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Transmission Electron Microscopy of Amorphisation and Recrystallisation of Silicon Nanowires under *in situ* Ion Irradiation

Abstract

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In the last decade, nanowires (NWs) have been the subject of intense scientific research and of particular interest are semiconductor NWs. Silicon (Si) is an attractive material for the microelectronic industry due to its mechanical strength, abundance, cost, electrical properties, ease of wafer production and high-temperature performance. The quest to continually miniaturise Si-based microelectronics poses challenges as the limits of current technologies are reached. For example, at increasingly small dimensions issues such as leakage current and short channel effects become critical. Therefore novel solutions are required with similar thermal, electrical, mechanical and optical properties whilst overcoming the shortcomings of bulk Si. Silicon NWs are one of the main candidates as they posses many of the same properties as bulk Si but whilst offering solutions to many of the challenges faced by virtue of their geometry.

Ion irradiation is the main processing technique for Si based devices. The current work is focused on understanding the underlying physics and mechanisms of amorphisation and recrystallisation of single crystal Si NWs under ion irradiation. The ion irradiation causes displacement of atoms and accumulation of damage resulting in the amorphisation of the NWs. However, the probability of the ions being implanted into the NW and the amount of damage they cause both vary as complicated functions of ion species, energy and NW diameter. Implanted ions may perturb the amorphisation and recrystallisation processes under study. Therefore the irradiation conditions must be designed to achieve maximum damage with the minimum amount of implanted ions. Monte Carlo calculations have been performed using the Stopping Range of Ions in Matter computer code [1] and these have been used to determine the optimum irradiation conditions.

Preliminary experiments have been carried out using the Microscope and Ion Accelerator for Materials Investigations (MIAMI) facility at the University of Huddersfield. Irradiation of Si NWs with 30 keV Ar^+ ions has been performed *in situ* within the JEOL JEM-2000FX transmission electron microscope (TEM) to induce amorphisation within the NWs. Through design of the experimental geometry, it has been possible to use the sample support to shadow part of the NWs from the ion beam and thus create a crystal-amorphous (c-a) interface across the diameter of a NW. Further, by careful tuning of the ion energy to the NW diameter it has been possible to create a buried c-a interface along the length of a NW.

Upon thermal annealing, Si NWs undergo recrystallisaton processes which have been found to cause either a return to a single-crystalline state similar to the pre-irradiated state or a polycrystalline state. Preliminary results suggest it is possible to control the recrystallation via the engineering of the c-a interface. TEM images and diffraction patterns are presented showing the amorphisation and recrystallisation processes in the crystalline, c-a interface and amorphous regions.

Further work will focus on the fundamental mechanisms behind the amorphisation and recrystallisation processes in Si NWs.

References

[1] James F. Ziegler, Jochen P. Biersack, Matthias D. Ziegler