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AlAs 2D Electrons at High Magnetic Field: The Role of Spin and Valley Degree of Freedom[1]

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Two-dimensional (2D) electrons in AlAs quantum wells occupy multiple conduction-band minima (or valleys) at the X point of the Brillouin zone. These valleys have large effective mass (m*) and g-factor compared to the standard GaAs electrons, and are also highly anisotropic. The system is rather unique in that, with proper choice of well width and by applying in situ symmetry-breaking strain in the plane, one can control the occupation of different valleys, thus rendering a system with tuneable m*, g-factor, Fermi contour anisotropy, and with single, double, or triple valley degeneracy. By adding a magnetic field, we obtain a system which allows us to explore very rich physics ensuing from the valley and spin degrees of freedom in a strongly interacting system. In this presentation, I will highlight some of our latest results on 2D electrons confined to wide AlAs quantum wells where the electrons reside in two in-plane valleys whose occupation can be controlled via the application of strain. I will present the results of our m* measurements, via analyzing the temperature dependence of the Shubnikov-de Haas oscillations. The measured m* shows a strong dependence on the occupation of valley and spin subbands, reflecting the electron- electron interaction in this system. Most remarkably, m* is suppressed with respect the band value when the 2D electrons are fully spin- and valley-polarized. I will also discuss the relation of m* suppression to the 2D metal-insulator transition problem. Our studies also include measurements of the valley susceptibility (dependence of valley population on applied strain) and the valley polarization of the fractional quantum Hall effect composite fermions. While part of our observations can be explained well by a simple Landau level fan diagram for composite fermions with a valley degree of freedom, there are some surprises.

[1]Work done in collaboration with N. Bishop, E. De Poortere, T. Gokmen, O. Gunawan, M. Padmanabhan, Y. Shkolnikov, E. Tutuc, K. Vakili. References: Phys. Rev. Lett. 98, 266404 (2007); Phys. Rev. Lett. 101, 026402 (2008); Phys. Rev. Lett. 101, 146405 (2008).