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Spontaneous time reversal symmetry breaking in atomically confined two-dimensional impurity bands in silicon and germanium[1]

ARINDAM GHOSH, Indian Inst of Science

Three-dimensional bulk-doped semiconductors, in particular phosphorus (P)-doped silicon (Si) and germanium (Ge), are among the best studied systems for many fundamental concepts in solid state physics, ranging from the Anderson metal-insulator transition to the many-body Coulomb interaction effects on quantum transport. Recent advances in material engineering have led to vertically confined doping of phosphorus (P) atoms inside bulk crystalline silicon and germanium, where the electron transport occurs through one or very few atomic layers, constituting a new and unique platform to investigate many of these phenomena at reduced dimensions. In this talk I shall present results of extensive quantum transport experiments in delta-doped silicon and germanium epilayers, over a wide range of doping density that allow independent tuning of the on-site Coulomb interaction and hopping energy scales. We find that low-frequency flicker noise, or the $1/f$ noise, in the electrical conductance of these systems is exceptionally low, and in fact among the lowest when compared with other low-dimensional materials. This is attributed to the physical separation of the conduction electrons, embedded inside the crystalline semiconductor matrix, from the charged fluctuators at the surface. Most importantly, we find a remarkable suppression of weak localization effects, including the quantum correction to conductivity and universal conductance fluctuations, with decreasing doping density or, equivalently, increasing effective on-site Coulomb interaction. In-plane magneto-transport measurements indicate the presence of intrinsic local spin fluctuations at low doping although no signatures of long range magnetic order could be identified. We argue that these results indicate a spontaneous breakdown of time reversal symmetry, which is one of the most fundamental and robust symmetries of nonmagnetic quantum systems. While the microscopic origin of this spontaneous time reversal symmetry breaking remains unknown, we believe this indicates a new many-body electronic phase in two-dimensionally doped silicon and germanium with a half-filled impurity band.

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