Ferromagnetic transition induced by laser and electron beam re-crystallization of (Ge,Mn)Te layers

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(Ge,Mn)Te is a IV-VI diluted magnetic (semimagnetic) semiconductor exhibiting ferromagnetic transition induced by a very high conducting hole concentration brought about by native defects (cation vacancies). The Curie temperature in crystalline (Ge,Mn)Te layers can be increased up to $T_C \approx 200$ K by independently optimizing the Mn content and the carrier concentration [1-4]. Amorphous (Ge,Mn)Te layers exhibit very high resistivity and show paramagnetic properties [5]. In GeTe and (Ge,Mn)Te layers a rapid (10 nanosecond time scale) switching between amorphous and crystalline phases can be induced locally by laser beam, electron beam or electric current flow. We examine magnetic properties of amorphous, polycrystalline (re-crystallized), and monocrystalline (Ge,Mn)Te layers with thickness of about one micron and Mn content up to 20 at. % grown on insulating BaF_2 (111) substrates by molecular beam epitaxy technique [6]. The local re-crystallization of amorphous layers was successfully achieved under the influence of light (YAG:Nd pulsed laser) and electron beam of a scanning electron microscope. Various polycrystalline, ferromagnetic (Ge,Mn)Te microstructures embedded in an amorphous (Ge,Mn)Te matrix were prepared. Magnetic properties of (Ge,Mn)Te layers and microstructures were studied by superconducting magnetometry and ferromagnetic resonance (FMR) methods. The analysis of the temperature and magnetic field dependence of magnetization confirmed paramagnetic properties of amorphous layers and revealed a sharp ferromagnetic transition in polycrystalline (Ge,Mn)Te microstructures re-crystallized either by laser or by electron beam action. In re-crystallized (Ge,Mn)Te samples with Mn content of 10 at. %. the ferromagnetic Curie temperature is $T_C \approx 70$ K. The angular dependence of the X-band FMR resonant field at low temperatures reveals the changes of the order of $4\pi M = 1.5$ kOe with the maximum resonant field observed for the external field normal to the layer. Model calculations of the FMR resonant field carried out taking into account demagnetization and crystalline contributions to magnetic free energy showed good agreement with experimental results indicating the formation of ferromagnetic (Ge,Mn)Te submicron structures in the form of thin discs (pulsed laser re-crystallization) or stripes (electron beam re-crystallization).

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