doi:10.1017/S1431927621006401
Microsc. Microanal. 27 (Suppl 1), 2021

Structural Effect of Carbon on Mn_5Ge_3 Thin Films Grown on Ge(001) Substrates by Solid Phase Epitaxy

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Spintronic devices take advantage of the electron spin, considered as an additional degree of freedom. One of the challenges on the design of spintronic devices, as the spin-field effect transistor, is the achievement of spin injection into IV-group semiconductors via a Schottky barrier at room temperature (RT) [1]. Mn5Ge3 compound is the only FM phase with a Curie temperature (TC) of 296 K, has been found that TC increases with carbon doping [2]. Mn5Ge3 has a hexagonal crystal structure P63/mcm and lattice constants a = 7.184 Å and c = 5.053 Å, these characteristics allow the growth on Ge(111) substrates within a lattice mismatch of 3.7% [3]. However, Ge(111) is not compatible with the Si(001) technology, while Ge(001)/Mn5Ge3 heterostructures offer a good possibility for the design of spintronic devices. In this work, we present the growth of Ge(001)/Mn5Ge3 thin films using the solid phase epitaxy (SPE) method, samples doped with carbon atoms and without carbon were grown by magnetron-sputtering technique. Carbon doping has been found to affect the arrangement of the atomic structure. The SPE method consists of the deposition of Mn or co-deposition of Mn and Ge at room temperature (RT) followed by thermal annealing at Ts = 250 °C to induce Ge diffusion into the Mn layer to form the Mn5Ge3 layer.

Figure 1 shows the bi-dimensional grazing incidence x-ray diffraction (2D-GIXRD) pattern collected for a sample doped with carbon. The pattern shows discontinuous Debye rings that are associated with the texture, there are observed four peaks at 20.4, 28.3, 35.0, and 40.5° corresponding to the (102), (4-21), (5-21), and (5-12) reflections from the Mn5Ge3 compound. The reflection Ge(311) corresponds to the substrate. The indexation was based on the ICSD #156103 crystallographic datasheet. Figure 2(a) shows the HRTEM micrograph for the sample without carbon, the c-axis of the Mn5Ge3 unit cell is normal to the Ge(001) plane of the substrate. The interface is relatively abrupt at the atomic scale along with a few atomic layers. The sample doped with carbon, figure 2(b), shows two stages of epitaxial growth: first, an Mn deposition, where the c-axis is normal to the Ge(001) plane, but the atomic arrangement is different from that in figure 2(a). In the Mn and Ge co-deposition stage, the c-axis of the Mn5Ge3 unit cell forms an angle with the plane of the substrate surface.

The authors thank the financial support obtained from Ciencia-Básica SEP-CONACYT grant No. 157559 and Fondo Mixto Chihuahua FOMIX grant No. CHIH-2011-C03-1688. The authors thank the beamtime at the beamline 7.1 MCX at Elettra Synchrotron to perform the 2D-GIXRD measurements.

