Characterization of metallic nanocyrstals in SiC formed after samarium and cobalt ion implantation

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There is considerable interest in the growth of magnetic nanocrystals inside a semi-conducting matrix aimed to the development of new devices for data information storage and high sensitive magnetic sensors [1]. The nanostructured materials may differ from their bulk materials in terms of magnetic anisotropy, magneto-resistance, Curie-temperatures and susceptibility [2, 3], therefore careful characterization on the nanometer scale is required. Here were study nanocrystals formed after co-implantation of the rare earth element Samarium (Sm) and Cobalt (Co) into 4H-SiC, that may lead to SmCo-nanocrystals with high magnetic crystal anisotropy and hard magnetic properties [3] inside a semiconducting matrix.

High doses of Sm (2×10^{15} cm^{-2}, 400 keV) and Co (8×10^{15} cm^{-2} 180 keV) have been co-implanted into SiC at high temperature (700°C) followed by rapid thermal annealing for 120 seconds at 1600°C. These conditions lead to the formation of nanocrystals as already shown in previous works of Ge- and Er-ion implantations into SiC [4, 5].

Cross-sectional TEM samples have been prepared using standard methods and the TEM investigation were done with a Jeol JEM 3010 microscope operating at 300kV and a FEI Tecnai F30 operating at 300kV.

Z-contrast TEM imaging [6] showed the appearance of nanoclusters in a depth of about 100 nm, with a size distribution ranging from 2 to 20nm (peak at 6nm) (Figure 1). HRTEM investigation showed the existence of nanocrystals with different phases. Metallic Co_2Si and $CoSi_2$ nanocrystals could be identified by HRTEM lattice analysis and HRTEM image simulation, these types of nanocrystals grow preferred inside matrix voids in a depth of about 50nm (Figure 2). HRTEM images of the nanocrystals deeper in the SiC-matrix show that they are of more complex structure. Accordingly to the HRTEM results, EELS (electron energy loss spectroscopy) maps confirmed that the nanocrystals in half-filled voids contain Co but no Sm, whereas EELS revealed that the nanocrystals with more complex structure in deeper regions of the samples always contain both, Sm and Co.

Electron paramagnetic resonance (EPR) measurements showed the presence of paramagnetic centres related to the implanted ions, however ferromagnetism could not be revealed above 80K so far.

1. S. Pokrant, C. Herwig, T. Hihara, and J. A. Becker, (1996) *Eur. Phys. Journ*. D 9, pp 509-512
2. J. Shi, S. Gider, K. Babcock, D. D. Awschalom (1996) *Metals and Semiconductors Science* 271, pp. 937-941
3. D. L. Leslie-Pelecky, R. D. Rieke (1996) *Chemistry of Materials* 8 177
4. Ch. Schubert , U. Kaiser, T.Gorelik, A. Hedler, J.Kräußlich, B. Wunderlich, G. Heß, K. Goetz, U. Glatzel, W. Wesch, (2002), *J. Appl. Phys*., 91, 1520
5. U. Kaiser, D. A. Muller, A. Chuvilin, G. Pasold and W. Witthuhn (2004) *Microscopy and Microanalysis* 10(2), 1-11
6. U. Kaiser and A. Chuvilin (2003) *Microscopy and Microanalysis* 9 41361

