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| Title: | Spin-polarized transport through 2-D quantum materials. |
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| Abstract: | Due to the growing demand for the miniaturization of electronic devices, there is an ur- gent requirement to develop novel materials that can facilitate the design of energy-efficient nano-scale electronic circuits. Two-dimensional (2D) quantum materials, owing to their unique electronic properties, have emerged as promising candidates for future electronic de- vices. Understanding the spin-polarized transport phenomena in these materials is crucial for the development of spintronics, offering potential advantages in spin-based information processing and storage. This thesis investigates the spin-polarized transport characteristics of various 2-D quantum materials through theoretical modeling and low-temperature-based scanning probe techniques. The thesis is divided into two parts: The first part contains our work on a family of vdW 2-D ferromagnets particularly those with the general formula Fe n GeTe 2 (where n=3,4) which possess desirable characteristics such as large electrical conductivity, a high ferro- magnetic Curie temperature, and strong saturation magnetization for application in next-generation spintronic devices. We have investigated the interplay of various quantum phe- nomena in the aforementioned vdW ferromagnets using low-temperature-based scanning probe techniques. Furthermore, to enable efficient detection of Majorana modes in topolog- ical superconductors, crucial for fault-tolerant quantum computing, in the second part of the thesis we have proposed a tunneling setup with weakly coupled Majorana nanowires. The setup offers controlled detection by manipulating the presence of a zero-bias conductance peak (ZBCP) based on wire parity. The major results, procured in this work are highlighted below. Measurement of transport spin polarization of the vdW ferromagnets Fe 3 GeTe 2 and Fe 4 GeTe 2 : We performed spin-resolved point contact Andreev reflection spectroscopy of the mesoscopic junctions of these ferromagnets with conventional superconductors. The results revealed a very high degree of transport spin polarization exceeding 50% in both the ferromagnets which is more than the conventional elemental ferromagnets, making them possible candidates for power-saving spintronic devices. Signatures of Kondo hybridization in Fe 3 GeTe 2 and Fe 4 GeTe 2 : We investigated the point contact spectroscopic features of the mesoscopic junctions of these ferromagnets with conventional superconductors, in the normal state and over high bias. A temperature- dependent asymmetric double-peak structure in the conductance spectra, indicating the open- ing of a gap structure, along with characteristic features for a Fano resonance was found. Similar features were observed in the scanning tunneling spectroscopic (STS) measure- ments establishing a significant role of strong electron correlations leading to a coherent Kondo-lattice state in the ferromagnets. Stripes and bubbles in Fe 3 GeTe 2 and Fe 4 GeTe 2 : To study the effect of an external ximagnetic field on the local magnetic properties of these systems, we imaged the ferromag- netic domains using low-temperature magnetic force microscopy(MFM). Interestingly, we observed a field-induced transition from a stripy magnetic phase to magnetic bubbles in both the ferromagnets. The MFM results were found to align well with a microscopic model of itinerant 2-D ferromagnets with Rashba spin-orbit coupling and magnetic anisotropy. Tunneling characteristics of weakly coupled Majorana wire: The experimental de- tection of Majorana modes in the topological superconductors has yet remained elusive. To address this issue, we have proposed a tunneling setup that consists of an array of weakly coupled Majorana nanowires, which are part of a quasi-two-dimensional topological super- conductor. This setup allows for a more controlled and effective detection of these topologi- cally non-trivial modes. In our proposed setup, the presence or absence of the ZBCP can be switched on and off based on the parity of the transport active wires, leading to an odd-even- like effect in the tunneling conductance. This provides a more comprehensive signature of the Majorana modes. Additionally, we have studied the effect of the magnetic field angle on the odd-even effect, where the tilt angle of the magnetic field can serve as another tuning parameter to confirm the Majorana origin of the ZBCP. |
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