Tungsten implantation of VO_2 nanobeams for neuromorphic applications

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INTRODUCTION

Vanadium dioxide (VO_2) is a phase change material known to present a near room temperature metal-insulator transition (MIT) at 69°C characterized by a strong electrical resistivity change (10^4-10^5 ratio) [1]. The MIT is accompanied by a structural phase transition where the low temperature (semi-conducting) phase has a monoclinic (M1) structure, and the high temperature (metallic) phase exhibits a rutile (R) structure. Traditionally under its polycrystalline thin film form, VO_2 can be used to fabricate compact electrical oscillators without using analog components. We intend to exploit this oscillatory behavior to highlight their potential in neuromorphic applications by realizing coupled oscillatory networks [2]. This work is focused on VO_2 nanobeams instead of thin films, with the main goal of improving the repeatability of the electrical properties. However, single-crystalline nanobeams show relatively high transition temperature [3]. Ion implantation of tungsten is therefore employed in the present work to reduce the transition temperature.

EXPERIMENTAL/THEORETICAL STUDY

The nanobeams are synthesized through a modified vapor solid liquid (VLS) method then extensively characterized with X-Ray diffraction (XRD) and electrical measurements. Tungsten Ion implantation was conducted on different samples of nanowires at different ion fluences of 1×10^{14}, 2×10^{15} and 3×10^{15} cm^{-2} at room temperature and at an energy of 500 keV using the 2MV ARAMIS Tandem Ion accelerator at the MOSAIC facility, Orsay. One sample was also irradiated with 2.5 MeV tungsten ions to study the influence of radiation damage without incorporation of ions in the VO_2 nanobeams. Simulations were calculated with the SRIM software with a statistic of 8000 ions in order to evaluate the concentration of W in nanobeams and the corresponding damage. Finally, all of the implanted samples were characterized with XRD θ-2θ scans to compare the change in structural properties.

RESULTS AND DISCUSSION

The implanted nanobeams showed a significant decrease in the measured integrated intensities of selective peaks in the XRD scans. This is characteristic of a strong structural disorder caused by the defects created during implantation and irradiation. However, the expected crystallographic <011> orientation of the nanobeams is still observed. When studied in a temperature dependent XRD measurement, the implanted nanobeams showed a structural phase transition shifted to lower temperatures, characteristic from the tungsten implantation from 80C° to 56C° for the $2x10^{15}$ cm^{-2} fluence.

CONCLUSION

This study highlights the effectiveness of ion implantation to modify the properties of VO_2 nanostructures to tune the transition temperature. This paves the way for their future integration in nanoelectronic devices.

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