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Photon and particle emission, heat production and surface transformation in Ni-H system

E. Campari[*+], G. Fasano[+], S. Focardi[*+], G. Lorusso[+], V. Gabbani[+], V. Montalbano[**+], F. Piantelli[**+], C. Stanghini[+], S. Veronesi[♦+]

[*] Phys. Department, University of Bologna

[**] Phys. Department, University of Siena

[♦]I.N.F.M. – UdR Siena

[+]Centro I.M.O.

The results obtained in several experiments on Ni-H system are presented here. Photon emission during the preliminary phases of activation and ^{1}H isotope absorption are shown; their correlation with the kind of surfaces (Ni and its alloys) and with neutron and other particle emission in the excitation progress and in large heat production is also presented. Finally the SEM-EDAX analysis of the sample surfaces after same months of heat production is shown; new elements (not present in the initial analysis) appeared. The concentrations of these elements with atomic number between C and Zn, is compared to the unmodified parts of same samples that remained inside the cell, outside of the activated region.

Introduction

In this paper we report a selection of more interesting experimental results obtained in a Ni-H system in the last years. In particular, we present photon, neutron and particle emission, energy production and surface analysis on metal samples.

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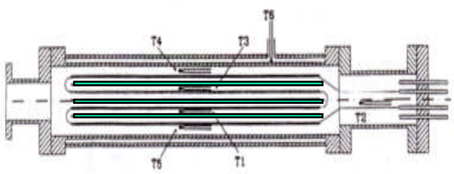
Cell for three planar samples



Cell for a cylindrical sample

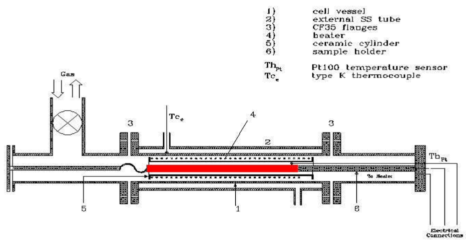


Figure 1. Two types of experimental cells.

We have studied systems composed by several kinds of metal samples, such as pure Ni, nickel alloys and nickel plated, of a cylindrical or planar shape, in a hydrogen atmosphere. In a typical experiment the samples were inserted in a cell, loaded with hydrogen at pressure in the range of 100-1000 mbar and kept at temperatures between 420 and 720 K [1-3].

Experiments were performed using three different kind of cells built to hold one cylindrical sample, four cylindrical samples, or three planar samples. The samples can be made of pure nickel, nickel alloys or they can be nickel-plated. They are chemically and physically cleaned by annealing cycles in vacuum and in hydrogen atmosphere.

Figure 2. A ceramic holder with a heater and a planar sample

A typical experimental set-up in these experiments is shown in Fig. 3. Usually, some temperature sensors are placed inside the cell in contact with the metal samples and heaters. Other thermocouples are places on the external wall of the cell in order to obtain a calorimetric measure of emitted power. All cell parameters, such as temperatures, pressure, power supply, are monitored by means of a computer data acquisition card (Labview).

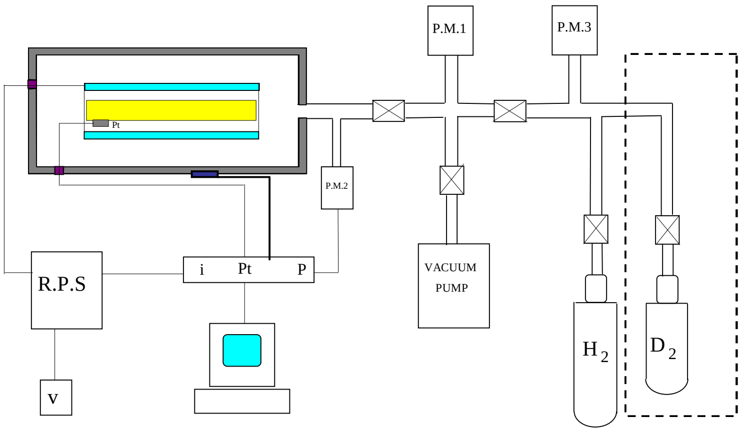


Figure 3. A schematic layout of experimental setup.

