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Palladium Facilitates Optical Switching

HYDROGEN ADSORPTION ALTERS PROPERTIES OF RARE EARTH FILMS

Hydrogen gas can permeate palladium, diffuse through it and be stored in it. This property has been known for many years, and has been discussed in this journal on numerous occasions; see (1–3) and references therein. Similarly, the effects resulting from the alloying of palladium with rare earth metals have been reported here (4). Now, physicists at Vrije University in The Netherlands have combined these properties to produce thin yttrium and lanthanum films coated with palladium, which display an optical switching phenomenon as they adsorb hydrogen (J. N. Huiberts, R. Griessen, J. H. Rector, R. J. Wijngaarden, J. P. Dekker, D. G. de Groot and N. J. Koeman, "Yttrium and Lanthanum Hydride Films with Switchable Optical Properties", *Nature*, 1996, **380**, (6571), 231–234).

Thin films of yttrium and lanthanum (500 nm) were evaporated under UHV and then coated with a thin layer of palladium (5 to 20 nm). The palladium film acts as a support for the films, forms an oxidation barrier, and allows hydrogen to permeate through and be adsorbed by the rare earths. It also enables various physical properties to be measured.

Films were examined by electrical resistivity and light transmission measurements. At the start of the experiment hydrogen, at room temperature and 0.9×10^5 Pa pressure, was introduced into the apparatus and began to diffuse through the palladium overlayer. The yttrium film adsorbed hydrogen and changed to yttrium hydride, YH_x, which remained metallic up to $x \sim 2$, but as more hydrogen was adsorbed, the YH_x changed to a semiconductor, corresponding to $YH_{2.86}$.

The films also undergo optical changes as hydrogen is taken up. After 17 seconds of exposure to hydrogen, an initially perfectly reflecting yttrium film, begins to precipitate the dihydride phase, with resistivity ~ 5 times lower than that of pure yttrium. After 65 seconds the resistivity increases rapidly and for a few seconds there is increased optical transmission, shown by a partially reflecting film, close to the dihydride composition. As hydrogen adsorption increases, optical transmission drops to zero, but after 80 seconds there is an abrupt and drastic increase in the optical transmission intensity, shown by a non-reflecting, transparent yellow film. This corresponds to $YH_{2.86}$ to the trihydride, YH_3.

For a lanthanum-palladium film the pattern is similar, but without the transparency window which occurred around 67 seconds; optical switching in LaH_x is more gradual than in YH_x.

Thus, there is a continuous, reversible metal-insulator transition in thin yttrium films supported and protected by a palladium overlayer, which can be brought about at room temperature by changing the hydrogen pressure, between hydrogen : yttrium ratios of 1.8 and 2.9. As hydrogen pressures increase, the films change from a reflective, shiny, mirror-like state to a yellow transparent state.

It is suggested that this technique could be used to investigate other rare earth films which undergo similar changes, and that such a significant optical phenomenon might find wide technological applications.

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