Emergence of a High Temperature Superconductivity in Hydrogen Cycled Pd compounds as an Evidence of a Superstoihiometric H/D Sites

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Introduction

- Dislocations in H-cycled Pd can absorb large amount of hydrogen (5-6 at. H/1Å of dislocation line)

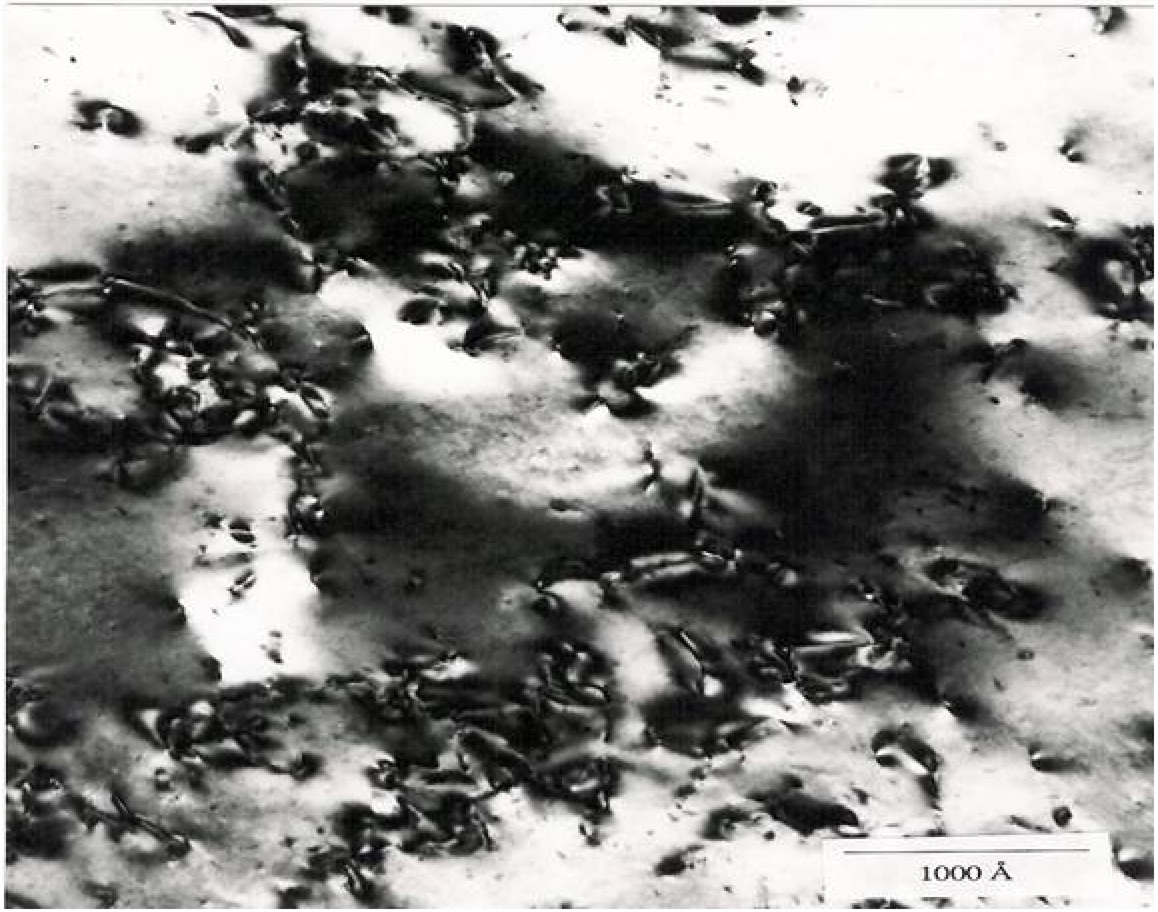
  B.J. Heuser and S.J. King Met. & Material Transaction A29, 1594 (1998)

  Under electrochemical cathode-anodic and/or H2 gas cycling the dislocation density in Pd foils reaches (2-5)$\times 10^{11}$ cm^{-2}.

  Hydrogen trapped inside deep dislocation cores may show specific behavior.

  Binding energy of this H should exceed 0.7 eV/H-atom.

Dislocations in the H-cycled Pd single crystal (x 80K)



What is expected ?

If hydrogen trapped inside deep dislocation cores:

- Very high loading ratio $x = H/Pd \geq 3$ or metallic H_n, $(H_2)_n$,
- Compression P ~ 120 GPa,
- High optic phonon frequency ($h\omega$ ~ 120 meV).
- Strong electron-phonon coupling ($\lambda_{e\text{-}ph} > 1.0$).
- Strong Pd-H(D) band overlapping (N. Ashcroft, PRL, 92, 187002, (2004)).
- Excellent Conditions to achieve High Temperature Superconductivity ?
- Triggering of LENR.

