Multiband Superconductivity in the Chevrel Phases $SnMo_6S_8$ and $PbMo_6S_8$

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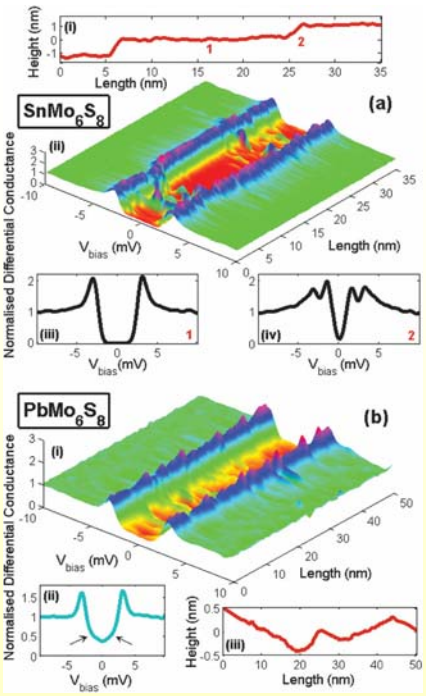
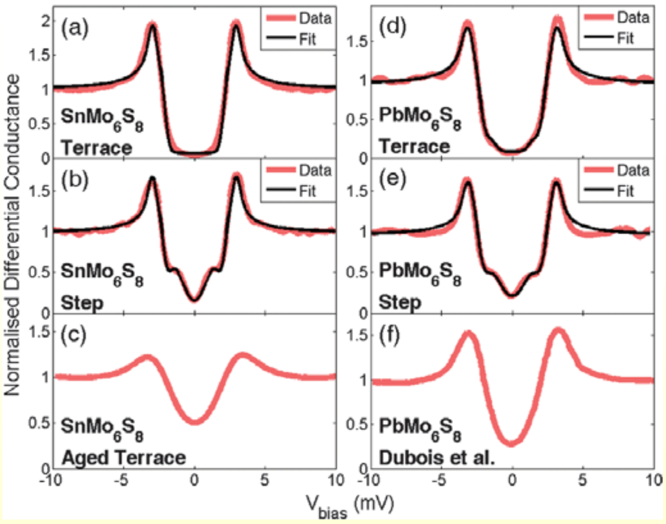
Sub-Kelvin scanning tunneling spectroscopy (STS) in the Chevrel phases $SnMo_6S_8$ and $PbMo_6S_8$ reveals two distinct superconducting gaps with Δ_1 = 3 meV, Δ_2 ~ 1.0 meV and Δ_1 = 3.1 meV, Δ_2 ~ 1.4 meV respectively. The gap distribution is strongly anisotropic, with Δ_2 predominantly seen when scanning across unit-cell steps on the (001) sample surface. The spectra are well fitted by an anisotropic two-band BCS s-wave gap function. Our spectroscopic data are confirmed by electronic heat capacity (HC) measurements, which also provide evidence for a twin-gap scenario. Our finding can explain the extraordinary high upper critical field in this family of superconductors and may provide clues on how to enhance the critical fields of novel superconductors.

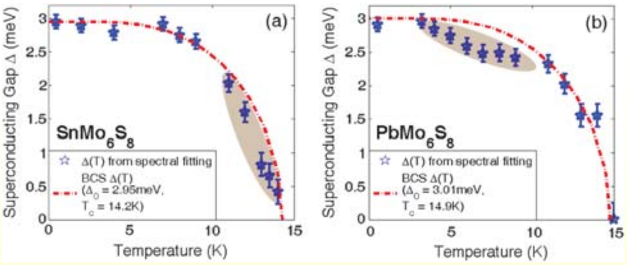


(a) Scanneling tunneling spectroscopic zero-field 35 nm trace on $SnMo_6S_8$ taken at T=0.4 K with junction resistance R_T = 0.03 GΩ.
(i) Topography showing steps two unit cells high; (ii) spectroscopic trace; (iii), (iv) raw spectra taken on a flat terrace (1) and above a topographic step (2).

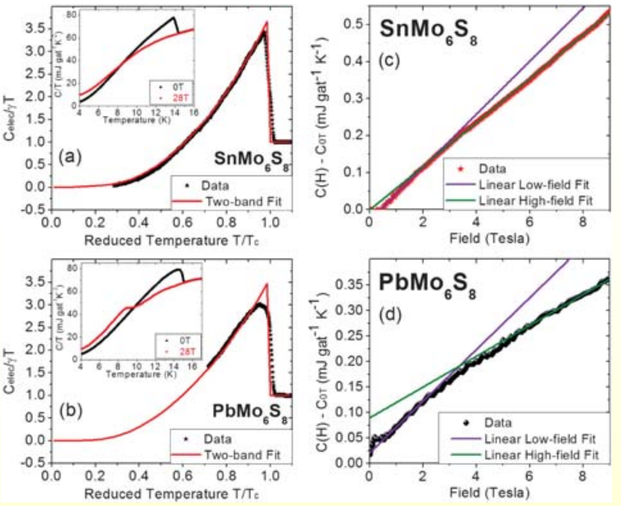
(b) Zero-field 40 nm trace on $PbMo_6S_8$ taken at T=0.5 K, R_T = 0.015 GΩ. (i) Spectroscopic trace; (ii) average spectrum from entire trace; (iii) topographic variation.



Scanning tunneling spectra taken on the steps between terraces consistently display additional kinks corresponding to a second superconducting gap at low energy:
(a)–(c) $SnMo_6S_8$ STS spectra and fits: T=0.4 K, R_T=0.03 GΩ.
(d)–(e) $PbMo_6S_8$ STS spectra and fits: T=0.5 K, R_T=0.015 GΩ.
(f) $PbMo_6S_8$ spectrum from [C. Dubois *et al.*, Phys. Rev. B 75, 104501 (2007)]: T=1.9 K, R_T= 0.025 GΩ. The second gap was hidden in the broadening of the data.



Temperature variation of the large gap Δ_1(T) in (a) $SnMo_6S_8$ and (b) $PbMo_6S_8$, measured by STS. The gap value was determined by fitting spectra acquired on a flat terrace (i.e., with a negligible Δ_2 component) using a BCS singleband anisotropic s-wave model.



(a),(b) $C_{elec}/\gamma T$ with two-band-model fits [H. Padamsee et al., J. Low Temp. Phys. 12, 387 (1973)]. Insets: C/T at 0 and 28 T. (c),(d) Field-dependent contributions to C_{elec} at T= 0.35 K with linear fits above and below a 2 gap crossover field H_x: In a single-band BCS s-wave superconductor, $\gamma(H)$ should be linear. However, at T= 0.35 K we observe bends in C_{elec} at H_x=2.8 T and 3.4 T in $SnMo_6S_8$ and $PbMo_6S_8$, respectively

Together, our spectroscopic and thermodynamic data provide compelling evidence for a multiband order parameter in Chevrel Phase superconductors. In both $SnMo_6S_8$ and $PbMo_6S_8$, a strongly coupled quasi-isotropic band (contributing the majority of the DOS at E_F) coexists with a highly anisotropic weakly coupled minority band. Looking ahead, we postulate that understanding and manipulating the interplay between two or more such bands may hold the secret to realizing high values for H_{c2} in future superconducting materials.