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Laser Stimulation Of Deuterated Palladium: Past And Present

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A method is disclosed to fabricate a Palladium cathode that can be electrolyzed in heavy water and stimulated with a laser at a predetermined wavelength to produce apparent excess power; the fabrication method involves cold working, polishing, etching and annealing the Palladium prior to electrolytic loading with Deuterium. Loading is accomplished with the cathode sitting in a magnetic field of 350 Gauss. After loading the cathode with Deuterium, Gold is co-deposited electrolytically on the cathode. When a coating of Gold is visible on the cathode, co-deposition is halted and the cathode is stimulated with a low-power laser with a maximum power of 30 milliwatts. The thermal response of the cathode is typically 500 mW with maximum output observed of approximately 1 watt. The effect is repeatable when protocols are followed and has been demonstrated in several laboratories.

1 Introduction

We have been investigating the possibility of triggering a Deuterated Palladium cathode for more than a decade. Previously we developed stimulation methods that involved chemical, magnetic and radiofrequency triggers. Until now, we had not concentrated on the metallurgical/surface aspects of the triggering mechanisms. It appears that laser stimulation of deuterated Palladium is very effective when metallurgical/surface conditions are taken into account.

2 Experimental

Figure 1 is a typical cell configuration for our laser stimulation experiments:

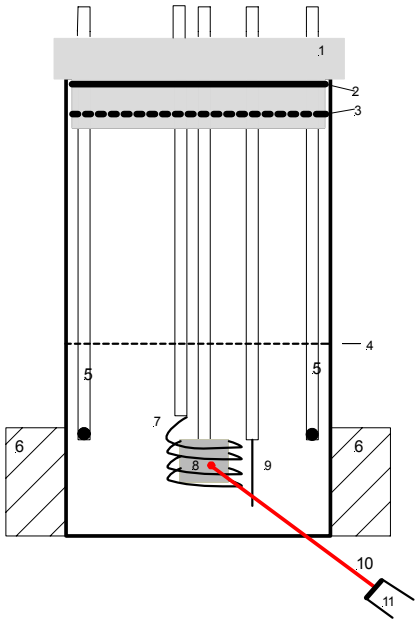


Figure 1

The cell consists of a machined Teflon lid (1) sealed with a Buna o-ring (2); gases are recombined by Platinum catalyst pellets imbedded in a groove cut in the lid (3). Cell temperature is reported by the average of two Beta-Therm 10k ohm thermistors sealed inside a 5mm glass tube(5). Electrolyte is typically 75 g of 1M LIOD (4). Two permanent magnets (6) sit adjacent to the cell. The magnets have field strength of 350 Gauss at the cathode. We think the magnetic field improves the loading of Deuterium. The anode (7) is typically platinum with a coil diameter of 10 mm. The cathode (8) is typically Palladium prepared according to a 17 step protocol discussed later. The cathode is normally 5 x 8 x .25mm.

After Deuterium has been bulk-loaded into the cathode for at least 120 hours at .1 amps, current is increased to at least 1 amp for at least 24 hours. A secondary anode of Gold (9) is then hooked up to the positive side of the power supply providing DC power for electrolysis. When the secondary anode is energized with positive DC current, Gold ions are released into the electrolyte and eventually migrate to the cathode and are co-deposited with Deuterium. When the cathode begins to turn dark, the secondary anode can be disconnected. Gold continues to plate onto the cathode out of solution. At this time a tunable laser (11) is directed onto the cathode with a spot diameter of about 2 mm.

3 Equipment

Figure two shows the cell in a temperature-controlled enclosure capable of holding ambient temperature at 24+/- .05 c. The enclosure was modified for stable temperature control by Scott Little of Austin, Texas.