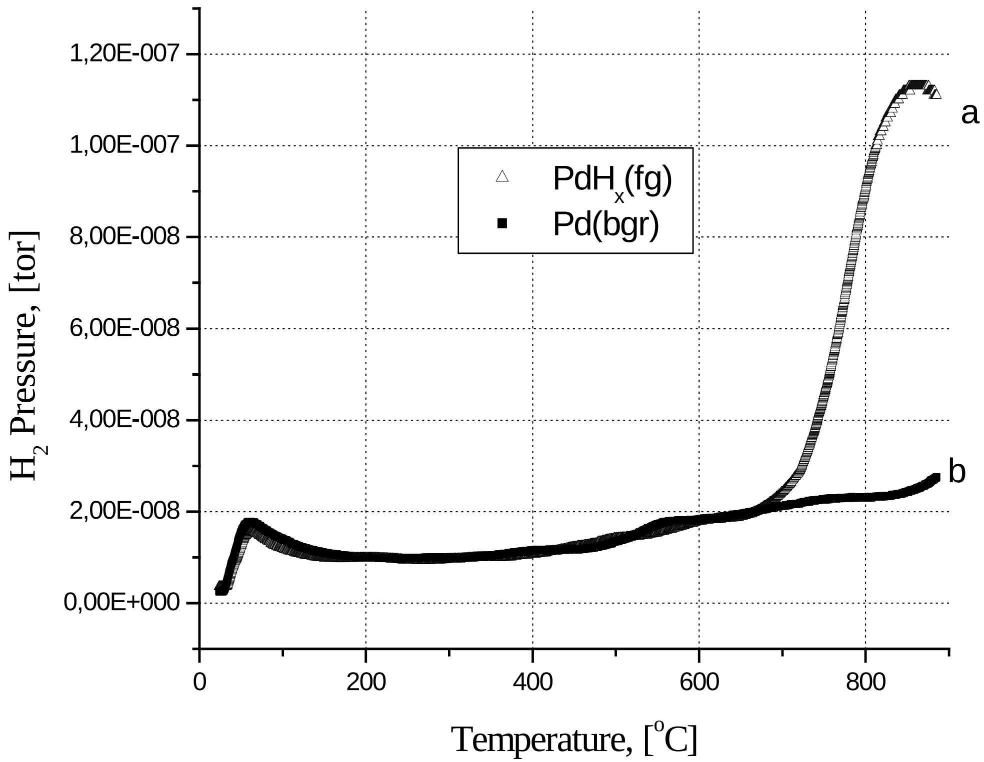
Objectives

- Study of hydrogen localization inside dislocation cores in Pd and Pd/PdO by vacuum thermal desorption technique.
- Study magnetic and transport properties of condensed hydrogen phase inside dislocation nano-tubes in Pd/PdO foils and Pd single crystal (1.8-300K).
- Define a role of these superstoihiometric D-sites in LENR to trigger various DD-reactions, including multibody type (3D).

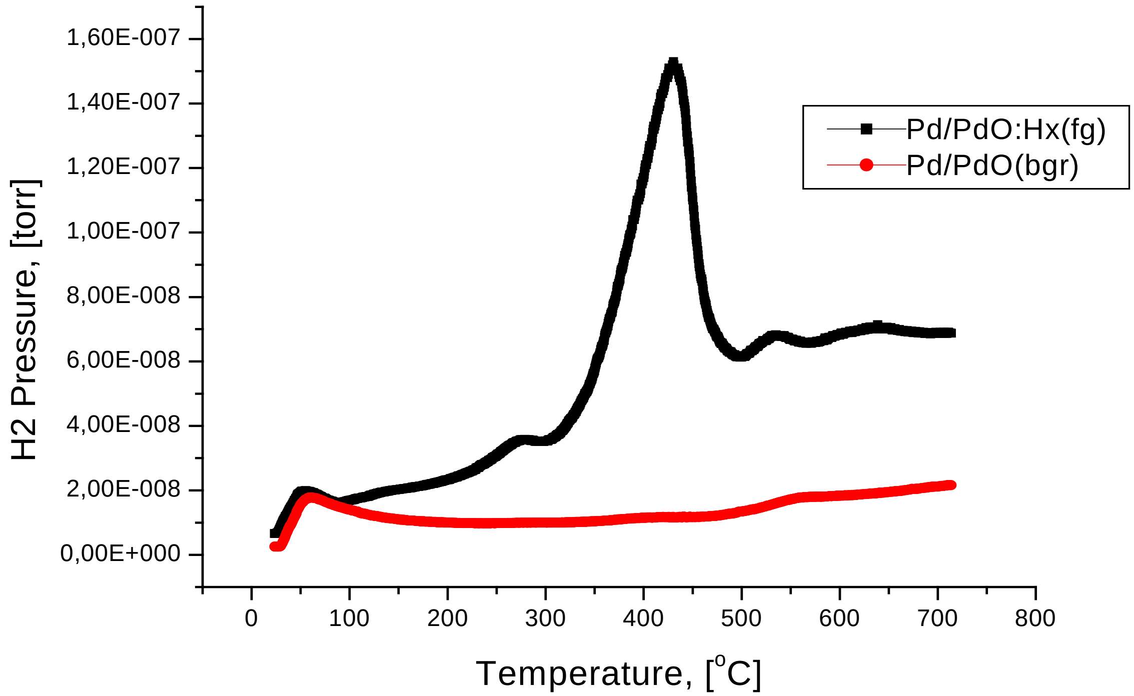
Sample Preparation

- Pd single crystal ingot (99.999%); samples m=62 mg, H2 gas loading-deloading cycles and annealing at T= 573 K for 2 hr.
- Pd/PdO cold worked heterostructure. h=12.5 μm, (PdO ~ 40 nm), 99.95 %, Nilaco Co., Japan, Fe 10 ppm. Electrochemical cycling (cathode loading-anodic deloading); j=5.0 mA/cm^2, 1MLi_2SO_4/H_2O, annealing at T=573 K.
- Measurements: TDA with mass-spectrometer; 1T-SQUID "Quantum Design" DC and AC modes, M(T), M(H), X'(T); 4 and 2 -probe resistance: R(T), R(I)

