Easy axis engineering in ferromagnetic semiconductors

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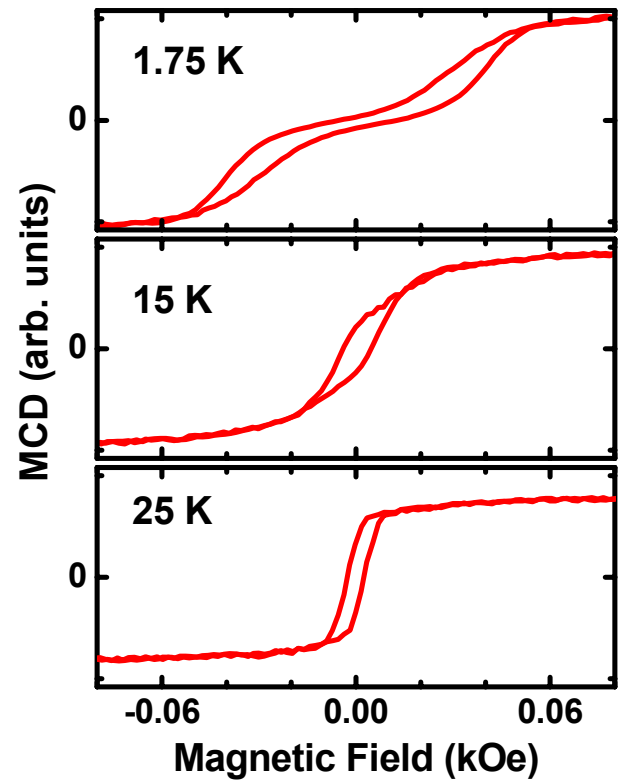
Magnetic anisotropy in ferromagnetic semiconductors (such as $Ga_{1-x}Mn_xAs$) is expected to play a key role in future spin-based devices based on these materials. Understanding and controlling magnetic anisotropy is therefore essential. Magneto-optic phenomena (such as magnetic circular dichroism (MCD)) provide a particularly convenient tool with which to monitor the orientation of the easy axis of magnetization. We have strategically designed $Ga_{1-x}Mn_xAs$-ZnSe multilayers where strain-induced anisotropy can be controlled by the lattice mismatch, doping, and/or temperature, thus providing a handle on the orientation of the easy axis of magnetization.



The evolution of magnetic hysteresis as a function of temperature in GaMnAs-ZnSe. By raising the temperature we can rotate the easy axis from the in-plane orientation at low fields (top panel) to the normal-to-the-layer-plane (bottom), as evidenced by the shape of the hysteresis loop.

Ferromagnetic semiconductors are new materials expected to play an important role in semiconductor-based devices aimed at storage capabilities and information processing. $Ga_{1-x}Mn_xAs$ is an especially attractive member of this class of materials, because it can be easily integrated into already existing electronics, while bringing a new degree of freedom – the electron spin – into the device operation. The functioning of spin-based processes in devices hinges in turn on the property referred to as magnetic anisotropy, which determines the direction of magnetization (the so-called "easy axis"). Understanding and controlling the orientation of the easy axis of magnetization holds promise of achieving devices that can be turned on and off by changing, for example, the temperature, charge concentration, or illumination. As a first step toward this goal, in our study we have demonstrated that we can rotate the easy axis in $Ga_{1-x}Mn_xAs$ by 90 degrees simply by slightly changing it's temperature.

Magnetization easy axis engineering in ferromagnetic semiconductors

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Education:
One undergraduate REU student (Elizabeth Martin); three graduate students (Lubov Titova, W.L. Lim and R. Chakarvorty); and two post-docs (Miroslaw Kutrowski and Kiju Yee) contributed to this work. Elizabeth Martin was an REU student, and just graduated from the University of Notre Dame. Lubov Titova received her Ph.D. in June 2004. W.L. Lim is a forth year graduate student writing his thesis, and R. Chakarvoty is a beginning graduate student.

Societal Impact:
Our group has been continually active as a resource of materials for other research groups. We are currently interacting with at least 25 other institutions by providing them with specimens. Thus additional understanding of defect formation during molecular beam epitaxy carried out in our laboratory is automatically of benefit to our collaborators who depend on the quality of materials which we provide.