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Theory of Topological Superconductivity in Ferromagnetic Metal Chains on Superconducting Substrates[1]

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Recent experiments have provided evidence that one-dimensional (1D) topological superconductivity based on transition metal atom chains formed on a superconducting substrate can be realized experimentally when the chain behaves like a ferromagnetic macrospin [1]. In this talk I will address the structural and bonding considerations which determine whether or not a particular atom chain will have magnetic and electronic properties favorable for topological superconductivity. By using a Slater-Koster tight-binding model to account for important features of transition metal electronic structure, I conclude that topological states are common for ferromagnetic chains on superconductors and that they are nearly universal when ferromagnetic transition metal chains form straight lines on superconducting substrates. The proximity induced superconducting gap on the chain is $\sim \Delta E_{so}/J$ where Δ is the s-wave pair-potential on the chain, E_{so} is the spin-orbit splitting energy induced in the normal chain state bands by hybridization with the superconducting substrate, and J is the exchange-splitting of the ferromagnetic chain d-bands. Because of the topological character of the 1D superconducting state, Majorana end modes appear within the gaps of finite length chains. I will specifically discuss the spatial decay length of the Majorana end modes which can be much shorter than the coherence length from the induced p-wave gap on the chain due to its strong coupling to the three-dimensional superconducting substrate, in agreement with experimental results [2]. Pb is a particularly favorable substrate material for ferromagnetic chain topological superconductivity because it provides both strong $s-$wave pairing and strong Rashba spin-orbit coupling, but there seems to be considerable scope to optimize the 1D topological superconductivity by varying the atomic composition and structure of the chain. [1] S. Nadj-Perge, I. K. Drozdov, J. Li, H. Chen, S. Jeon, J. Seo, A. H. MacDonald, B. A. Bernevig, and A. Yazdani, Science 346, 602 (2014). [2] J. Li, H. Chen, I. K. Drozdov, A. Yazdani, B. A. Bernevig, and A. H. MacDonald, arXiv:1410.3453

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