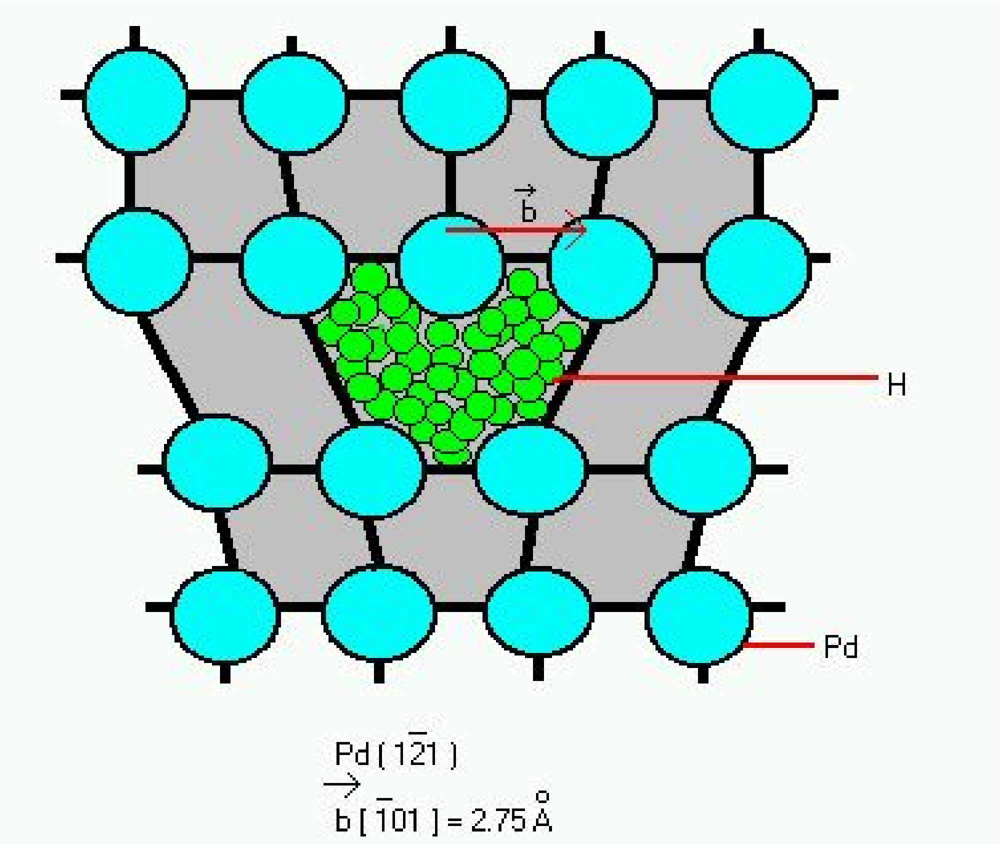
Thermal desorption of Hydrogen from Pd:Hx ($x=H/Pd=3.8 \times 10^{-4}$). T_{max}=870 °C, ε_H = 1.6 ±0.2 eV



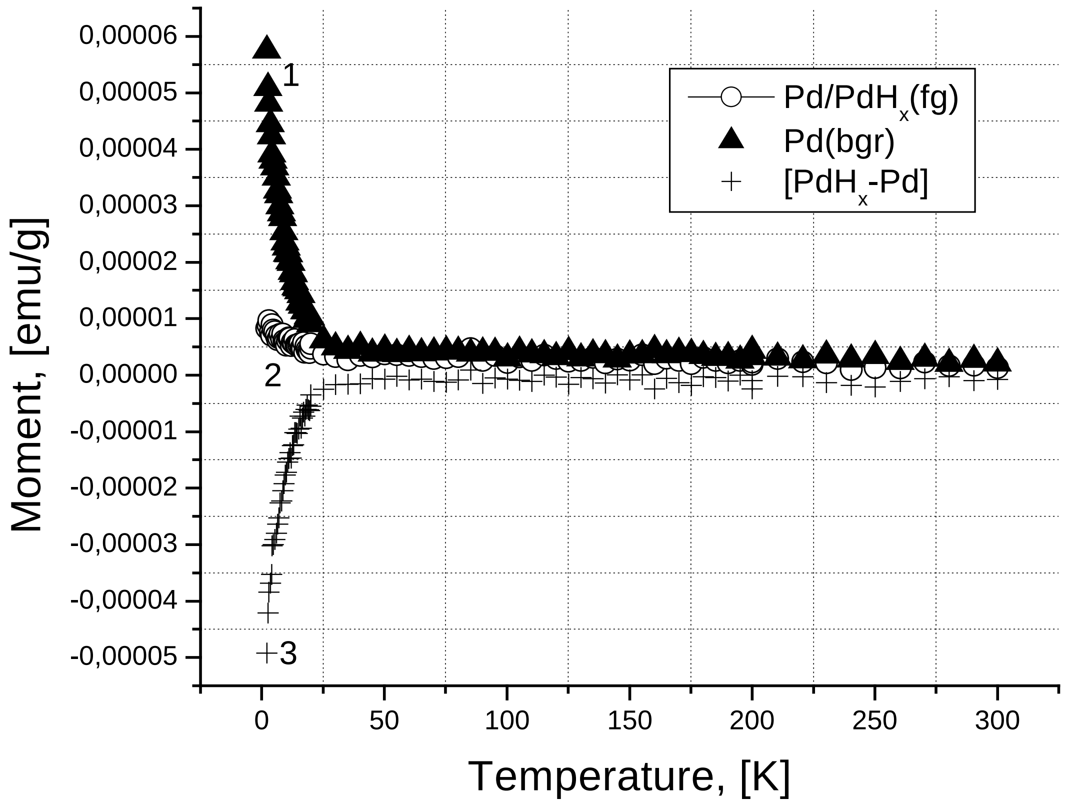
H-Thermal Desorption from Pd/PdO:Hx (x ~ 5.5x10^{-4}), T_m = 440 ° C, ε_H = 0.65 ±0.10 eV



