P10

EFFECT OF ANNEALING ON THE STRUCTURAL PROPERTIES OF Si:Mn

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Ferromagnetic ordering in silicon implanted with Mn^+ ions (Si:Mn) has been reported recently. This ordering is related to the structure of Mn-enriched near-surface layer of the implanted and subsequently processed material [1, 2].

The aim of this work was to investigate an influence of Mn-implantation dose, D, substrate temperature during implantation, T_s, and post-implantation temperature of annealing, T_a, on the structure of Si:Mn exhibiting magnetic properties [2, 3], prepared from Si with various interstitial oxygen concentrations, c_o.

Single crystalline Czochralski-silicon wafers were implanted with 160 keV Mn^+ ions to doses, $D = 2\times10^{15}$, 1×10^{16} or 1.2×10^{16} cm^{-2}, T_s = 340 or 610 K. Projected range (R_p) of Mn^+ was equal to 140 ± 50 nm. The c_o value, in Cz-Si was up to 9×10^{17} cm^{-3}. Si:Mn was processed after implantation for 1 h at T_a up to 1270 K under ambient pressure (10^5 Pa).

Structural characterization of the near-surface polycrystalline layers was performed using synchrotron radiation at the W1.1 beamline at DESY-HASYLAB (Hamburg). The monochromatic X-ray beam of wavelength λ = 1.54056 Å was used. The phase analysis of the near-surface layers was performed using coplanar 2θ scans in the grazing incidence geometry.

The structure of Si:Mn samples was also investigated by X-ray diffractometry in the double and triple axis configurations using high-resolution Phillips-MRD diffractometer. Reciprocal space maps (RSMs) for the 004 reflections were registered.

For Cz-Si:Mn prepared at T_s = 340 K, with D = 2×10^{15} cm^{-2} or 1×10^{16} cm^{-2}, the implanted layer remains to be amorphous both after implantation and after annealing at T_a = 610 K (Fig. 1a). The reflections originating from polycrystalline Si were detected in the case of D = 1×10^{16} cm^{-2} and T_s = 340 K after the treatment at T_a = 1270 K. It shows on re-crystallization of nano-crystalline layer (Fig. 1b). Simultaneously the diffraction peaks of small intensity, corresponding to the Mn_4Si_7 phase, were detected.

The defect structure of Si:Mn depends first of all on T_s during implantation, on oxygen concentration, c_o, on Mn^+ dose, D, as well as on the annealing conditions.

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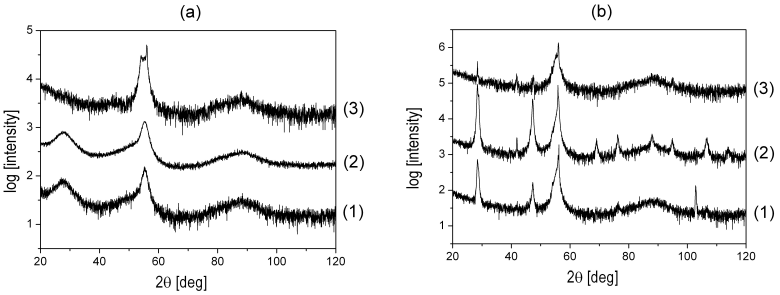

Figure 1. Coplanar 2θ scans in grazing incidence geometry for Cz-Si:Mn implanted with different conditions and annealed at T_a = 610 K (a) and T_a = 1270 K (b) for 1 h under ambient pressure: T_s = 340 K, $D = 2\times10^{15}$ cm^{-2} (1); T_s = 340 K, $D = 1\times10^{16}$ cm^{-2} (2); T_s = 610 K, $D = 1\times10^{16}$ cm^{-2} (3).