Electronic Materials and Processing
Room 310 - Session EM+MI-TuA

Spin Injection

Moderator: C.J. Palmstrom, University of Minnesota

2:40pm **EM+MI-TuA3 Characterization of Mn-based Contacts on GaAs**, ***J.L. Hilton***[1], *B.D. Schultz, S. McKernan, C. Adelmann, X. Lou, P.A. Crowell, C.J. Palmstrom,* University of Minnesota

Mn-based ferromagnetic materials, such as binary metals, Heusler alloys, diluted magnetic semiconductors, and digital alloys, are potentially useful as epitaxial spin injection contacts in GaAs-based spintronic devices. Defects and solid-state reactions at a ferromagnet/semiconductor interface have a significant influence on the spin injection efficiency of spintronic devices. Consequently, a detailed understanding of the interfacial interactions of Mn and Mn-based materials with GaAs is needed. In order to understand the thermodynamic phase behavior of the Mn-Ga-As ternary system, thin film Mn/GaAs structures were grown using molecular beam epitaxy. RHEED, LEED, STM, XPS, RBS, XRD, and cross-sectional TEM were used to characterize the Mn/GaAs interfacial reactions. These reactions initially resulted in the formation of a two-phase region of tetragonal Mn@sub 2@As and tetragonal @delta@-MnGa, with an average composition of Mn@sub 0.6@Ga@sub 0.2@As@sub 0.2@. The two phases formed an epitaxial lamellar layer on the GaAs substrate with Mn@sub 2@As(001) and @delta@-MnGa(001) // GaAs(001). Higher temperature anneals resulted in the dissociation of the Mn@sub 0.6@Ga@sub 0.2@As@sub 0.2@ region into a @delta@-MnGa layer near the sample surface and a Mn@sub 2@As layer near the GaAs substrate. Anneals of @delta@-MnGa films on GaAs suggest that @delta@-MnGa is thermodynamically stable in contact with GaAs over a narrow compositional range up to at least 400°C. For more Ga-rich Mn@sub 1-x@Ga@sub x@ films, no evidence of interfacial reactions with GaAs was observed, but there were significant structural changes within the film. Stable @delta@-MnGa films are especially desirable for use in spintronic devices due to their inherent perpendicular magnetization. Spin injection measurements utilizing @delta@-MnGa contacts on GaAs-based spin-LEDs will be presented. Supported by ARO, ONR, DARPA, NSF, and AFOSR.

3:00pm **EM+MI-TuA4 Interface Structure and Spin Injection Efficiency in a Ferromagnetic/Semiconductor Spin-LED**, ***A.T. Hanbicki,*** *G. Kioseoglou, R. Goswami, T.J. Zega, O.M.J. van 't Erve, C.H. Li, R.M. Stroud, G. Spanos, B.T. Jonker,* Naval Research Laboratory

Considerable effort has been made to incorporate ferromagnetic metals into semiconductor spintronic devices. The nature of the interface between a magnetic contact and a semiconductor is expected to influence the spin-injection efficiency. Indeed, we have discovered interface effects play a role in the spin-injection efficiency for an all-semiconductor system.@footnote 1@ Recently we demonstrated robust spin injection from Fe into an AlGaAs/GaAs spin-LED. With this system, we have successfully injected spin polarized electrons with an electron spin polarization of 32% in the GaAs quantum well (QW).@footnote 2@ To correlate the interface structure with the observed QW polarization, we have characterized our Fe/AlGaAs contacts using high-resolution transmission electron microscopy (HRTEM), electron energy-loss spectroscopy, and high-angle annular-dark-field (HAADF) imaging. HRTEM together with HAADF imaging provides compositional information that can also be used to determine the interfacial character. We have studied several samples with different detector heterostructures. Optimized annealing can improve the measured spin polarization, therefore for each sample several pieces were annealed to generate a systematic dataset. Enhancement in polarization is seen with anneals as low as 175°C, and the maximum increase in polarization occurs for anneals above 200°C. Measured spin polarizations increase by 8 to 10%, independent of the starting value. Preliminary results reveal a correlation between the GaAs QW spin polarization and the thickness of the Fe/AlGaAs interface. As the interface thickness increases from 0.5 to 0.9 nm, the measured polarization decreases from 27% to 18%. There are also indications that the Fe film is affected by annealing and implications toward spin injection will be discussed. This work was supported by the DARPA SpinS program and ONR. @FootnoteText@ @footnote 1@R.M. Stroud, et al, PRL 89 (2002)@footnote 2@A.T. Hanbicki, et al, APL 82 (2003).

3:20pm **EM+MI-TuA5 Gate-Controlled Electron Spin Transport for Nonmagnetic Spintronics**, ***K.C. Hall,*** Dalhousie University, Canada; *K. Gundogdu, J.L. Hicks, A.N. Kocbay, M.E. Flatte, T.F. Boggess,* University of Iowa; *K. Holabird, A. Hunter, D.H. Chow, J.J. Zinck,* HRL Laboratories, LLC **INVITED**

The prospect of novel high-performance spin-based semiconductor technologies has lead to new research in spintronics, in which the fields of electronics, photonics, and magnetics merge with the promise of applications in ultra-low-power logic architectures, non-volatile reprogrammable gate arrays, and optoelectronic technologies. Innovation in these areas requires the development of efficient methods for spin injection and manipulation in semiconductor materials. Spintronic device architectures that do not require external magnetic fields or magnetic contacts are especially attractive as they would provide seamless integration with the materials and processing techniques of existing semiconductor devices, while avoiding undesirable stray magnetic fields that may hinder device performance. We show that highly spin-polarized electron spin injection may be achieved in side-gated resonant interband tunnel diodes (RITDs) based on nonmagnetic (110) InAs/GaSb/AlSb heterostructures.@footnote 1@ Due to the strong spin-orbit effects in this system, electron spin splittings due to bulk inversion asymmetry approach 40 meV, permitting operation of the spin-RITD at practical temperatures. A nonmagnetic spin field effect transistor incorporating RITD contacts and gate-controlled spin relaxation will be described, along with our recent experiments demonstrating low-threshold spin lifetime switching in this device.@footnote 2@@FootnoteText@This research is supported by DARPA MDA972-01-C-0002, DARPA/ARO DAAD19-01-1-0490, NSF ECS 03-22021, and NSERC. @footnote 1@K.C. Hall et al., Appl. Phys. Lett. 83, 2937 (2003); @footnote 2@K.C. Hall et al., to be published in Appl. Phys. Lett. (2005).

[1] **Falicov Student Award Finalist**

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