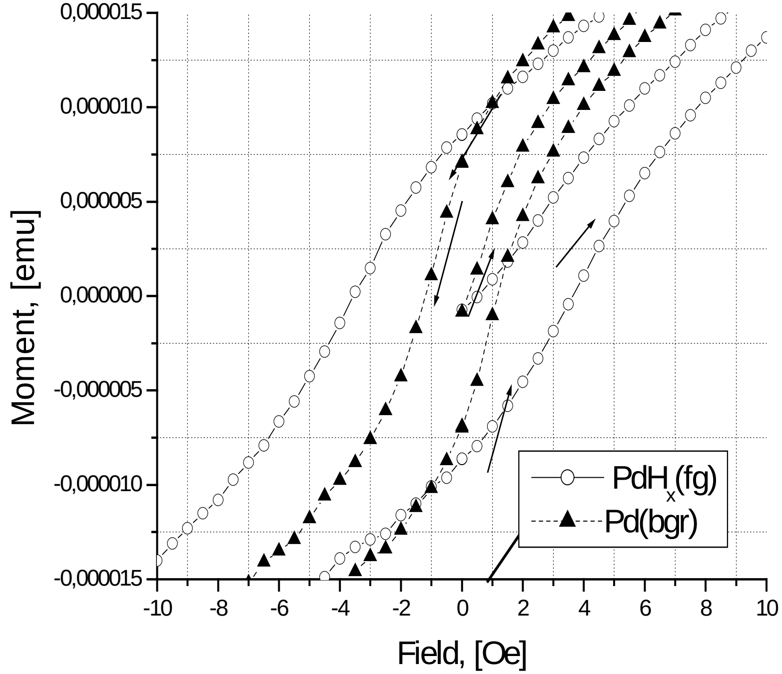
Edge dislocation core in Pd with H_n-condensed hydrogen phase