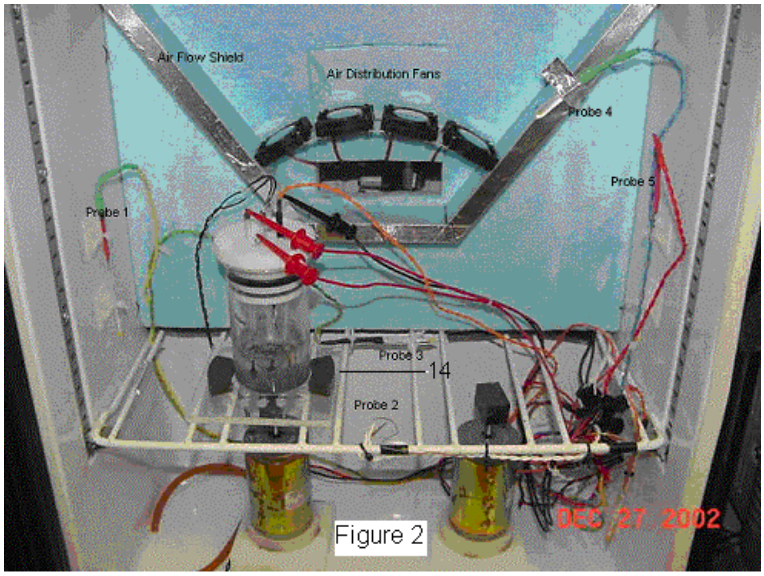


Figure 2

The air is well stirred by four fans and is distributed evenly by a thin plastic shield placed in front of the distribution fans. Enclosure temperature is maintained by an Omega temperature controller. The resultant enclosure temperature stability is shown in Figure 2a:

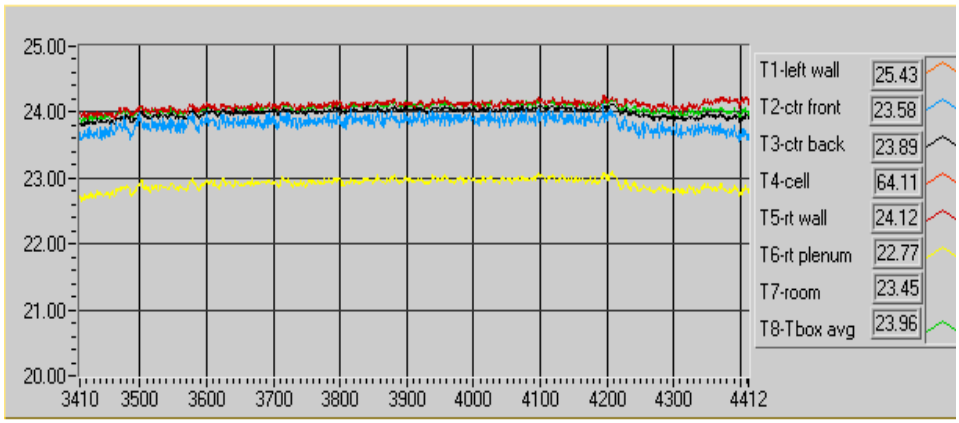


Figure 2a

The graph shows a 15 hour run with the enclosure temperature set at 24c; over 15 hours ambient enclosure temperature varied less than a tenth of a degree.

4 Cathode Fabrication

The general idea behind the cathode fabrication process is to create a uniform surface while increasing the Palladium grain size. Creating dislocations and defects with cold rolling is also important. The protocol is as follows:

1. Cut a billet of Palladium 10mm x 10 mm x .5mm.
2. Polish to bright using a dremel tool/ fiber brush and Nicksand (Al. Oxide)
3. Rinse in tap water.
4. Heat in furnace to 750 c for 3 hours; slowly cool to ambient.
5. Etch for 2 minutes in Aqua Regia at room temperature.
6. Re-polish with dremel and a METAL brush using Nicksand.
7. Polish with dremel and fiber brush using Nicksand.
8. Ultrasonically clean for 5 minutes.
9. Anneal 2.5 hours at 850c.
10. Polish with dremel/metal brush.
11. Ultrasonically clean 5 minutes using an oxide remover.
12. Cold roll to .25 mm thickness.
13. Re-polish with dremel/metal brush.
14. Ultrasonically clean 5 minutes with oxide remover.
15. Anneal for 2.5 hours at 850c.
16. Etch with Aqua Regia for 2 minutes at room temperature.
17. Rinse in distilled water; cathode is ready to load at low current.

Shown in figure three are photographs of two Palladium cathodes prepared by cold rolling, polishing and annealing; the cathode on the left was annealed once at 850c while the cathode on the right was annealed three times at 850c. The grains have increased in size.

