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Phenomenon of Low Energy Emissions from Hydrogen/Deuterium Loaded Palladium

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ABSTRACT

Palladium loaded with either hydrogen or deuterium is found to give a clear autoradiograph on exposure to X-ray film. The phenomenon is found to be 100% reproducible and is independent of the technique of loading, be it electrolytic, gas loading, plasma discharge or ion implantation. It appears only if the exposure to X-ray film is done in atmosphere of hydrogen, oxygen or air. These emissions are also detected by TLD measurements. Investigations seeking to identify the nature/energy of the radiation through transmission measurements using various filters tentatively indicate that the radiations could be low energy electrons having an energy of around 300 to 400 eV.

1. Introduction

The occurrence of anomalous emissions from certain metals (such as palladium and titanium), when loaded with deuterium, either electrolytically (Jones 1989) or in gas phase (De Ninno 1989) or in plasma phase (Rout 1991), has been reported by various laboratories. Most of these emissions have been found to be sporadic and are not easily reproducible. We report here emission of some low energy radiations emanating from palladium when loaded either with deuterium or hydrogen, by any loading technique. The phenomenon is reproducible and the low energy radiations have been observed from all the samples loaded so far.

2. Experimental Methods & Results

2.1 Loading of Gas

The majority of the samples used were in the shape of disks, 16 mm diameter and 2 mm thick. These were loaded by affixing them on a plasma focus (PF) (Mather 1971) central electrode or by first degassing in vacuum (600°C, 10^{-5} mb) and then allowing them to cool in the D_2 or H_2 atmosphere (at 1 bar pressure, for 2 hours). A few Pd samples (in form of needles) were loaded using the Wada gas discharge technique (Wada 1989). The bulk loading obtained varied between 0.1 and 0.6. It is possible that the loading in the surface layer may be much higher. The H_2 and D_2 gases used for loading had tritium content of ~ 10^{-4} Bq/ml and < 10^{-5} Bq/ml respectively.

2.2 Measurement of radioactive emissions

The radiations emitted from the samples were predominantly of very soft nature and of comparatively low intensity (as will be evident from subsequent sections). They were short lived (maximum life of a few days).

Autoradiography was the most extensively used diagnostics. For autoradiography the X-ray films were kept in contact or a few mm away from the sample. The exposure time varied from 24 to 120 hours. Fig. 1 shows a contact autoradiograph of a disk loaded with D_2 using a PF device (30 discharge shots, 24 hours exposure). Fig. 2 is an autoradiograph of a similar H_2 loaded sample (30 discharge shots, 90 hours exposure) kept 0.2 mm away from the film. In all the autoradiographs obtained (under any condition), the fogging was always observed only on the side of the film facing the samples, in spite of the fact that the X-ray film is transparent to optical radiation and had sensitive coating on both sides. This confirms the low range of the radiations and absence of optical emissions.

No fogging above threshold could be observed on the autoradiographs when the PdH_x samples were kept in vacuum ($<10^{-2}$ mbar). Some samples were also kept in atmospheres of nitrogen, helium and argon gases. The gas pressure was retained slightly (~ 50 mbar) above one atmosphere. The exposure time in all the cases was 96 h. No radiation, above threshold, was observed on any of these autoradiographs.

By means of a sensitive densitometer, it was possible to measure density of even very faint autoradiographs. Some samples were also autoradiographed in an atmosphere of hydrogen (~ 50 mbar pressure) for 96 h, the fogging obtained on the autoradiographs was just discernible over threshold (see Table 1). PdH_x samples kept in oxygen atmosphere (pressure ~ 50 mbar) above atmosphere, for 96 h, fogged the autoradiographs to an average density which was 40 to 60% less than what was obtained with control samples in air (see Table 1). Fogging was also detected when thin filters (2 μm aluminised polycarbonate foil (0.25 mg/cm^2) in one or several layers) were kept between the film and loaded samples. Weak fogging was always measured with one layer of such a filter (see Table 1). With two layers of filters fogging was observed only in one instance (barely above threshold). No fogging was ever observed, above threshold, with three or more layers of filters.

The autoradiography and TLD ($CaSC_4$ based) measurements were made with and without glass and fused silica filters. Activity observed without filter in case of TLD study was seven times above background. No radiation was observed to cross glass or fused silica, indicating the absence (or very low intensity) of optical, ultraviolet or infrared radiators. These results were confirmed by photomultiplier and photodiode study.