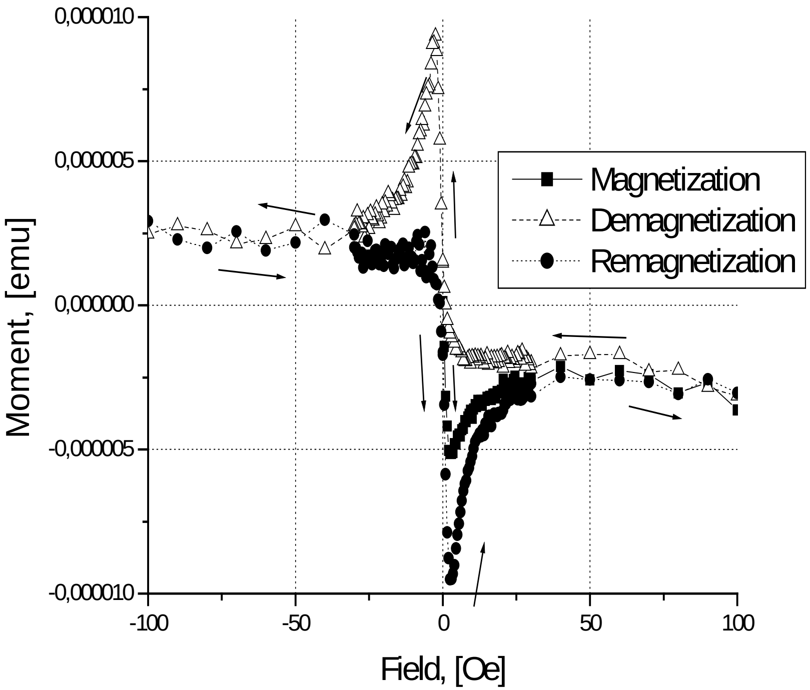


DC Magnetic SQUID measurement with PdHx and Pd single crystal: M(T), H=1.0 Oe

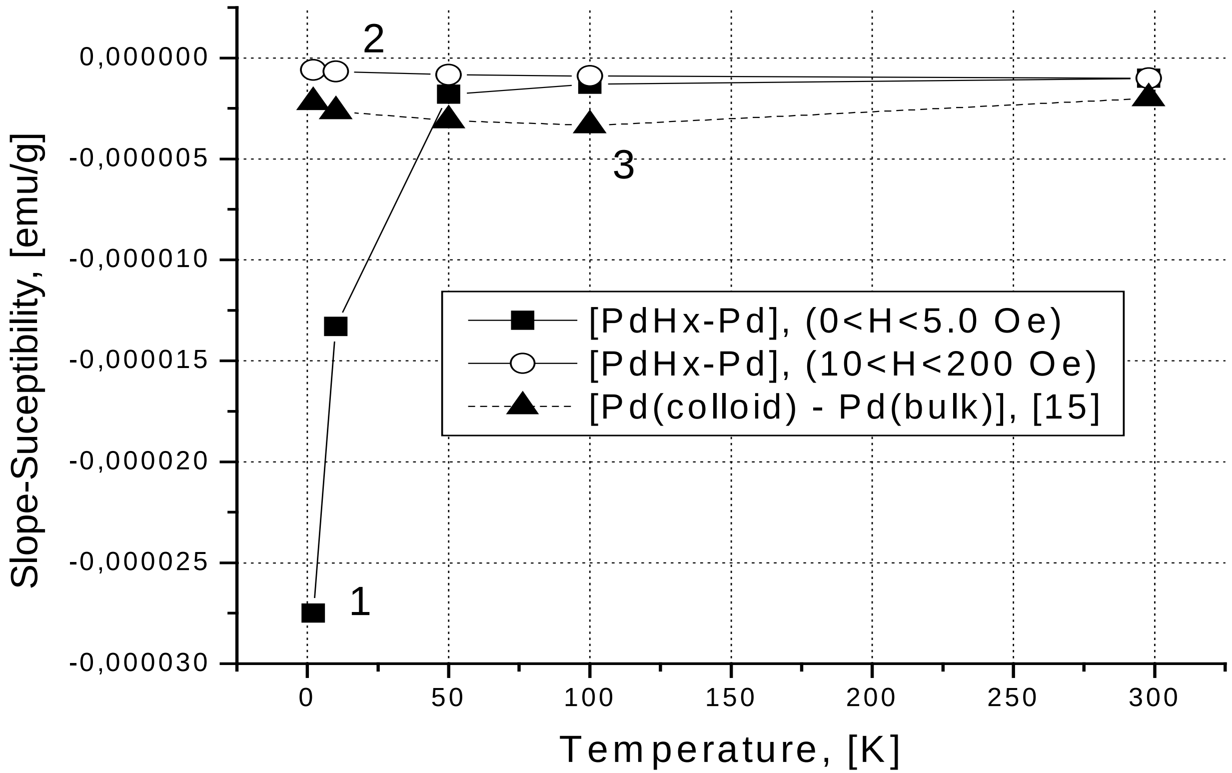


PdH_x, Pd single crystal and [PdHx-Pd] phase: M(H), T=2.0 K

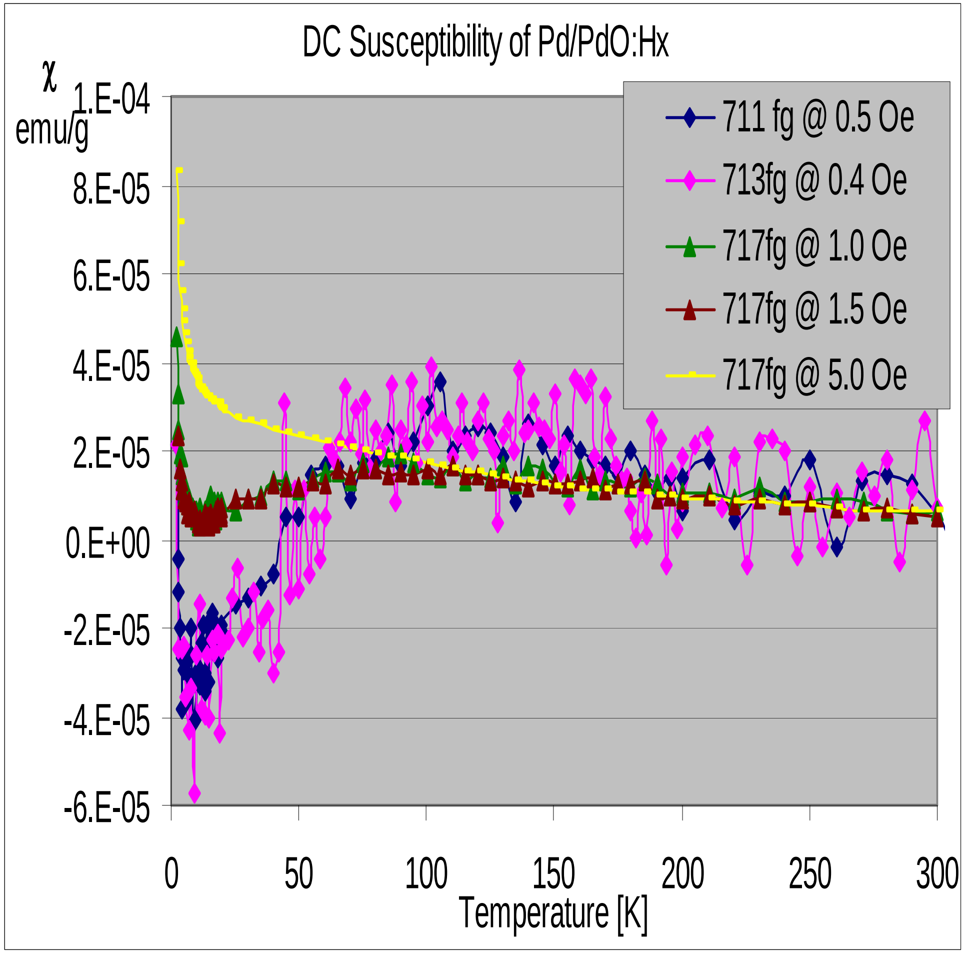