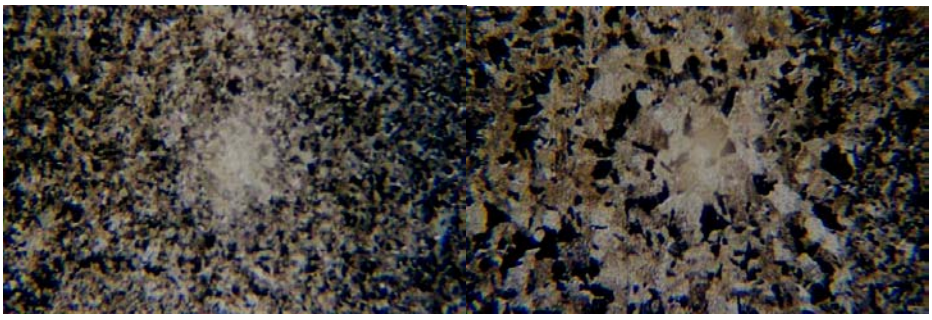


Figure 3

5 Results

It has been observed that a common red laser (30mW) when tuned to specific wavelengths appears to trigger a cathodic exothermic reaction 5-30 times greater than the magnitude of its radiant power output. The effect has not disappeared or diminished as calorimetric quality improved. It has also been observed that the magnitude of the thermal response of the cell may be altered by the polarization of the laser beam with respect to an external magnetic field. Figure 4 shows a cathode being plated with Gold from a Gold wire wrapped around the secondary Platinum anode in the right foreground. Note the discoloration on the cathode, indicating that the cathode is ready for laser stimulation

Figure 4

Figure 5 shows the cathode being stimulated by a 682.3 nm laser with 30 mW of radiant power. The thermal response of this cell is shown in Figure 6.

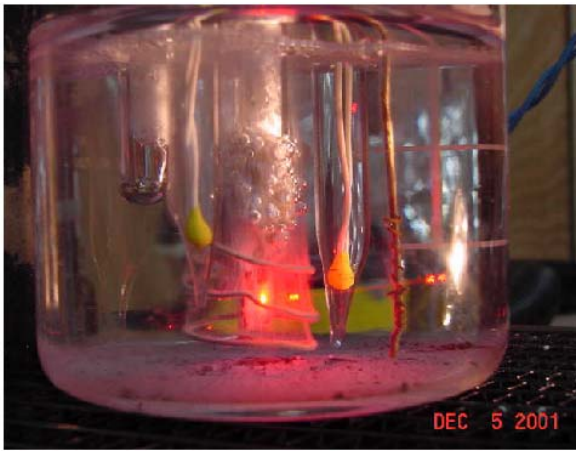


Figure 5

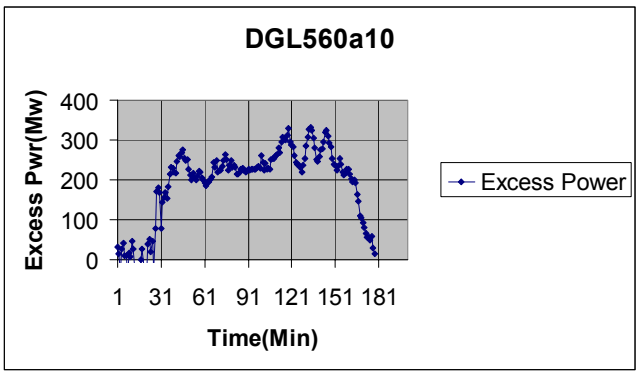


Figure 6

The 30 mW laser was switched on at point 30 and the cell reached a maximum excess power of 350 mW; at point 134 the laser was switched off and the excess power signal declined to baseline. The irradiated area was about .03 square centimeters, making the surface power density 10 watts per square centimeter. The best solid-oxide fuel cells available today have a surface power density of 1 watt per square centimeter.

Experimentation continued into 2002; as long as the fabrication protocol was followed, the laser effect was reproducible. On October 11th and 12th, 2002 the results shown in figures 7 and 8 were obtained.

