Effects of Valley Polarization on Spin Polarization in a Silicon 2DEG

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Understanding the physics surrounding the valley degree of freedom and harnessing it is becoming an area of growing research interest, on one hand due to possible valleytronics applications and issues related to silicon based quantum information processing, and on the other hand due to topical material systems such as graphene and MoS_2 also possessing this degree of freedom. In traditional semiconductor based 2-dimensional electron systems (2DES), extensive studies on AlAs quantum wells have revealed rich physics in which valley and spin both play similar but important roles in determining the properties of the 2DES. In particular, freezing one degree of freedom has strong effects on the 2DES's properties in relation to the other.

Here, we address the effect valley polarization has on spin polarization in silicon, by measuring in-plane magneto-transport with and without valley polarization. Valley degeneracy and polarization are achieved by using a (001) silicon-on-insulator based structure in which the valley splitting can be continuously enhanced in situ to 10's of meV [1].

At valley degeneracy, as known from numerous previous studies in silicon 2DESs, the in-plane magnetic field required to spin polarize the electrons (B_P) is much lower than expected from single particle considerations demonstrating the importance of electron-electron interactions. With valley polarization at high electron density, we find B_P to increase, but not nearly as much as the doubling expected from the single particle picture, also qualitatively consistent with previous work in AlAs [2].

As the density is reduced, the increase in B_P with valley polarization is suppressed further and remarkably, at the lowest density, we find B_P to decrease with valley polarization which is qualitatively opposite to single-particle expectations. i.e. at low enough density, it can be easier to spin polarize a valley polarized system than polarizing a valley degenerate one. Our data are interpreted in terms of electron-electron interactions and disorder and are directly compared to parameter free quantum Monte Carlo simulations [3] which show good agreement.

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