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PALLADIUM METALLURGY AND COLD FUSION: SOME REMARKS

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The recent confusion surrounding claims for the observation of cold fusion involving palladium electrodes in electrochemical cells containing deuterium (1,2) might be clarified to some extent if the palladium metallurgy, particularly in the context of fundamental microstructures, were accurately defined.

Both the palladium/hydrogen and palladium/deuterium systems have been extensively investigated, and Lewis (3) asserted more than two decades ago that the palladium/hydrogen system was perhaps the most extensively, experimentally investigated metal/gas system. In fact, Paneth and Peters (4,5) claimed during the 1920's that ordinary hydrogen absorbed in palladium fused to form helium, while in the 1940's Wilner (6) actually observed the fusion reaction at the center of the current cold fusion controversy: $d + d \longrightarrow {}^3He + n$ (where $d = {}^2H$ represents a deuteron, and n is a neutron). In the experiment by Wilner (6), a deuterium-saturated palladium sheet was bombarded with accelerated deuterons. The product neutrons (n) were slowed by paraffin wax and detected by the activation of silver.

While neutrons in cold fusion cells have been confirmed by a number of laboratories (most recently Los Alamos National Laboratory), many experiments, while producing heat when deuterium is present in identical electrochemical arrangements, show no evidence of fusion reactions ($d + d \longrightarrow {}^3He + n$; $d + d \longrightarrow {}^4He + \gamma$, etc.). Although it might be possible somehow for the energy to go directly into the palladium lattice as heat, it is more likely that the creation of proximity conditions necessary for tunneling-induced fusion of absorbed deuterium is very dependent upon the microstructure, and correspondingly the palladium electrode metallurgy. It is unclear from the literature that anyone has even observed the grain size or grain size differences in the palladium electrodes, let alone specific defects, defect arrangements, or defect densities introduced by processing or fabrication.

It is also interesting to note that palladium is surrounded by elements in the periodic chart with which it forms solid solutions: Co (27), Ni (28), Cu (29), Rh (45), Ag (47), Ir (77), Pt (78), and Au (79) (7). Alloys (solid solutions) of Pd/Ag allow the stacking fault free energy (γ_{sf}) and correspondingly the microstructures, to be varied over a wide range: planar faults/twin faults for Ag ($\gamma_{sf} \cong 22$ mJ/m^2) to dislocation cell structures for Pd ($\gamma_{sf} \cong 175$ mJ/m^2) (8). These features are illustrated in the comparisons of flash-evaporated PVD single-crystal films epitaxially grown on large (001) NaCl substrates as shown in Figs. 1 and 2, under identical conditions. The Ag films (Fig. 1) are characterized by a high density of microtwin-faults even in the island growth stage (Fig. 1(a)), while such faults are generally absent in the Pd films (Fig. 2) which permit rapid permeation of hydrogen and provide a convenient method for separating it out of gaseous mixtures. Both palladium

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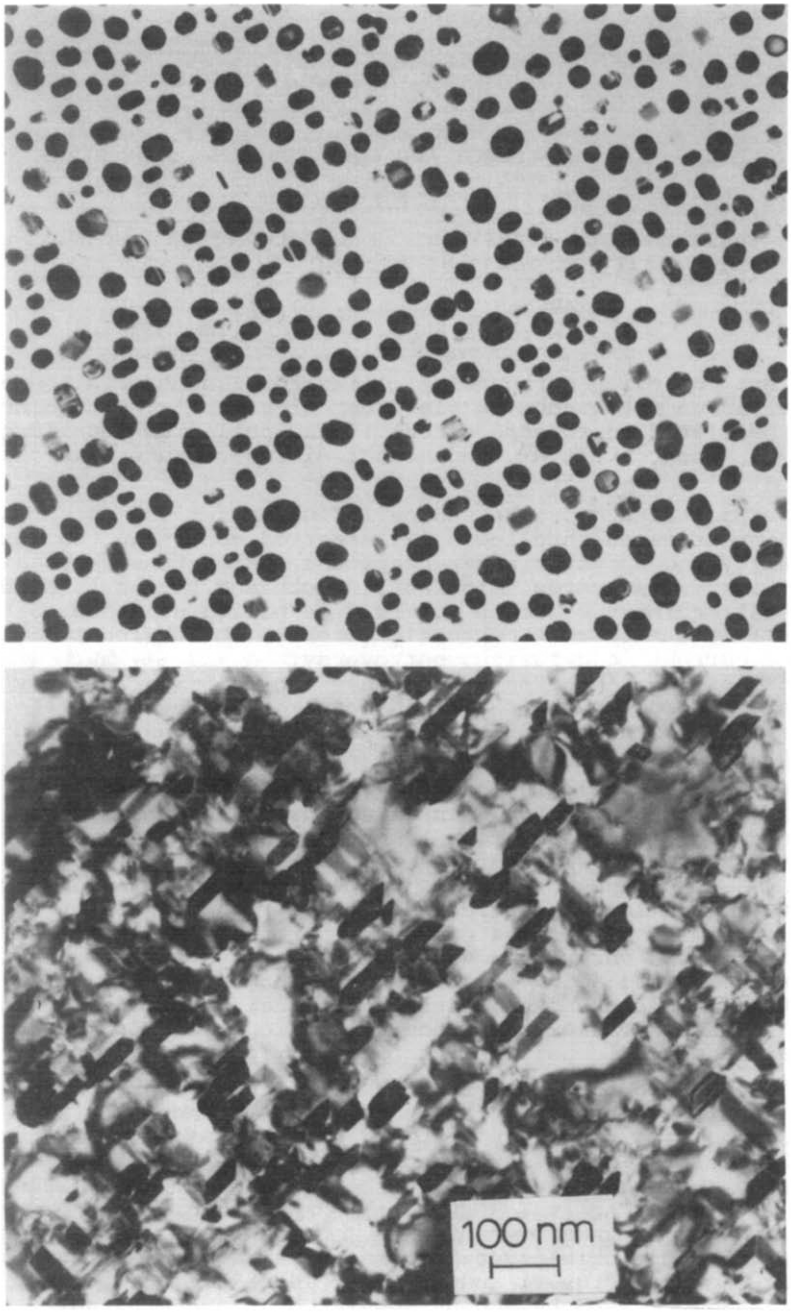