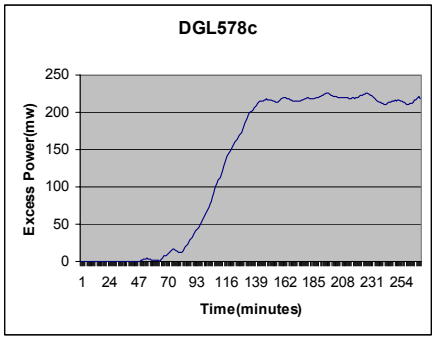


Figure 7

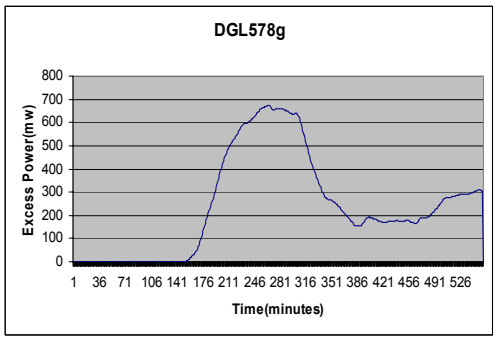


Figure 8

A 661.5 nm laser with radiant power of 30 mW was used in both Figure 7 and Figure 8; the principal difference between the two runs was the amount of Gold plated onto the cathode. The cathode of Figure 8 received 24 hours of additional Gold co-deposition. The thermal response of the cathode was three times greater in Figure 8. At point 300 the laser was switched off and the excess power signal declined toward but did not reach baseline.

6 Polarization

During the course of experimentation it was discovered that polarization of the laser beam can dramatically affect the thermal response of the cathode to the laser beam. Cravens observed during one of our runs that when the laser beam polarization is perpendicular to an external magnetic field, the thermal response of the cathode is maximized. The polarization of the beam was rotated with a ½ wave retarder; as the polarization of the beam became parallel to the external magnetic field lines, apparent excess power declined. With the ½ wave retarder shown in Figure 9, the laser beam polarization was rotated with respect to an external magnetic field of 350 Gauss. The results are shown in Figure 10.

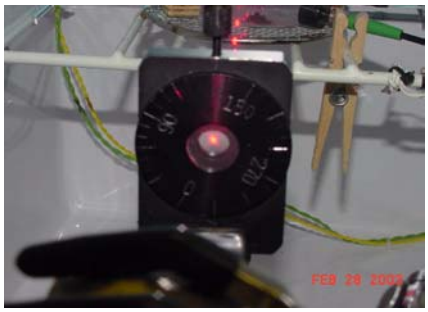


Figure 9

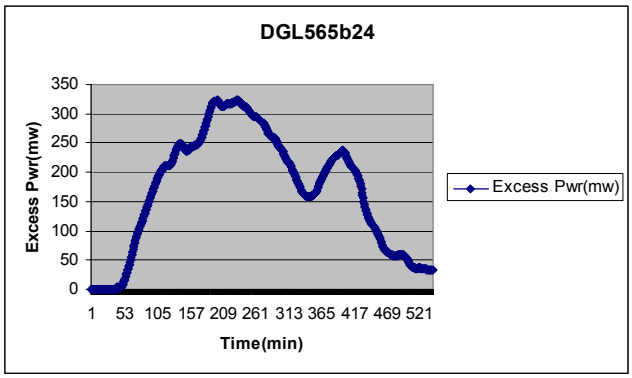


Figure 10

- At point 200, ½ wave retarder was inserted in the laser beam; excess power signal weakened immediately. The ½ wave retarder attenuated the 30 mW laser beam by about 1mW. Polarization was parallel to the external magnetic field after point 200 and the excess power signal declined.

- At point 335 the ½ wave retarder was removed and excess power signal recovered; polarization was returned perpendicular to the external magnetic field.

- At point 400, the ½ wave retarder was re-inserted in the laser beam. The excess power signal reversed its direction and declined to about laser heating of 30 mw; when the beam polarization was parallel to the external magnetic field, apparent excess power declined.

Experiment #587e was run at the laboratories of Earthtech, International of Austin, Texas and was witnessed by Scott Little, George Miley, Ed Storms and Tom Claytor. The cathode was a Gold substrate 5mm x 8mm x .75mm with Palladium plated onto the substrate with a rare earth additive provided by Cravens. The cathode didn't respond well to the laser stimulation until the rare earth solution was added to the electrolyte. With the additive, the cathode became responsive to a laser operating at 657nm with a radiant output of 30 mW. Results are shown in Figure 11.

