Converting Ferromagnet into Antiferromagnet - Annealing Induced Transformation from Ferromagnetic MnAs to Antiferromagnetic MnTe

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MnAs is a well known intermetallic compound with room-temperature ferromagnetic (FM) properties (Curie temperature T_C of 313 K). Below T_C MnAs occurs in the hexagonal NiAs-type structure. At T_C it undergoes combined magnetic and structural phase transition from hexagonal ferromagnetic (α-MnAs) phase to the nonferromagnetic (β-MnAs) orthorhombic one [1] (it is still debated if this second phase is paramagnetic or antiferromagnetic [2]). The β-MnAs phase exists up to about 400 K and at higher temperatures it changes again to the hexagonal (γ-MnAs) phase with paramagnetic properties [1,2]. MnAs can be grown as epitaxial layers on GaAs substrates with different orientations. Growth on GaAs(111)B results in the *c* axis of hexagonal MnAs unit cell oriented perpendicularly to the substrate surface, whereas in MnAs layers grown on GaAs(100) or GaAs(110) the *c* axis is in-plane.

MnTe shares the same crystallographic structure with α-MnAs, but differs in magnetic properties. Until recently MnTe was considered as an antiferromagnet (AFM), with Néel temperature T_N equal to 307 K, but currently it has been identified as an altermagnetic compound with a zero net magnetic moment but spin-split band structure below T_N, akin to ferromagnets [3].

Hexagonal MnAs and MnTe differ slightly in the lattice parameters: *a* and *c* for α-MnAs are equal to 3.72 Å and 5.70 Å, respectively, whereas the corresponding lattice parameters for MnTe amount to 4.20 Å and 6.72 Å. Due to substantial differences in the lattice parameters of MnAs and MnTe with GaAs (with bulk lattice parameter of 5.653 Å, and (111) surface lattice constant of 3.99 Å), the epitaxial growth of both materials directly on GaAs substrates results in the lattice relaxation of epilayers in the early stages of epitaxy.

In our recent experiments we have observed that annealing of thin MnAs layers at moderate temperatures (of about 400 °C) in the ultra-high vacuum (UHV) conditions of a molecular beam epitaxy (MBE) growth chamber in the presence of a Te flux impinging on the MnAs surface transforms thin MnAs films into MnTe. This transformation can be observed *in-situ* with reflection high energy electron diffraction (RHEED) directly upon annealing in the MBE system, and has been confirmed by X-ray diffraction, magnetometry measurements and transmission electron microscopy investigations. The surface of MnAs thin film can effectively be protected by deposition of amorphous As capping layer directly after the MBE growth, enabling transfer to another MBE system without UHV connection. Hence the observed phenomenon can be applied to form lateral FM-AFM junctions or lateral patterns, e.g., by use of surface masks.

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