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Tuning the Quantum Stability and Superconductivity of Ultrathin Metal Alloys[1]

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Superconductivity is inevitably suppressed in reduced dimensionality. In this talk, I will show how quantum confinement of itinerant electrons in a soft metal, Pb, can be exploited to stabilize atomically-smooth crystalline superconductors with lateral dimensions of the order of a few millimeters and vertical dimensions of only a few atomic layers. The thin film growth experiments were done in ultrahigh vacuum and the superconductive properties of the films were probed ex-situ with (contactless) magnetic susceptibility measurements and dc transport measurements. These extremely thin superconductors show no indication of defect-or fluctuation-driven suppression of superconductivity and sustain enormous supercurrents of up to ten percent of the theoretical depairing current density. Their magnetic hardness implies a superconducting critical state with strong vortex pinning that is attributed to quantum trapping of vortices. Our study paints a conceptually appealing picture of a model nanoscale superconductor with calculable critical state properties and surprisingly strong phase coherence. These results are contrasted with in-situ measurements of the order parameter using local probes such as scanning tunneling spectroscopy. I will furthermore discuss how the superconductive properties of these films can be tailored by alloying or 'Fermi surface engineering'. This includes the possibility of kinetically stabilizing metallic alloys of thermodynamically immiscible elements through size quantization. Superconductivity data from these alloys films narrow down the possible mechanisms for the general Tc suppression in Pb-based alloy films and furthermore reveal that critical supercurrents are already established in two-monolayer thin films.

[1]In collaboration with M.M. Ozer, E.J. Moon, J.R. Thompson, and Z.Y. Zhang