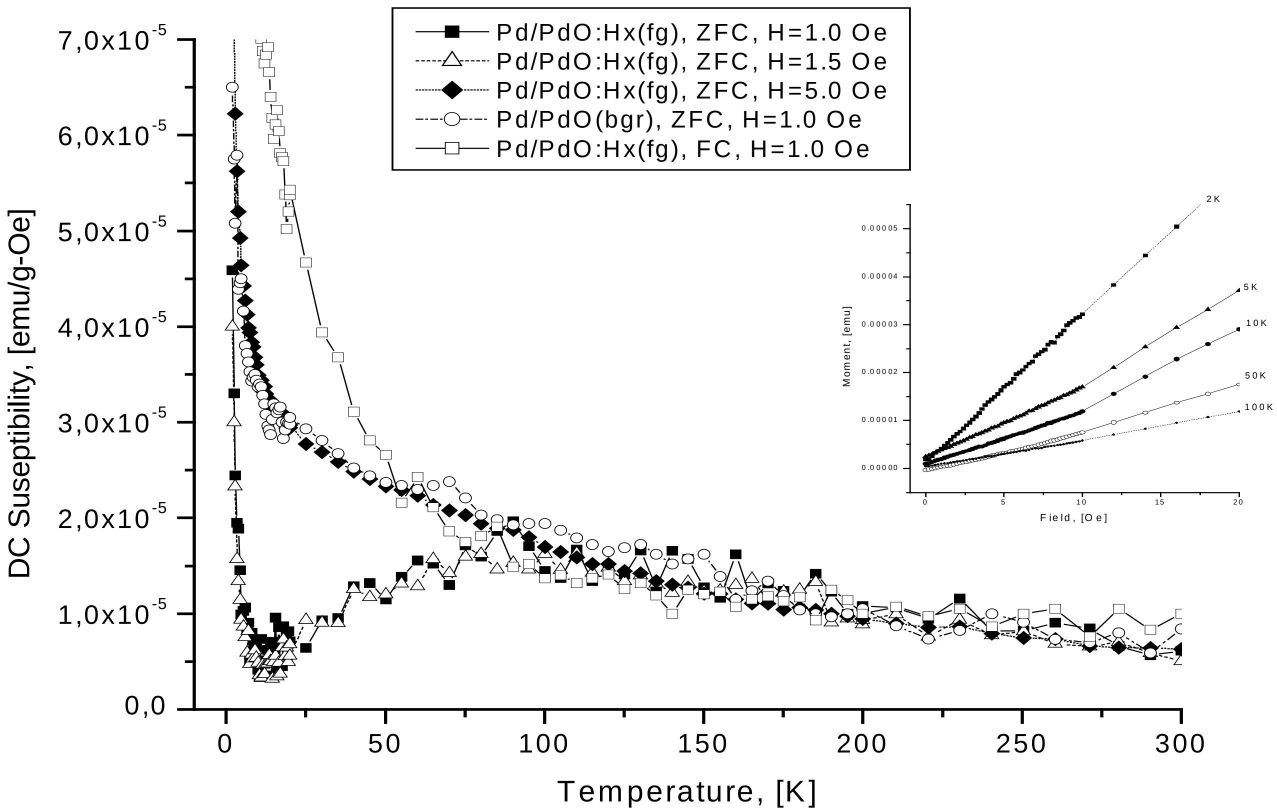
DC X(T) for [Pd:Hx-Pd] phase



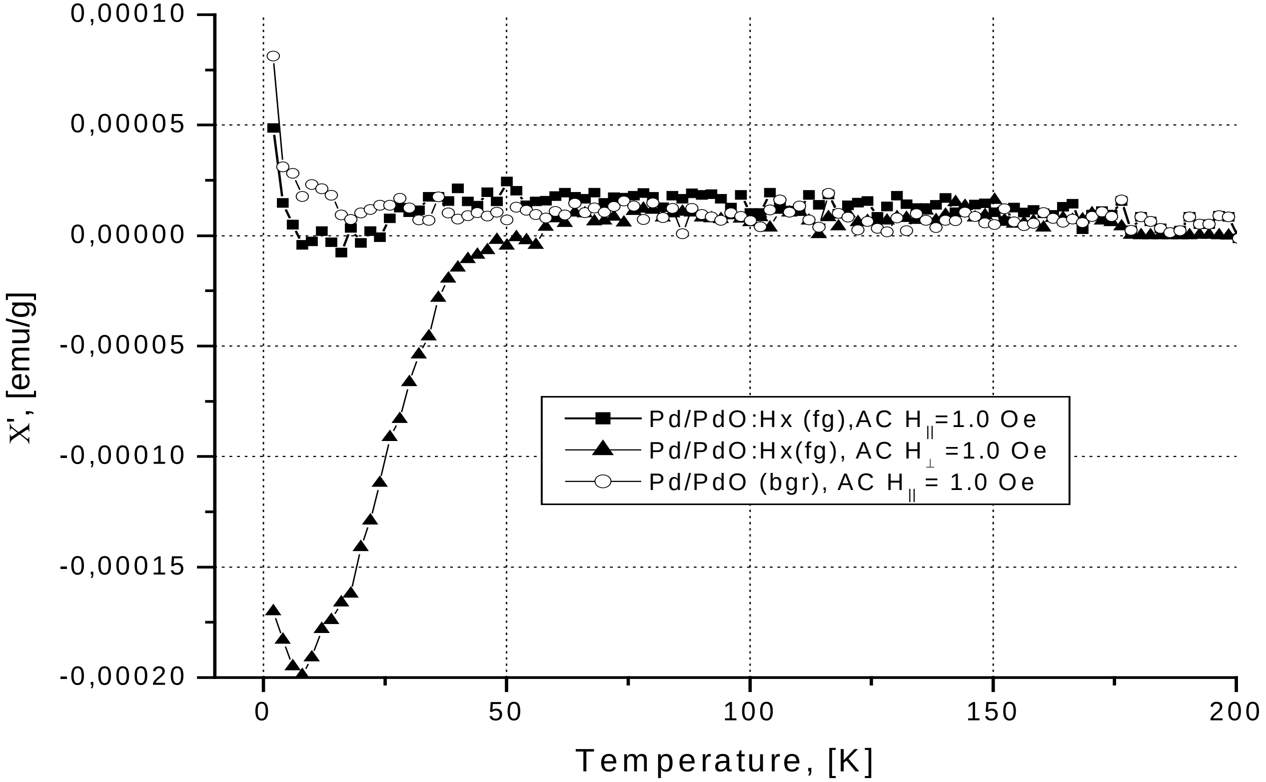
Low magnetic field DC-susceptibility for $Pd/PdO:H_x$ sample



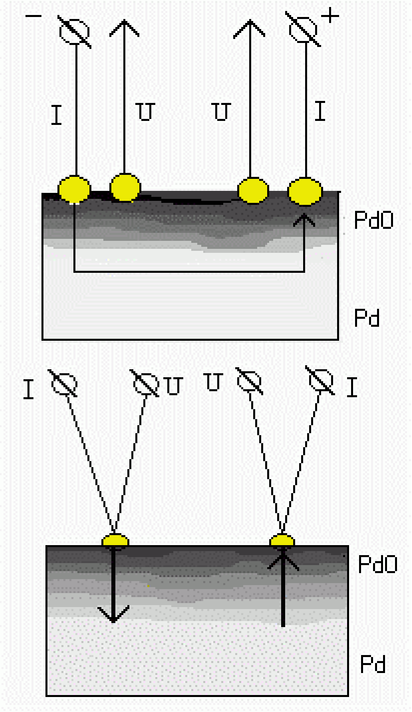
Pd/PdO:Hx and Pd/PdO blank: M(T) and M(H)



