum interference device (SQUID) sensors, nanomechanical systems, and significant tools for fundamental low temperature physics and quantum information technologies.

Figure 1 shows the schematic of the nanowire fabrication by using 30kV Ga^+ FIB. A SMI9200 system (SII NanoTechnology Inc.) was used to fabricate nanowires from both $C_{14}H_{10}$ mixing $W(CO)_6$ and $W(CO)_6$. In addition, a SMI3050 system (SII NanoTechnology Inc.) was used to fabricate nanowires from both $W(CO)_6$ and $C_{14}H_{10}$. Various ion beam currents and temperatures of $C_{14}H_{10}$ in the mixture were used to change the component ratio of nanowires. Figure 2 shows a scanning electron microscope (SEM) image of a deposited nanowire. Temperature dependency of electrical properties of nanowires was examined by physical property measurement system (PPMS) with temperature.

The temperature dependency of normalized resistances of nanowires was summarized in Fig. 3(a)-3(c). Nanowires deposited by using the precursor of $W(CO)_6$ all showed superconductivity, with critical temperatures (T_c) from 4.6 K to 5.8 K. Nanowires deposited by using the precursor of $C_{14}H_{10}$ didn't show superconductivity. The electrical property of nanowires, deposited by using the precursor of the mixture, was varied by fabrication conditions, as shown in Fig. 3(c). T_c of superconducting tungsten-containing carbon nanowires deposited by using the mixture were 2.8 K and 4 K. The relationship between T_c and W concentration of all deposited superconducting nanowires was summarized in Fig. 3(d). We found that T_c of superconducting nanowire could be selected by controlling ion beam current and also temperature of $C_{14}H_{10}$ in the mixture.

[1] Wuxia Li, et al. , J. Appl. Phys. **104**, 093913 (2008).
[2] Takahiko Morita, et al. , J. Vac. Sci. Technol. B **22,** 3137 (2004).

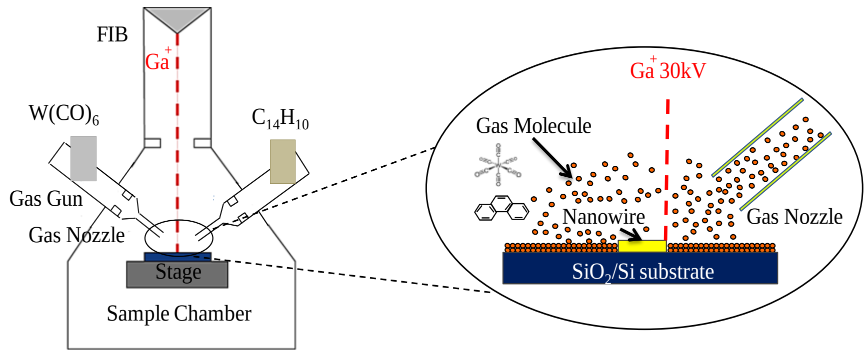

Figure 1: Schematic of the nanowire fabrication by using 30kV Ga^+

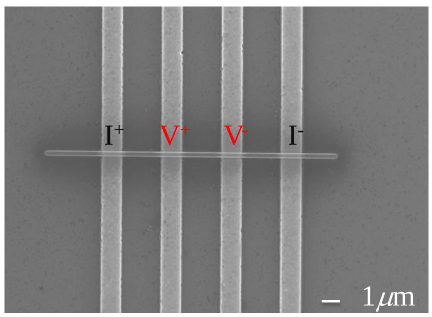

Figure 2: SEM top-view image of a typical four-terminal configuration of a nanowire, for electrical-property measurement.

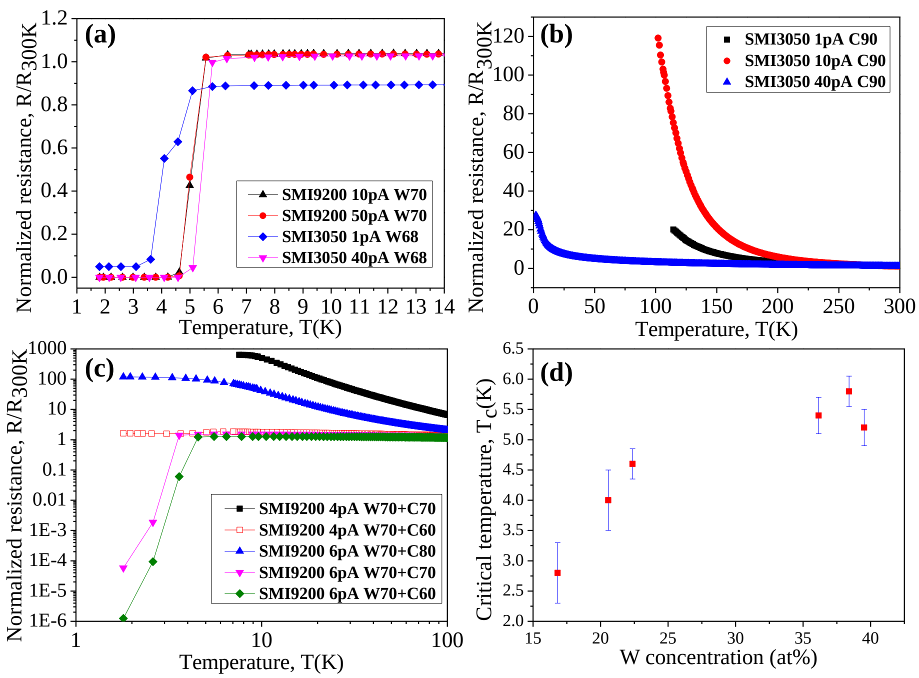

Figure 3: The temperature-dependent normalized resistance of FIB induced depositions. (a) Deposition of $W(CO)_6$. (b) Deposition of $C_{14}H_{10}$. (c) Deposition of $C_{14}H_{10}$ mixing $W(CO)_6$. (d) Relationship between critical temperature (T_c) and W concentration of the nanowires. Tungsten (W) concentration of superconducting nanowires was obtained by scanning electron microscopy energy dispersive spectroscopy (SEM-EDS). Fabrication information is represented in the box, e.g. 'SMI9200 4pA W70+C70' means the deposition of $C_{14}H_{10}$ (70 ºC) mixing $W(CO)_6$ (70 ºC) by SMI9200 with ion beam current of 4 pA.