The emissions were also subjected to electric field. The electric field between the loaded sample (disk type) and the film was maintained by a perspex spacer, 1.2 mm thick, having an opening of 12 mm at its centre. In different sets of experiments the voltage was varied from ± 1.5 V to ±400 V (field varying from +3.3 KV/cm to -3.3 KV/cm). Application of the field very much increased the intensity of fogging of the autoradiographs. The fogging increased as the voltage was increased, saturating approximately at 100 V. Surprisingly, when positive voltage was applied to the sample (for electrons to be retarded towards the film), the fogging was higher as compared to negative voltage. The Fig. 3 and 4 are the autoradiographs of two identical plasma focus loaded (15 PF shots) disks. The first one was with 100 V positive and the second one with 100 V negative supply. The exposure time for both the cases was 41 hours.

Table 1. Density of autoradiographs under various conditions. Density averaged and normalised to 24 h exposure time.

Condition for autoradiography		Density ($\times 10^{-3}$)
1	In normal air atmosphere	80
2	In oxygen atmosphere	32
3	In hydrogen atmosphere	3.5
4	In air with 0.25 mg/cm^2 filter	6.0
5	In air with +0.67 kV/cm field	230
6	In air with -0.67 kV/cm field	210

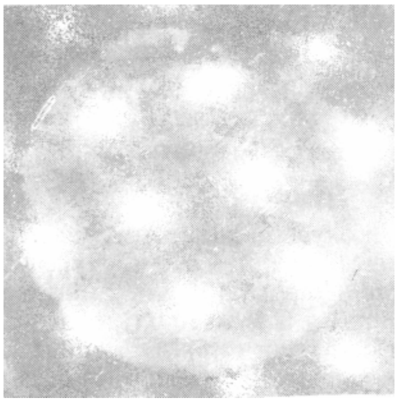

Figure 1. Autoradiograph (sample in contact)

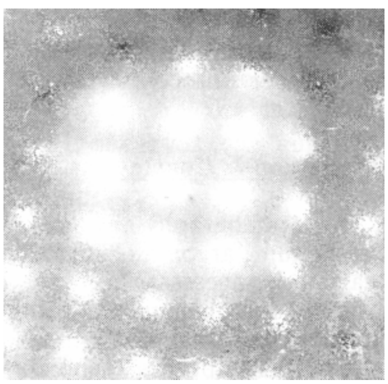

Figure 2. Autoradiograph (sample 0.2 mm away)

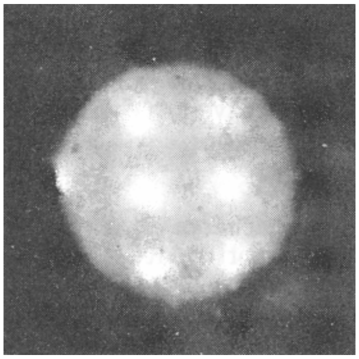

Figure 3. Autoradiograph (+ 0.67 kV/cm field)

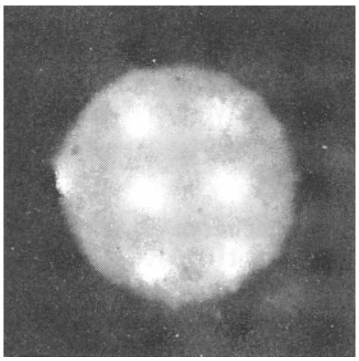

Figure 4. Autoradiograph (- 0.67 kV/cm field)

A few samples were also checked for X-ray emission on a low background silicon lithium (SiLi) detector with a thin beryllium window (1 keV energy threshold). The measurement time was typically 18 hours. No sample showed emission of X-rays above background.

Higher energy (≥ 20 keV) radiations emanating from the samples was also measured by a end window type gas flow detector (operating in Geiger Muller mode, 0.8 mg/cm^2 window). The typical background of the detector was 0.01 ± 0.002 count/s. Samples with D_2 or H_2 loading were observed to give 0.02 ± 0.002 counts/s (18 hours of counting). No counts above background were however observed when the sample was kept inside a windowless gas flow detector.

3. Discussion & Conclusions

Autoradiographs have been observed in oxygen and air atmospheres but not in helium, argon and nitrogen atmospheres. The presence of oxygen or air appears to be necessary to observe strong radiographs. It is likely that oxygen is assisting the phenomenon (Some other impurity present in oxygen as well as in air causing this phenomena although unlikely, cannot be ruled out). However there appears to be an optimum concentration (< 100 %) of oxygen in atmosphere at which the fogging is maximum.

The energy released in H_2-O_2 recombination reaction is 1.5 eV. If a few hundred to thousand times this energy gets transferred to a D ion then normal hot fusion can take place resulting in emission of energetic charged particles ($\leq 10^{-2}$/s), if there is a pathway to transfer the chemical recombination energy to deuterons. This may be possible only for certain metallurgical compositions and conditions. However there are several other phenomena in condensed matter which suggest that short lived large energy fluctuations (Dasannacharya 1989) do take place. These fluctuations can impart 100 to 1000 times the average energy.

4. References

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