FIG. 1. Flash evaporated (~ 0.1 μ/s) PVD silver films epitaxially grown on (001) NaCl crystals at 250°C, 10^{-5} Pa. (a) TEM bright-field image of island growth. (b) TEM bright-field image of 50nm thick film showing high density of microtwin faults.

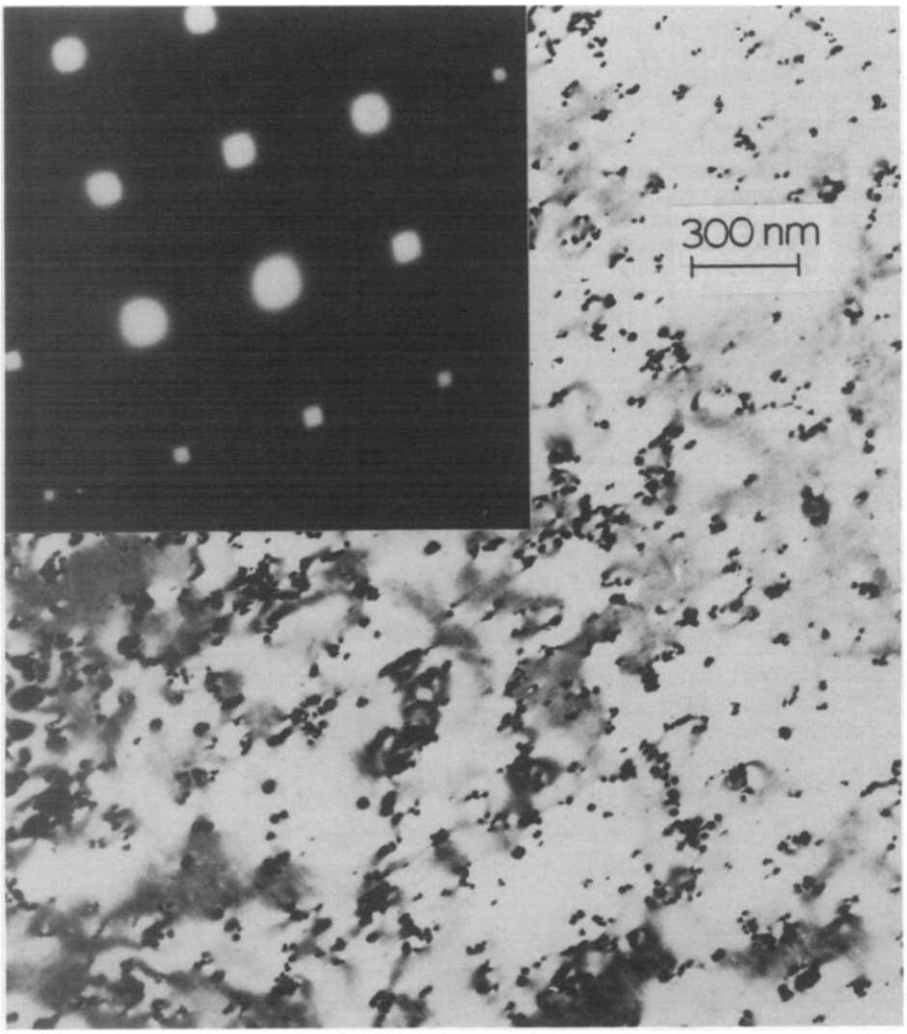

FIG. 2. Bright-field TEM image and (001) SAD insert showing 50nm thick palladium film containing dislocations. The growth conditions were the same as those in Fig. 1.

membranes (films) and Pd/Ag membranes have also been used as anodes in fuel cells. While the solubility of hydrogen is generally twice the solubility of deuterium in palladium, deuterium diffuses through palladium faster than hydrogen under the same concentration gradient (3).

Conclusions

It is apparent that the unique metallurgy of palladium or the palladium/deuterium system, if it does indeed promote electrochemical cold fusion, could be altered dramatically by deformation or fabrication-related microstructures. The presence of high densities of dislocations (Fig. 2), or other defects in palladium could alter the characteristic separation in the isotopic hydrogen molecules, and allow the nuclei to approach the critical barrier width for quantum-mechanical tunneling. Systematic experiments to control the grain size and dislocation substructures in palladium electrodes in identical electrochemical cells containing deuterium would seem to be a logical step in sorting out the variations in the evidence observed in cold fusion experiments. Indeed, materials characterization using transmission electron microscopy as illustrated in comparing Figs. 1 and 2 should have been (and should now be) a key element of cold fusion research programs. It may well be that cold fusion, like high-temperature superconductivity and a host of related phenomena, will prove to be a materials issue which can only be understood by utilizing the arsenal of tools available for microstructural observations and microstructural characterization (9).

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