Focused Ion Beam For Charge Transport Characterization Along Si And SiC Nanocrystals In SiO_2

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Si nanocrystals embedded in dielectrics show great potential in a number of applications like light emitting devices [1] or memories [2] and more recently switch components exploiting non-linear optical properties of nanocrystals [3]. The composition and structure of the system will determine the optical and electrical behaviour of the device, mainly by modifying the emission energy and charge transport phenomena. Consequently, these characteristics should be well understood in order to fabricate optoelectronic devices, and this is the main goal of the present work.

C implantation in Si-rich silicon oxide and next thermal treatment were used to obtain a layer of C-rich Si nanocrystals embedded in a SiO_2 matrix [4]. Then, Focused Ion Beam (FIB) was used to fabricate structures suitable for characterization of charge transport along the nanocrystal layer. In particular, two trenches ~10 µm long and spaced about 100 nm were milled into the matrix until reaching the nanocrystals. Low Ga+ current (up to 10 pA) was used in order to control aspect ratio and separation of the trenches. They were next filled *in situ* with W to contact microscopic Al electrodes previously fabricated by standard microelectronic techniques. Deposition was performed by introducing WCO_3 gaz to react with the Ga+ beam and deposit W in a direct-writing mode. Again, low current allowed to deposit in very localized zones, limiting electrical contact between trenches, but a further cleaning just in between both W-deposited zones ensured isolation between them. A cross section of the final structure is presented in figure 1.

The obtained structure allows current flow in the SiO_2 parallel to the sample surface, what means along the nanocrystal layer. This is an unusual configuration able to provide information about charge transport in longitudinal direction along the layer. Its electrical characterization indicates a charge effect when low voltage is applied. As summarized in the I-V curves of figure 2, successive polarization sweeps from 0 to 60 V and to -60 V present an expected symmetrical behaviour but an unexpected increase of resisitivity after each measurement (from curve 1 to 2). A progressive and irreversible current decrease was observed with time, giving rise to a stabilization when a quite large potential is applied during a long time (curve 3 in figure 2 corresponds to 30 V for half an hour). This charge-retention effect has not been observed in similar nanocrystal layers in which current flows perpendicularly, i.e. across the layer.

This result suggests a charge accumulation effect promoted by the external bias. The reason of this effect is not yet clear. It could be related to the presence of C in the nanocrystals originating compounds of C, Si and O, or to a decrease of defect density in the dielectric matrix due to charge flowing, or even to the implantation of Ga+ ions during process. What is clear is that this device shows good-quality charge retention, which can be interesting for application in memories but not for optoelectronic devices, as this effect is found to be irreversible.

As a general conclusion, structures for characterization of charge-transport phenomena taking place along a nanocrystal layer imbedded in dielectric can be obtained by this procedure based on FIB. I-V are not yet well understood, but further work is expected to clarify its origin.

References:

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Figures:

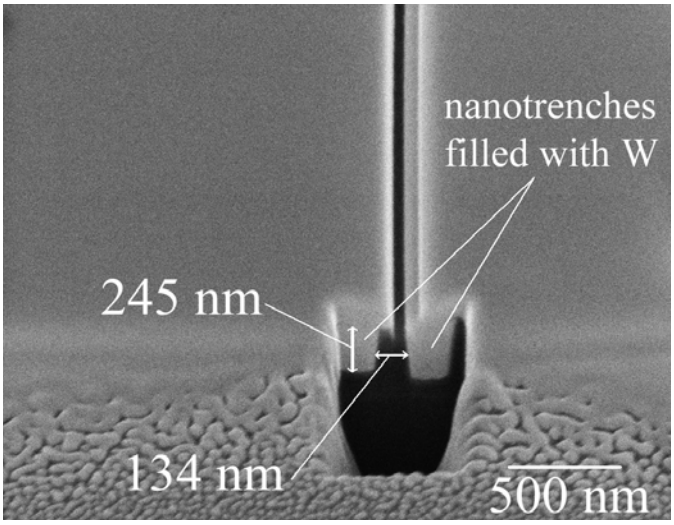

Figure 1. Cross section of the structure for longitudinal charge transport in a nanocrystal layer embedded in dielectric.

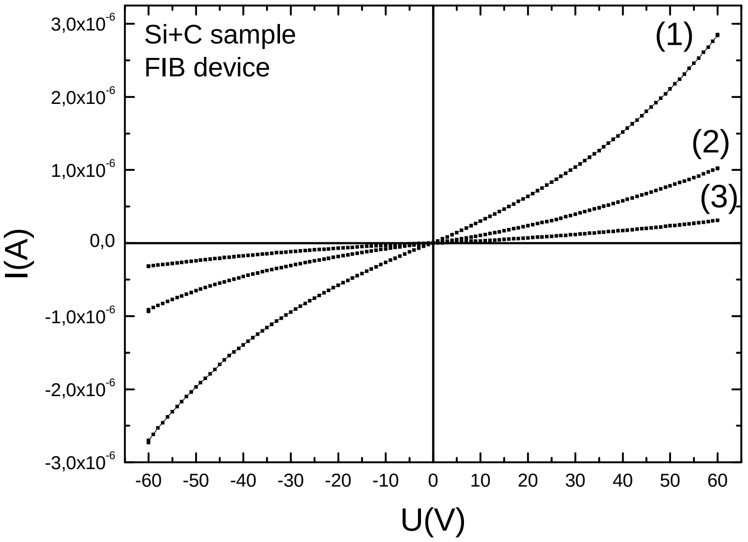

Figure 2. I-V characteristics of the structure obtained by the proposed FIB procedure: (1) first sweep to 60 V, (2) second sweep and (3) after half an hour at 30 V.