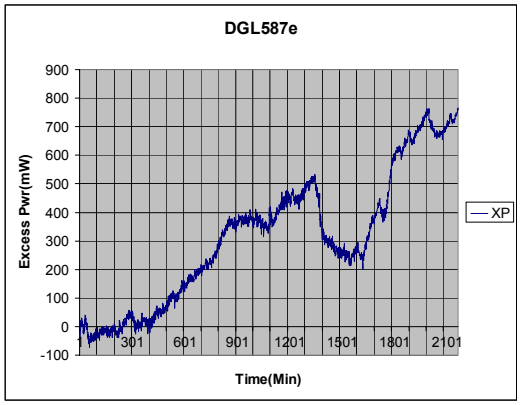


Figure 11

The cell ran at about zero excess power from point 0 to point 300 (5 hours); at point 320 Letts turned on the 30 mW laser. Over 15 hours the excess power rose to 500 mW. On March 6th, at point 1374, Letts and Miley visited the lab and switched off the laser. At point 1629 Scott Little switched the laser back on. During the course of this experiment the ambient temperature was held constant at 24 +/- .05 C and power to the cell was constant at 7 +/- .01 watts. The laser beam polarization was perpendicular to the external magnetic field of 350 Gauss. The recovery of the cell's thermal output from 250 mW to 750 mW was witnessed by Ed Storms, Tom Claytor, George Miley and Scott Little.

7 Conference Demonstration Cell #602

As part of our ICCF-10 conference presentation on August 26, 2003, we provided a live internet demonstration of a working cold fusion cell. The cell performed in a manner consistent with our previous work.

Figure 11a

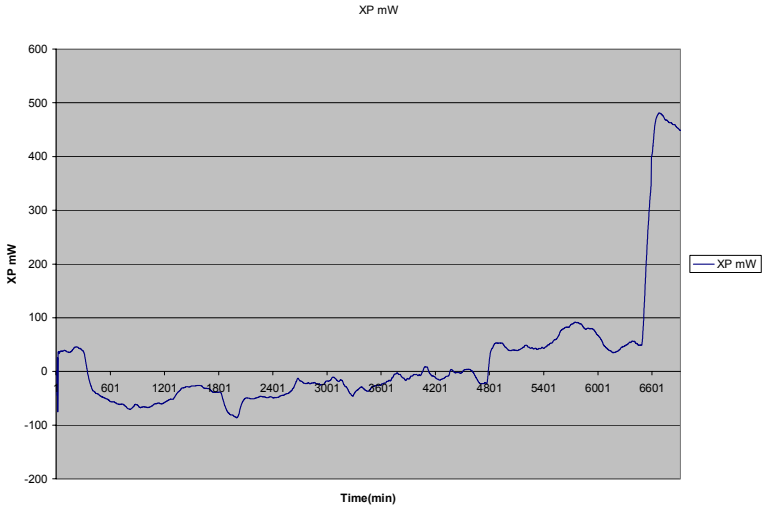
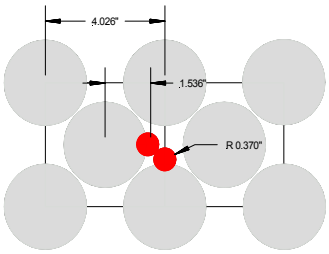


Figure 11b

Cathode #602 shown in figure 11a was loaded with deuterium from August 9 to August 14, 2003. At the far right of the chart(figure 11b), a 30 mW laser was switched on. The cathode produced an excess power signal of approximately 500 mW. DC power to the cell was a constant 500 mW. The laser was turned off when the excess power signal reached 500 mW and the effect declined.

8 Crude Model

A crude model has been proposed by one of us (Letts); its only redeeming quality is that it does provide a method to tune the laser. The wavelengths produced by the model have worked in the laboratory but there is no physical reason why they should work, other than luck. For discussion purposes, please consider the graphic shown in Figure 12.



Hydrogen In Surface Palladium Lattice
Scale: 1" = 1 Angstrom

Figure 12

The model used to compute a resonant laser wavelength is that of the Particle-in-a-Box, found in all basic quantum mechanics textbooks. The model assumes that Deuterium can be localized in the open space between Palladium surface atoms, thus forming a two or three dimensional quantum well. The lattice parameters of Deuterated Palladium are well known, as is the Palladium-Hydrogen equilibrium distance. The quantum well dimension is then:

Eq. (1) L = beta phase lattice parameter – 2* Pd-D equilibrium distance
= 4.026 Angstroms – 3.072 Angstroms
= .954 Angstroms.

