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Intershell Exchange and Sequential Electrically Injected Spin Populations of InAs Quantum-Dot Shell States

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Quantum dots (QDs) are attractive for a variety of spintronic applications. Their electronic structure exhibits the s, p, d, f shells characteristic of atoms. We report electrical injection of spin-polarized electrons from Fe contacts into the individual shells of highly uniform self-assembled InAs QDs, and we determine the s-p and p-d inter-shell exchange energies. The electron population and polarization of each shell are controlled by the spin bias current. The circular polarization of the electroluminescence (EL) spectra exhibits maxima red-shifted with respect to the EL intensity peaks, in contrast with simple models of shell occupation. Using exact diagonalization techniques, calculations of spectra from multi-exciton complexes show that this is due to inter-shell exchange [1]. We determine exchange energies for the $s-p$shells $\sim$ 6-7 meV, and for the $p-d$ shells $\sim$ 13-14 meV. These results are significant to our understanding of QD behavior, and provide a mechanism for electrical control of spins in QDs.

[1] M. Korkusinski and P. Hawrylak, Phys. Rev. Lett. 101, 027205.