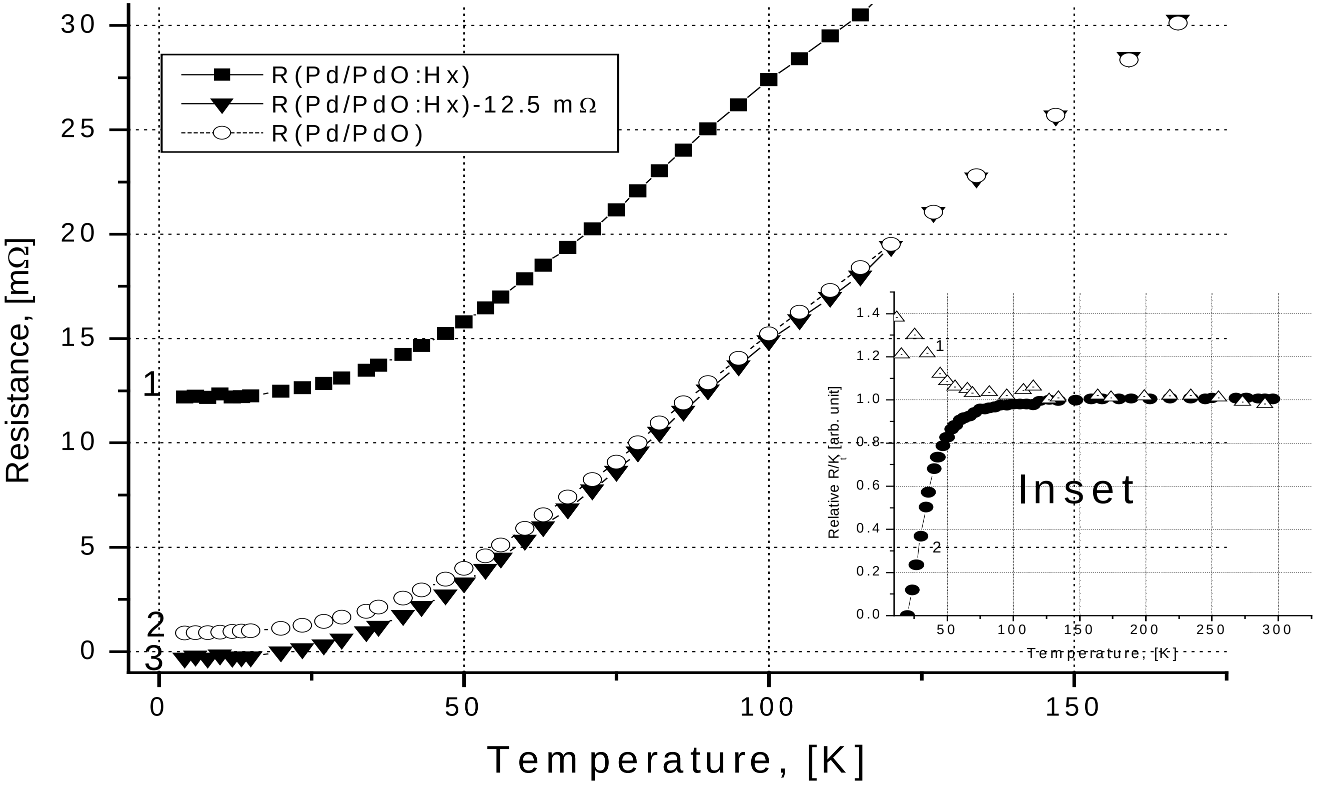
X' AC susceptibility of Pd/PdO:Hx and Pd/PdO-blank samples vs. T for H⊥ and $H_{||}$ with respect to the sample



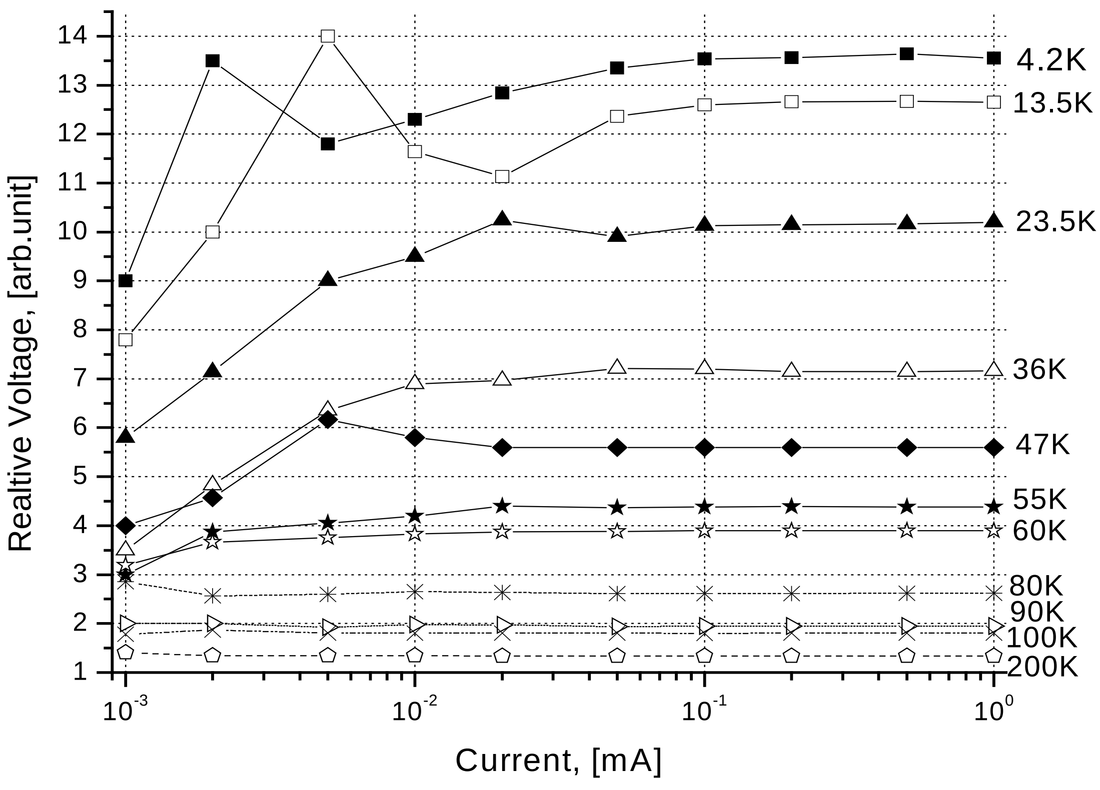
Diagrams of 4-probe and 2-probe(pseudo-four probe) resistance measurements



