Highlights

RESEARCH AREA 1 - Superconductors and Innovative materials for Energy and Environment - 2023

Superconductivity induced by gate-driven hydrogen intercalation in the charge-density-wave compound 1T-TiSe2

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The search for a roadmap towards high-temperature superconductivity is one of the hot topics of modern material science. During the last decade, conventional BCS superconductivity at 203 K and 250 K was shown to occur in H_2S [1] and YH_{10} [2] at very high pressures (~200 GPa). These ground-breaking experiments proved that in BCS-conventional superconductors Tc is not upperbounded, provided the proper mixture of high density of states and high phonon frequencies is available. At the same time, such experiments proposed hydrogen as a highly effective way to tune the phononic spectra and, thus, for inducing superconductivity with a high critical temperature.
This work presents the effects of hydrogen intercalation in 1T-$TiSe_2$ via the ionic-liquid gating method. The H-intercalated compound, namely H_xTiSe_2, becomes a superconductor at about 3.6 K and, interestingly, and its intrinsic charge-density-wave state coexists with superconductivity. The H-induced superconducting phase is possibly gapless-like and multi-band in nature, in contrast with those induced in $TiSe_2$ via copper, lithium, and electrostatic doping. This unique behavior is supported by ab initio calculations showing that high concentrations of H dopants induce a full reconstruction of the band structure, although with little coupling between electrons and high-frequency H phonons. Such findings provide a promising approach for engineering the ground state of transition metal dichalcogenides and other layered materials via gate-controlled protonation.

References

[1] A. P. Drozdov, et al, Conventional superconductivity at 203 kelvin at high pressures in the sulphur hydride system. Nature 525, 73 (2015).
[2] A. P. Drozdov, et al, Superconductivity at 250 K in lanthanum hydride under high pressures. Nature 569, 528–531

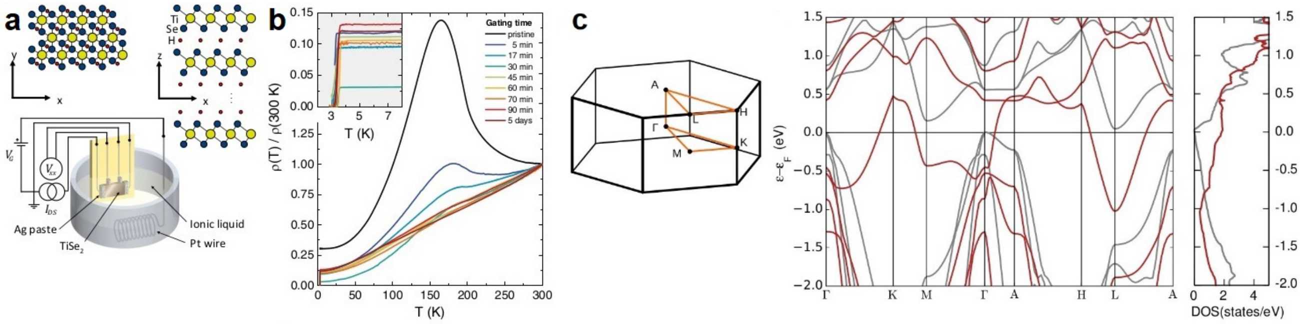

Figure a Sketch of a $TiSe_2$ crystal immersed in the electrochemical cell for ionic liquid gating-induced protonation, including the electrical connections. The side panel shows a ball-and-stick model of the H_x-$TiSe_2$ structure with $x \lesssim 1$. **b** Temperature dependence of the electrical resistivity ρ(T) normalized by the value at 300 K of a series of $TiSe_2$ crystals gated for increasing amounts of time. The inset shows a magnification of the T range where the superconducting transitions are observed. **c** The Brillouin zone with high symmetry points and the electronic band structure and the density of states of 1T-H_1TiSe_2 (red) compared with the pristine 1T-$TiSe_2$ dispersion (gray).