Semiconductor-ferromagnet-superconductor planar heterostructures for 1D topological superconductivity

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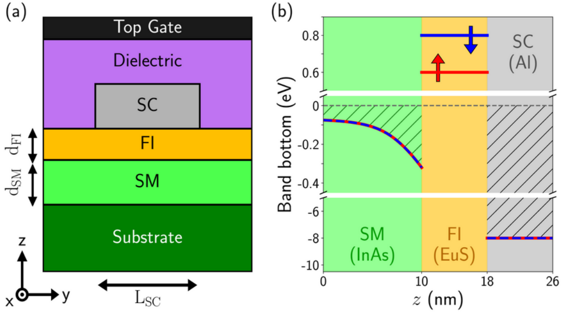
For a preprint of the article and author's affiliations, see **github.com/Samdaz/SM-FI-SC-paper**

1. Introduction and Model

We want to know whether a stuck semiconductor-ferromagnetic-superconductor device can support 1D topological states.

The SC is a stripe. It screens the top gate creating effectively a quasi-1D channel.

The ferromagnetic is an insulator. If it is thin, electrons could tunnel through it.



We include in the Hamiltonian the conduction band of the three materials and the electrostatic interactions

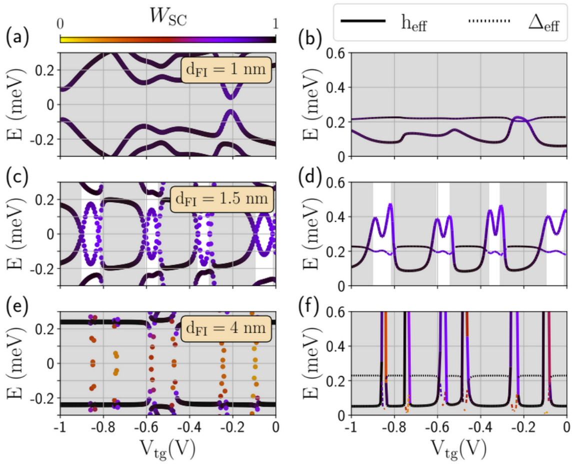
$$H=\left[\frac{\hbar^2\vec{k}^2}{2m_{\rm eff}(\vec{r})}-E_{\rm F}(\vec{r})+e\phi(\vec{r})+h_{\rm ex}(\vec{r})\sigma_x\tau_z+\frac{1}{2}\vec{\alpha}(\vec{r})\cdot\left(\vec{\sigma}\times\vec{k}\right)\right]\tau_z+\Delta(\vec{r})\sigma_y\tau_y$$

We solve the Schrödinger-Poisson equation taking into account a realistic device and using experimental parameters for the Hamiltonian.

3. Results

Spectrum at k_x=0 for three different FI thickness

Effective exchange energy and pairing potential for the lowest-energy state



(a,b) For too thin FI layers, the effective Zeeman is not strong enough to drive the device into a topological phase.

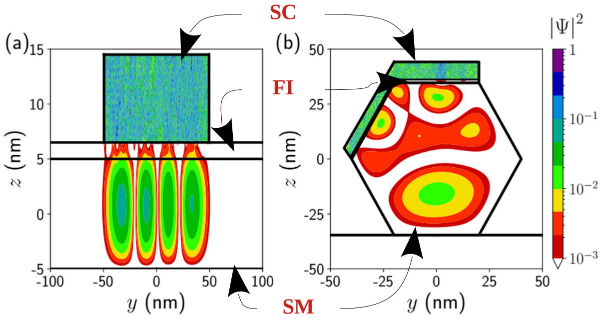
(e,f) For too thin, electrons cannot tunnel to the SC, and therefore acquire a superconducting pairing amplitude.

(c,d) **We find 1.5-3 nm to be the ideal thickness to have topological states.**

We find that the **planar device have a regular phase diagram** (i.e., all the subbands develop a topological phase with the same extension and minigap) **and a hard gap** (i.e., no states below the minigap).

These features are not present in the same geometry but with a wire.

This is **because the wavefunction spreads more across the wire section** than in the planar geometry. This leads to weaker proximity effects and less predictable topological phases for the wire.



Conclusion.– This planar platform support predictable and robust topological states. Since they are based on 2DEG, they present reduced disorder in comparison to a wire. And because there is no need of a magnetic field, different effective wires could have different orientations. Hence, this geometry is promising for QC.