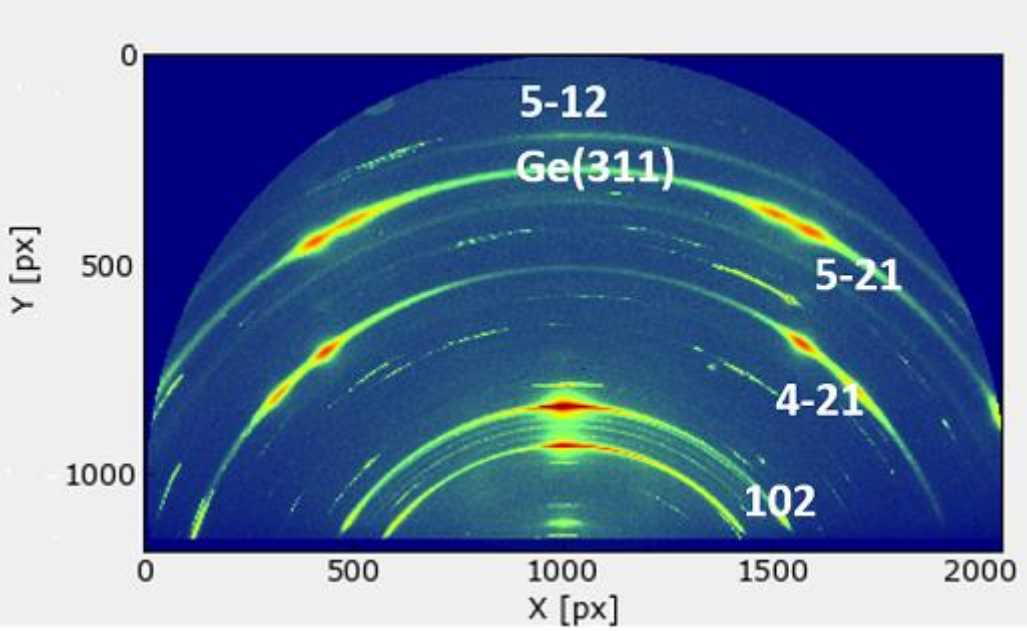

Figure 1. 2D-GIXRD for a simple with carbon, where the indexed Debye rings belong to the Mn5Ge3.

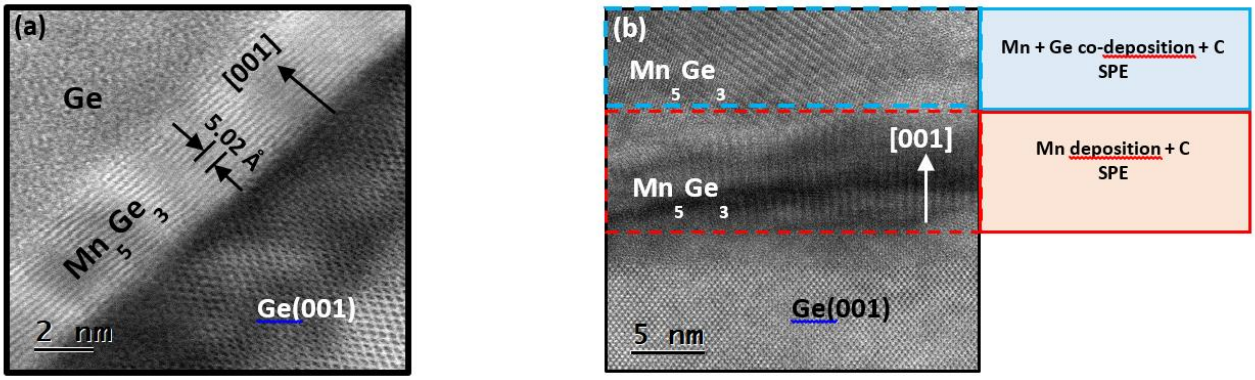

Figure 2. HR-TEM micrographs of Mn5Ge3 samples: (a) without carbon and (b) with carbon.

References

[1] A. Spiesser, H. Saito, R. Jansen, S. Yuasa, K. Ando, Large spin accumulation voltages in epitaxial Mn_5Ge_3 contacts on Ge without an oxide tunnel barrier, Phys. Rev. B 90 (2014) 205213.
[2] O. Abbes, A. Portavoce, V. Le Thanh, C. Girardeaux, L. Michez, Phase formation during Mn thin film reaction with Ge: Self-aligned germanide process for spintronics, Appl. Phys. Lett. 103 (2013) 172405.
[3] C. Zeng, S.C. Erwin, L.C. Feldman, A.P. Li, R. Jin, Y. Song, J.R. Thompson, H. H. Weitering, Epitaxial ferromagnetic Mn_5Ge_3 on Ge(111), Appl. Phys. Lett. 83 (2003) 5002.

https://doi.org/10.1017/S1431927621006401 Published online by Cambridge University Press