Hydrogen loading

In the cell, thermal cycles are performed in vacuum and in a hydrogen atmosphere. The gas pressure is maintained in the range 100 to 1000 mbar. During hydrogen loading it is possible to recognize two distinct types of behaviour [5,9]. Some samples shows a fast loading with characteristic time of a few hours. In Fig. 4, a typical fast loading, well fitted by an exponential function, is shown.

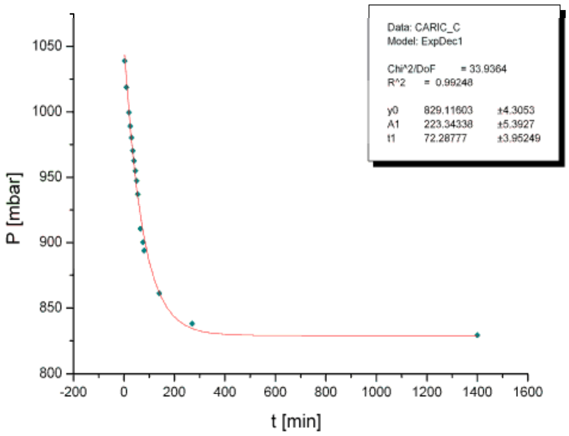


Figure 4. An example of fast hydrogen loading

In other experiments, a slow loading can be observed with characteristic time of days. In this case, the quantities of loaded gas are smaller and it is not easy to excite the metal sample in order to obtain excess heat. Fig. 5 shows an annealing cycle during a slow loading.

Moreover, it is possible to observe different slow rates of loading depending on the sample's temperature [5,6,9]

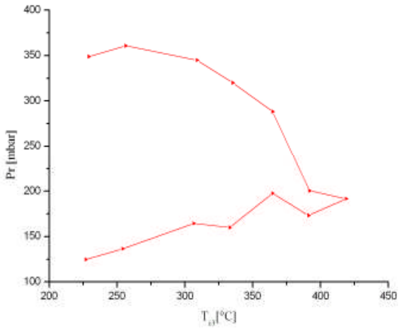


Figure 5. A cycle of slow hydrogen loading

Excess heat production

In all experiments, excess heat production is detected by means of a calibration. At the beginning of the experiment, a set of calibration curves is constructed by plotting the temperature of several reference positions as a function of the input power. An increase of measured temperatures allows us to determine the emitted power by using a simple calorimetric model [3].

In two experiments [3, 7] a considerable amount of energy was produced: a cell with a single cylindrical sample produced 900 MJ in 278 days; a second cell with four cylindrical samples produced 600 MJ in 319 days.

Many other examples of heat productions have been detected, such as that shown in Fig. 6. This shows a cell with planar samples where the measure of the energy production was made by using an internal probe of temperature and an external one. Both measurements give the same result. Thus, it is proved that no local phenomena on the internal probe (i.e. for example vortex) affected the measurement of heat production.

