In-plane uniaxial anisotropy rotations in (Ga,Mn)As thin films

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Carrier-mediated ferromagnetism in the magnetic semiconductor (Ga,Mn)As has attracted considerable interest due to its potential application in spintronics, where the electron spin is used to carry information. It has been known since early works that (Ga,Mn)As films show rather strong magnetic anisotropy, which is largely controlled by epitaxial strain. This is well understood within the framework of the *p-d* Zener model of the hole-mediated ferromagnetism [1]. More recent works have shown, that these systems also exhibit a strong in-plane uniaxial magnetic anisotropy, which indicates the existence of a symmetry breaking mechanism, whose microscopic origin has not yet been identified. Since the magnetic anisotropy will have a marked influence on spin injection and magnetotunnelling devices, it is important to develop a greater understanding of this property, and the methods for its control.

We show that the easy magnetization axis of (Ga,Mn)As films is associated with particular crystallographic axes and that it does not originate from surface anisotropy. Using SQUID magnetometry we find that the orientation of the in-plane uniaxial anisotropy is generally dependent on the hole concentration, and for a specific combination of hole density and Mn composition is temperature dependent too. On the other hand our effort emphasizes the importance of careful tracking of both [-110] and [110] directions in any application oriented studies, particularly at high temperatures, where we expect the spintronics devices to function.

We demonstrate that the magnitude of uniaxial anisotropy as well its dependence on the hole-concentration and temperature can be explained in terms of the *p-d* Zener model of the ferromagnetism assuming a small trigonal-like distortion. While such a distortion has not yet been seen in other experiments, it may be associated with magnetostriction, or may result from a non-isotropic Mn distribution, caused for instance by the presence of surface dimers oriented along [-110] direction during the epitaxy. However, the dominating microscopic mechanism that breaks D_{2d} symmetry of (Ga,Mn)As epitaxial films is to be elucidated.

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