

Enhanced Superconducting Transition Temperature in Focused Ion Beam Deposited Nano-wires

The direct fabrication of nano-structures or the modification of existing structures using focused ion beams (FIB) has attracted significant interest in recent years. Such a technique offers the means to rapidly develop nano-scale devices in a single processing step in-situ with no need for time consuming mask fabrication or extensive prior preparation of the sample.

The ability to remove and deposit material with a high precision provides the ideal tool for the rapid prototyping of a whole range of devices in areas such as: molecular electronics, micro-electro-mechanical systems and optical applications.

Focused ion beam induced chemical vapour deposition (FIBICVD) also has applications in failure analysis and modification of integrated circuits and in the modification and repair of lithography masks.

FIBICVD can be used to directly write patterns of metal, semi-conductor or insulator into a desired two or three-dimensional shape. The process involves the introduction of a precursor gas that contains the desired material to the vacuum chamber. The gas is introduced through a capillary needle in the vicinity of the focused beam and is absorbed onto the surface of the sample. As the beam is scanned over the surface of the sample in the desired pattern the precursor is decomposed into volatile and non-volatile components. The non-volatile component is deposited on the sample surface whilst the volatile product is removed via the instruments vacuum system.

Tungsten is one of the most commonly used materials in FIBICVD. Using the precursor gas Tungsten Hexacarbonyl \((W(CO)_6)\) and a focused beam of Gallium ions we have fabricated tungsten nano-wires. Fig 1 shows a scanning electron microscope (SEM) image of a typical nano-wire.

Bulk Tungsten has a resistivity of 5 \(\mu\Omega \text{ cm}\), however, the FIBICVD process results in a material that includes various impurities including Carbon and Oxygen from the precursor gas and Gallium from the incident ion beam. As a consequence of the various impurities, material deposited by IBICVD has an increased resistivity of around 200 \(\mu\Omega \text{ cm}\). Despite the increase in the room temperature resistivity of the material it has been shown that the material has a higher superconducting transition temperature of \(~ 5 \text{ K}\) compared to bulk Tungsten, which has a transition temperature of 10 mK [1]. Fig 2 shows the temperature dependence of the resistance of a typical ion beam deposited nano-wire.

This opens up the possibility to fabricate novel superconducting devices in two and three dimensions using FIB techniques, the electrical properties of which can easily be measured using a conventional liquid helium cryostat.
Fig 1. SEM image of a Tungsten nano-wire deposited between gold electrodes on a Silicon Oxide substrate.

Fig 2. Temperature dependence of resistance of FIB deposited tungsten nano-wire. The superconducting transition occurs at ~ 5 K.

References