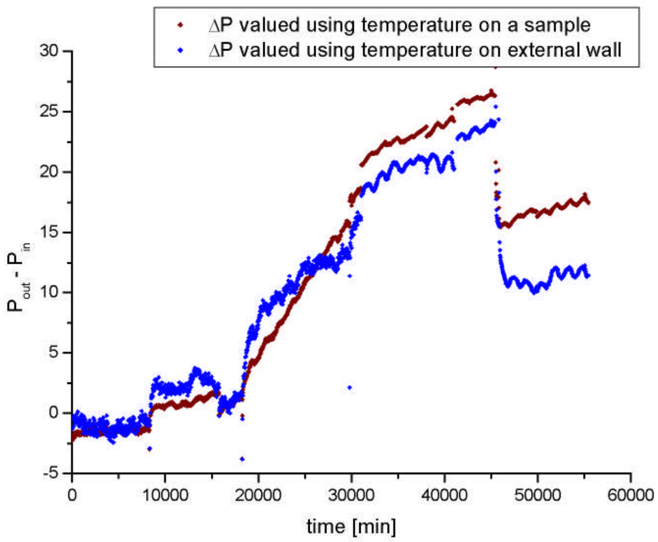


Figure 6. The difference between the measure of power by using a temperature inside the cell and a temperature on the external wall and the power supply during a heat production.

Photon, neutron and particles emission

A paper dedicated to evidence of photon emission from these systems is presented elsewhere [10]. Here we present, just as an example, an emission by a planar cell detected with a NaI counter [5]. The spectrum detected (Fig. 7) shows, superposed to the background, a peak centered at 661.5 ± 0.8 keV. Such peak energy was determined by using a High Purity Germanium detector. The emission arose when the cell was isolated from external influences and a sudden and brief decrease of the power supply induced a photon emission for a period of about twelve hours.

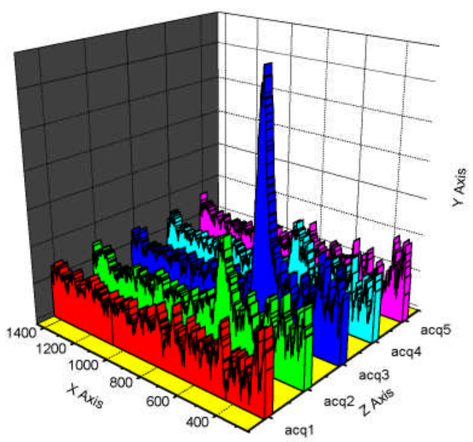


Figure 7. NaI γ-rays spectrum showing a peak superimposed on the background. Five following acquisitions are shown.

Moreover, in a previous experiment a neutron emission was detected [4] both by using He^3 counters, shielded with paraffin or polythene for neutron thermalization, and by means of gold activation shown in Fig. 8.

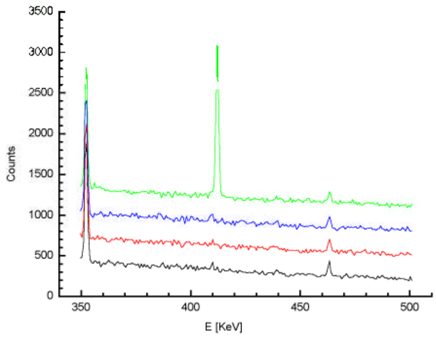


Figure 8. Gold activation $^{197}Au + n \rightarrow ^{198}Au + \gamma \rightarrow ^{198}Hg^{*} + e^{-} + \overline{\nu_e}$ is revealed by detecting the γ-ray emitted by Hg.

In the same experiment [5,7], particles emission has been detected by using a cloud chamber. An example of tracks is shown in Fig. 9.

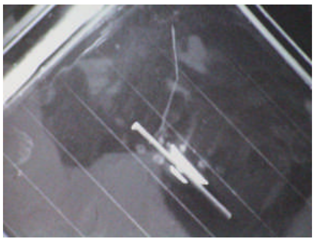


Figure 9. A charged particle emitted from a metal sample after loading, excitation and a long heat excess production.

Surface analysis

The surface of the samples has been analyzed by using a SEM which allows two different type of analysis: morphology and elemental distribution of the surface.

An electron gun excites atoms in the surface (until a depth of few μm), secondary electrons (SE) emitted by the atoms and back-scattered electrons (BSE) allow us to obtain images of the surface.

Furthermore, an X–microprobe with an energy-dispersive X–ray (EDX) system for elemental analysis is used to measure the elemental distribution on the surface in a quantitative fashion.