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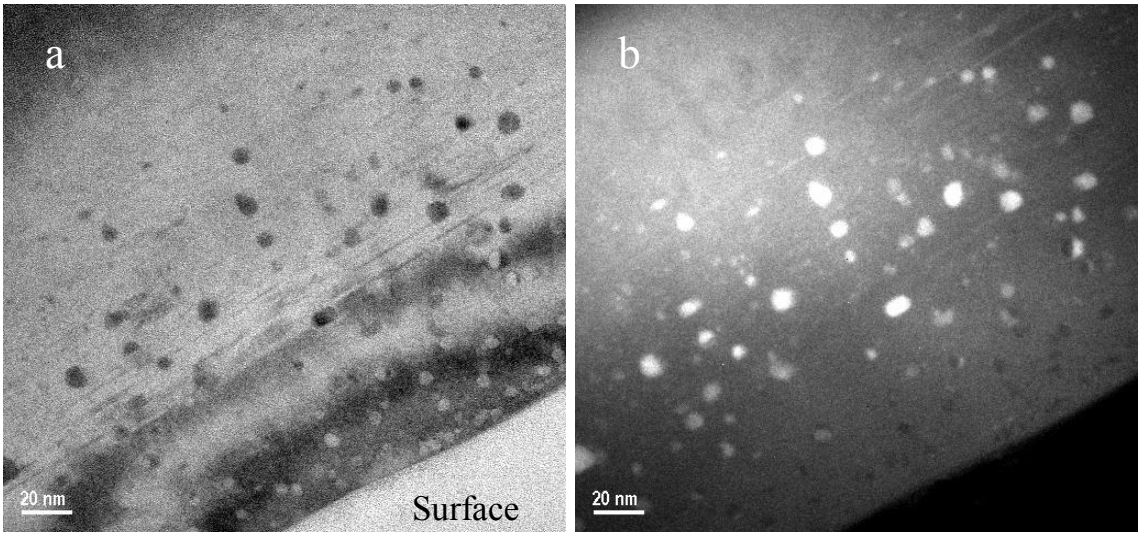

Figure 1.
(a) Bright-field image with voids near the surface and interstitial loops in deeper regions. In (b) the nanocrystals can be seen clearly in the Z-contrast image.

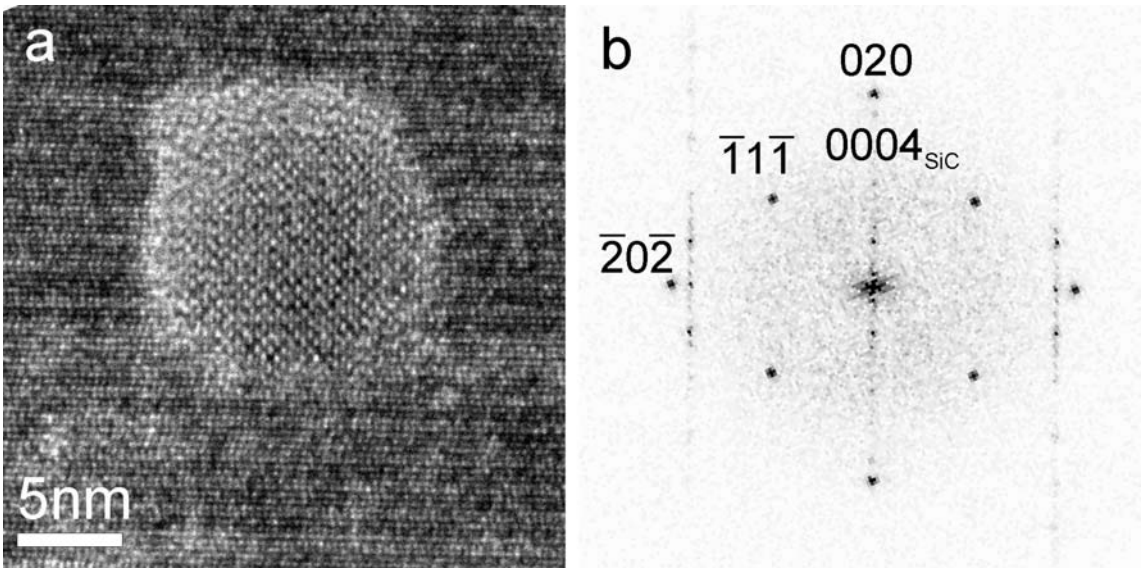

Figure 2.
(a) HRTEM image of a metallic Co_2Si nanocluster in [11-20] 4H-SiC, (b) the calculated diffractogram