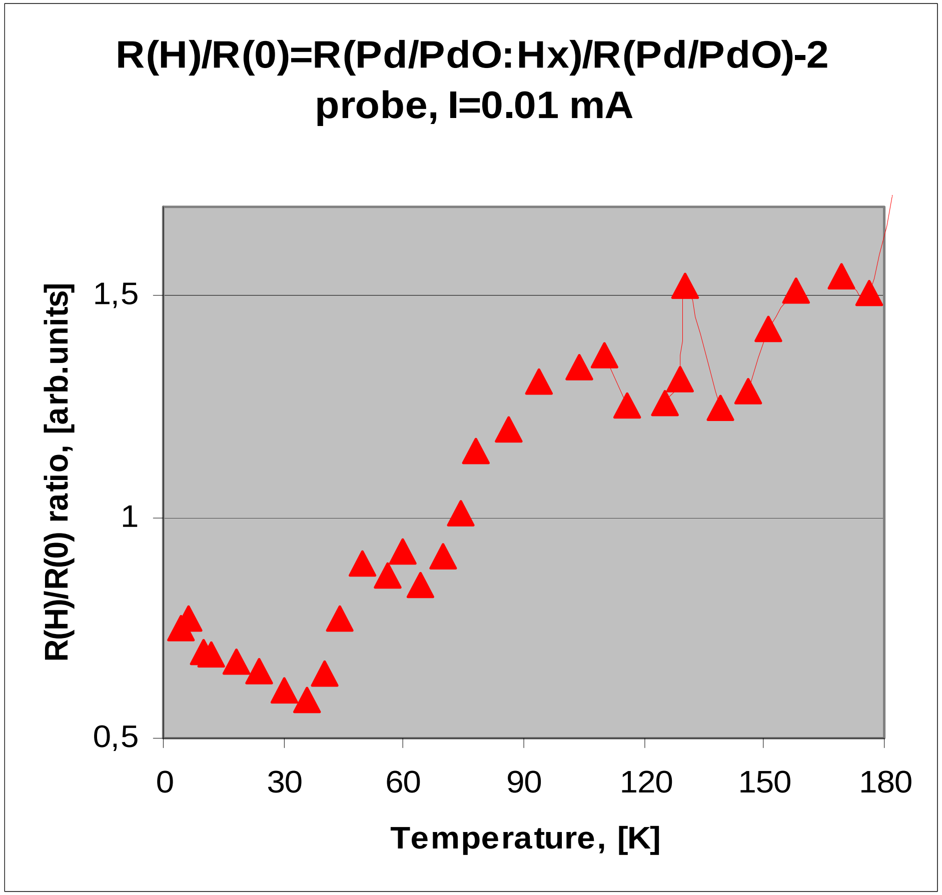
R(T) for Pd/PdO:Hx and blank Pd/PdO. Inset: - Relative resistance (black circles)R = R(Pd/PdO:H_x-Ri)/R(Pd/PdO) and temperature coefficient of resistivity (triangles) K=K(Pd/PdOH_x)/K(Pd/PdO)



Relative I-V characteristics for (Pd/PdOHx)/(Pd/PdO) ratio vs.T. Resistance decrease with decrease in I below 60 K.



2-probe resistance measurement: Relative resistance of Pd-PdO:H_x boundary [R(Pd/PdO:H_x)/R(Pd/PdO)] vs. T. R(Pd/PdO:H_x) < R(Pd/PdO) at T < 75 K



Summary of results

- Pd:H_x and Pd/PdO:Hx samples after H-cycling and annealing at T=573 K contain only condensed hydrogen phase inside deep dislocation cores: x=H/Pd = (3.8-5.5) x 10^{-4} with respect to the sample. Inside dislocation nanotube x=H/Pd ~ 3.0.
- Accordingly to SQUID measurements the H2-cycled PdHx single crystal sample demonstrates signature of a weak type II superconductivity, involving condensed hydrogen phase in deep dislocation cores [PdH_x-Pd] below 30 K.
- Results of both magnetic and transport measurements in Pd/PdO:Hx are suggested superconducting transition below 70 K. Reproducible Meissner-effect was obtained at H≤ 1.0 Oe in AC field (f = 1 kHz).

Conclusions and LENR connection

- Deep dislocation cores in Pd could be considered as a H-dominant Pd hydride (x =H/Pd $\geq$ 3.0) sites suggesting HTS properties.
- Triggering of LENR at such sites will be appreciated due to:
- - shortest DD-distance (close to Bohr radius)
- - highest D-loading and lattice compression
- - effective electron screening
- - large optic phonon energy ($\hbar\omega_D \geq 120$ meV) resulting in a most effective lattice-nuclei energy transfer.