The surface analysis of nickel alloys are presented in ref. 11. Here we describe an analysis performed on a pure nickel specimen. As an example of morphological analysis, Fig. 10 shows a sample with two different regions.

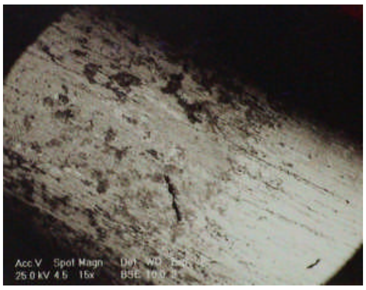


Figure 10. A Scanning Electron Microscope picture of a sample.

The right side of this image shows an unaltered surface, and the left side shows a surface with several alterations. In this case the sample was heated only in the region on the left, and it is likely that only here the loading and the excitation occurred.

The corresponding elemental analysis shows many new elements on the metal surface. Fig. 11 shows an X-microprobe analysis of the unaltered surface, where only nickel is present.

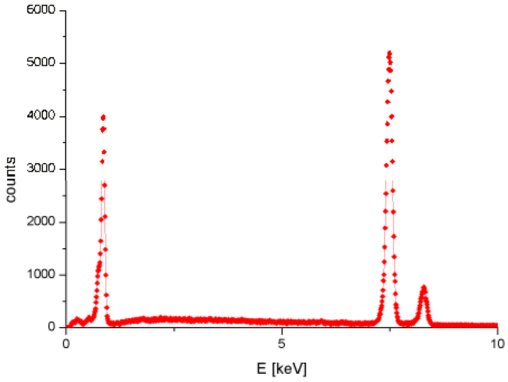


Figure 11. Elemental analysis of unaltered surface.

In contrast, the elemental analysis of the altered surface (Fig. 12) is very different from Fig. 11, and there is considerable variation at different points along the sample. Two examples are shown in Fig. 12 and 13.

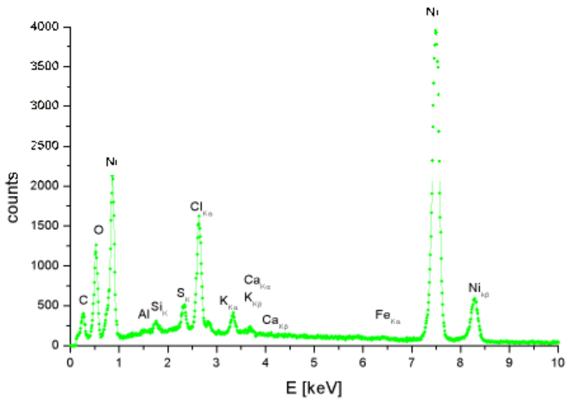


Figure 12. Example of elemental analysis of the sample

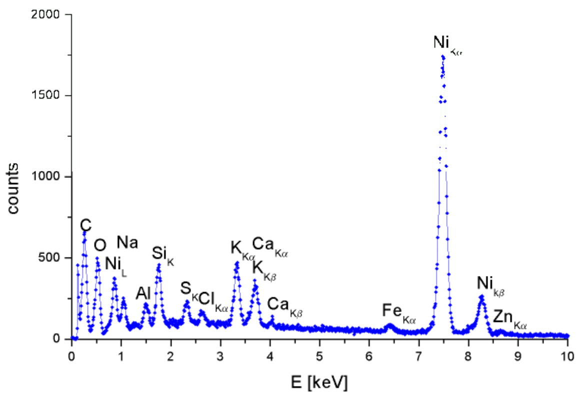


Figure 13. Another example of elemental analysis

Remarks and conclusion

This survey shows that very interesting and complex phenomena can arise in Ni-H system. On the other hand, these experiments seem to indicate that other, poorly understood parameters must be controlled to obtain similar experimental results. In particular, surface structure and geometry of cells are critical for loading and exciting nickel samples.

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