Bringing Tunneling Spectroscopy to new Extremes: Revealing Superconducting Symmetries in Sulfur at Ultra High Pressures

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The application of high pressures enables precise tuning of a system´s free energy, leading to novel behaviors that are otherwise unattainable. Elemental sulfur is one such system: under 0.9 Mbar it undergoes an insulator-to-metal transition and becomes a superconductor upon cooling. However, the high-pressure conditions generated within small diamond anvil cells significantly restrict the range of techniques available to characterize many superconducting properties of these materials.

Researchers at the Max-Planck Institute for Chemistry, in collaboration with the National High Magnetic Facility at the Los Alamos National Laboratory, have pioneered tunneling spectroscopy measurements at high pressures up to 1.6 Mbar in diamond anvil cells. This significantly extends the pressure range from the previously reported 0.03 Mbar. For the first time, the researchers directly observed a superconducting gap tunneling spectra under extreme pressures and applied magnetic fields by measuring differential conductance (Fig. 1).

This is a critical advancement, as many superconductors, both conventional and unconventional, exhibit enhanced performance under applied pressure. Additionally, the highest known critical transition temperature of superconductivity belong to hydrogen-rich compounds – a family that only exists under similarly high-pressure conditions. These techniques will enable further characterization of their superconducting properties, paving the way for the design and understanding of future superconductors.

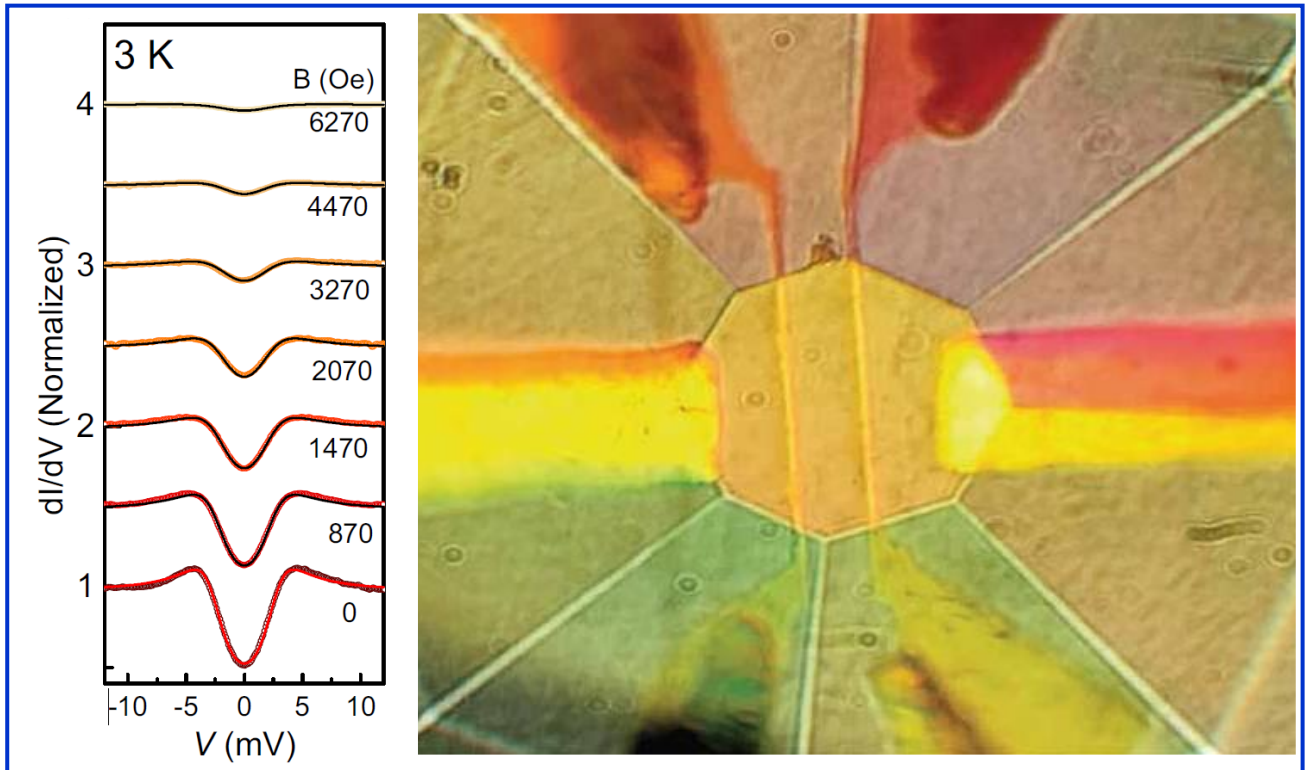

Figure 1. **a**, The change of differential conductance in response to applied voltage. The drop that forms near 0 mV is due to the opening of the superconducting gap. Vertical spectra are offset by increasing magnetic fields values shown on the right. **b**, An image of the tunneling circuit formed on the tip of the diamond anvil press.

Facilities and instrumentation used: NHFML-PFF DynaCool PPMS.

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