Magnetic Orientation of MnAs/GaAs (001) by Resonant Soft X-Ray Scattering and Magnetic Force Microscopy

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Introduction

Manganese arsenide (MnAs) films grown on GaAs(001) are among the most promising materials for integration of magnetic films with III-V semiconductors for spin injection, forming a defined interface between the two materials. However, the films exhibit a complicated magnetic and topographic structure, where ferromagnetic and paramagnetic phases coexist in a certain range near room temperature (278 K < T < 328 K). In this work, we have used a combination of magnetic force microscopy and resonant (magnetic) soft X-ray scattering to better understand the magnetism of a 130nm thick MnAs film.

Methods and Materials

The 130nm thick MnAs film was grown on GaAs(001) by molecular beam epitaxy [1] and studied by temperature variable magnetic force microscopy and resonant X-ray scattering.

Results

We observe that a periodic configuration of the two phases is formed and that the period is constant throughout the coexistence range [2]. The temperature dependent MFM measurements show a decrease of the ferromagnetic phase as temperature rises and, at a certain temperature, the magnetic moments aligned in the film plane (*x*-direction) flip to the *z*-direction. Hysteresis loops measured at a correlation peak by soft X-ray resonant scattering at the Mn-L3 edge have a square shape for lower temperatures, which change to s-shaped for temperatures above 24^0C. This change in the MFM profile and in the hysteresis loops shapes is related to the decreasing width of the ferromagnetic terrace as the temperature is increased and determined to be common to all terraces.

Discussion

Manganese arsenide has a strong crystalline anisotropy hard axis along the c-direction (y axis) which is along the stripes length. This forbids the magnetic moments to align in that direction despite the large aspect ratio between the y-axis and both the terrace width (x-axis) and thickness (z-axis). However, the difference in crystalline anisotropy constants for the in-plane x-direction and the out-of-plane z-direction is less then 10% [3], and the magnetic moment orientation will be defined by the shape anisotropy energy. When the terraces are wide enough, the prefered magnetic moment orientation will be in plane. As temperature rises and the terraces become narrower, shape anisotropy energy forces a reorientation of domains, now oriented perpendicular to the film. Energy minimization calculations were performed and compared to the MFM images suggesting that the best magnetic configuration above 24^0C is a three domain arrangement oriented in the z-direction. This hipothesis was confirmed by soft X-ray resonant scattering by measuring the scattered intensity dependence as function of a magnetic field applied in the x-direction. This reconfiguration of magnetic domains in the stripes would result in the change of the hysteresis loops shape as a function of temperature. Furthermore, the hysteresis loops were measured at the terraces structural correlation peak, showing that the reconfiguration is common to all terraces in the sample. The terrace width at the magnetic reconfiguration temperature was determined from rocking scans [2] and used as an input for the hysteresis loops fits. The hysteresis curves were fitted according to the Stoner-Wohlfarth model-Wohlfart model [4] considering the shape anisotropy of an infinit slab [5] and the reconfiguration was determined to occur when the terrace width equals 2.9 times its thickness. This result is in good agreement with the energy minimization calculations done for this kind of system.

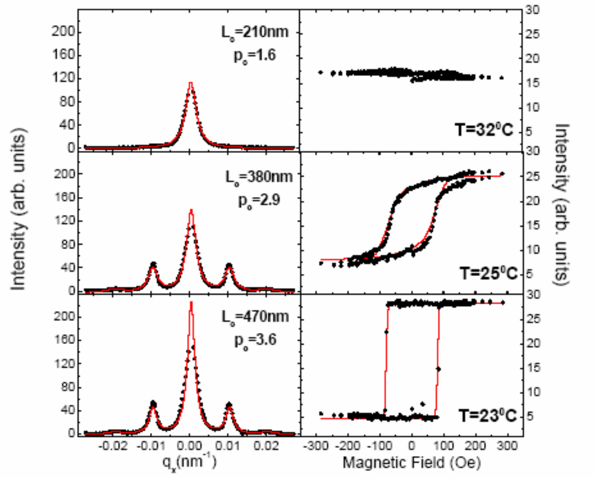

Fig. 1.:Rocking scan (left) and the corresponding hysteresis loop (right), measured at the same temperature. The terrace width L was used as an input for the hysteresis loops fits.

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