The quantized energy levels for Deuterium localized in the quantum well of dimension L are computed according to:

Eq. (2)

$$E_{final} := \left(N_x^2 + N_y^2 + N_z^2\right) \cdot \frac{h^2}{8 \cdot mass \cdot L^2}$$

Eq.(3)

$$E_{initial} := \left(1^2 + 1^2 + 1^2\right) \cdot \frac{h^2}{8 \cdot mass \cdot L^2}$$

h is Plank's constant, mass is the mass of Deuterium and L is the dimension of the quantum well. The laser wavelength that is resonant with the energy difference between the two states shown above is computed as (c is the speed of light):

Eq. (4)

$$\lambda := \frac{h \cdot c}{\left| E_{final} - E_{initial} \right|}$$

The N's shown in the final energy equation can be selected so that the laser wavelength is in the red laser range. There are only a few sets of numbers that will work; quantum numbers of (10,8,1) or (12,4,2) will yield resonant laser wavelengths of 679.91 nm and 684.83 nm respectively. These wavelengths can be realized from an off-the-shelf diode and tuned with a laser controller such as the ILX 3722b. The tuning range is typically 5 nm. Other quantum numbers can be selected to produce resonant wavelengths in the range of all standard red laser diodes: 635nm, 650nm, 660nm, 670nm and 680nm. All of these ranges have been tested except the 635nm diode.

9 Discussion

The important point of this work is that it appears to be reproducible when all of the specifics are rigorously followed. For example, the cathode preparation includes many steps that may or may not be *necessary*-however they are *sufficient* for the effect. There have been multiple experiments with cathodes prepared in other ways; however such experiments did not give consistent results.

The lack of reproducibility has been a recurring problem in this field. One key goal of these experiments has been to achieve consistent results instead of maximizing excess heat. Another goal has been to achieve conditions, which will trigger the immediate release of excess power. This is important since it avoids some systematic errors such as slow variation in the calorimeter "constants".

A very useful feature of laser stimulation is that it allows for specific areas upon a single cathode to be investigated without undo interference. Several experiments have shown that the magnitude of excess heat release is dependent on the location of the laser spot upon the cathode. This opens the door to many future studies on surface conditions required for heat production.

It is hard to conceive of any error that leads to variation in excess heat as the beam's polarization is changed. The effects from external magnetic fields and beam polarization have not been investigated enough to come to a clear understanding of their roles. However, the fact that heat production from some runs varies with changes in polarization, hints at some deep underlying events. This promises to be a fruitful tool to understanding some of the mechanism involved.

Most experiments were conducted to check the variation of excess heat as the frequency was varied within a part of the red area of the visible spectrum (630 to 680 nm). This range was mainly chosen simply because of the cost and availability of narrow frequency sources. It is envisioned that the effect may be more robust for sources nearer the more populated ground states of the system. The preliminary theoretical model given above was developed to try to explain the frequency dependence seen experimentally. The important point is not the model itself but the experimental fact that the effect is seen to depend on frequency; investigators must make attempts to select laser frequencies with regard to cathode temperature when attempting replication.

This approach promises a vast array of experimental approaches since it allows for site selection, external triggering of events, application of external fields, and a specific frequency response of heat release mechanisms.

10 Conclusions

Laser stimulation of deuterated metals is a new and powerful method, which promises a wealth of new experimental approaches to probe the mechanism of anomalous heat. Its ability to select surface sites allows for probing variation in metal surface conditions that are important for the mechanism. Its frequency and polarization specificity may reveal internal mechanisms involved in heat production. Its ability to trigger heat allows avoidance of some troubles normally besetting calorimeter measurements. Much work remains to optimize the approach but it is hoped that laser stimulation will become a powerful tool in understanding the heat releasing mechanism in deuterated systems, which now seems so inexplicable.

References

1. Brehm, John J. and Mullin, William J. 1989. *Introduction to the Structure of Matter,* John Wiley and Sons, Inc., New York, New York.

2. Smith, Donald P. 1948. *Hydrogen in Metals,* The University of Chicago Press, Chicago, Illinois.

3. Van Vlack, Lawrence H. 1959. *Elements of Material Science,* Addison Wesley Publishing Company, Inc., Reading Massachusetts.

4. Zehner, D.M. and Goodman, D. W., editors, 1987. *Physical and Chemical Properties of Thin Metal Overlayers and Alloy Surfaces,* Materials Research Society, Pittsburgh, Pennsylvania.