IL NUOVO CIMENTO VOL. 11 D, N. 6 Giugno 1989
NOTE BREVI

Neutron Emission under Particular Nonequilibrium Conditions from Pd and Ti Electrolytically Charged with Deuterium.

P. PERFETTI, F. CILLOCO, R. FELICI, M. CAPOZI and A. IPPOLITI
Istituto di Struttura della Materia del C.N.R.
Via E. Fermi 38, 00044 Frascati (Roma), Italia

(ricevuto il 29 Aprile 1989)

Summary. — We report on neutron emission in palladium and titanium electrolitically charged with deuterium. The detection of neutrons is observed after thermal treatment of the electrode. In the hypothesis that neutrons came from cold fusion processes, we estimate a fusion rate as high as $1.3 \cdot 10^{-21}$ fusions/deuteron pair/second.

PACS 64.75 – Solubility, segregation and mixing.
PACS 28.20 – Neutron physics.

Since the first announcements [1,2] that cold nuclear fusion is possible when deuterium atoms are electrochemically inserted into palladium (Pd) or titanium (Ti) lattices, there have been many attempts all around the world in trying to reproduce those results. Until now confirmations are very few and quite confused except the very recent experiment reported by Scaramuzzi *et al.* [3]. The reasons are that all the scientists facing the problem obtain, as first result of deuterium charging process on Pd or Ti, a very low neutron emission rate not very far from the background level. Without a very efficient neutron counter the

[1] S. E. JONES, E. P. PALMER, J. B. CZIRR, D. L. DECKER, G. L. JENSEN, J. M. THORNE, S. F. TAYLOR and J. RAFELSKI: *Observation of cold nuclear fusion in condensed matter*, to be published.
[2] M. FLEISCHMANN and S. PONS: *J. Electroanal. Chem.*, **261**, 301 (1989).
[3] A. DE NINNO, A. FRATTOLILLO, G. LOLLOBATTISTA, I. MARTINIS, M. MARTONE, L. MORI, S. PODDA and F. SCARAMUZZI: *Europhys. Lett.*, **9**, 221 (1989).

chances to observe neutrons are very small. This was indeed predicted by Jones [1] who used a very efficient neutron detector able to resolve the 2.45 MeV neutron coming from the

$$\text{(1)} \qquad \mathrm{D} + \mathrm{D} \Rightarrow {}^3\mathrm{He}(0.82\,\mathrm{MeV}) + \mathrm{n}(2.45\,\mathrm{MeV})$$

fusion reaction.

The expected fusion process rate reported by Jones' experiment was

$$\text{(2)} \qquad \lambda_f \simeq 10^{-23}\,\text{fusions/deuteron pair/second}.$$

For a 6 g Pd cathode used in an electrolytic cell and for a deuterium concentration D/Pd ≈ 0.6 (β phase), we obtain from relation (2) $N_f \simeq 1 \cdot 10^{-1}$ fusions/second. The real counting rate is given by $N_f \cdot \varepsilon$, where ε is the efficiency due to the experimental arrangement of neutron detectors. The possibility to extract neutron signals from the background strongly depends on ε and on background level. For example, in our laboratory we have a neutron experimental set-up with an efficiency $\varepsilon \approx 1\%$ and we should expect for the above example a real counting rate $\approx 10^{-3}$ neutrons/second to be compared with a background of $\approx 3.3 \cdot 10^{-2}$ neutrons/second. In this case it would be very hard to observe any neutron signal coming from fusion processes.

On the other hand, the results obtained by Fleischmann and Pons [2], based on calorimetric experiments and indirect neutron measurements, seem to predict a fusion rate much higher than what established by relation (2) and other fusion processes have been considered [2]. This is quite in contradiction with the first findings of scientists working on this subject, where the observed number of neutrons/second is quite in agreement with relation (2). We cannot exclude that a pretreatment of the electrodes could be the reason for these discrepancies.

Figure 1 describes our experimental apparatus. We used a platinum anode and 6 g of palladium wire ($\varnothing \approx 1$ mm) as cathode. The electrolyte was either D_2O + LiOH or D_2O + LiOD and the concentration was in the 0.1 to 0.3 M range. The electrolytic process obtained with a current flow of 8 mA/cm^2 occurs in a glass cell ($\varnothing = 2.5$ cm) immersed in a larger tank ($\varnothing = 11.0$ cm) containing H_2O as neutron moderator. Water has the purpose of thermalizing the high-energy neutrons coming from the cell. The size of the water moderator is optimized to get the highest efficiency with our available 30 neutron detectors placed around the H_2O container. The detectors are RS-P4-0406-221 proportional counter filled with ^{3}He at 20 atm manufactured by Reuter-Stokes. All the electronics from the preamplifiers and discriminators to the computer interface was developed inside our laboratory for time-of-flight analysis purpose. This electronic apparatus allows us to perform measurements as a function of time with different time resolution. With 30 independent detectors we have 256 available channels with a minimum measuring time of 3 μs each. The neutron detector apparatus is

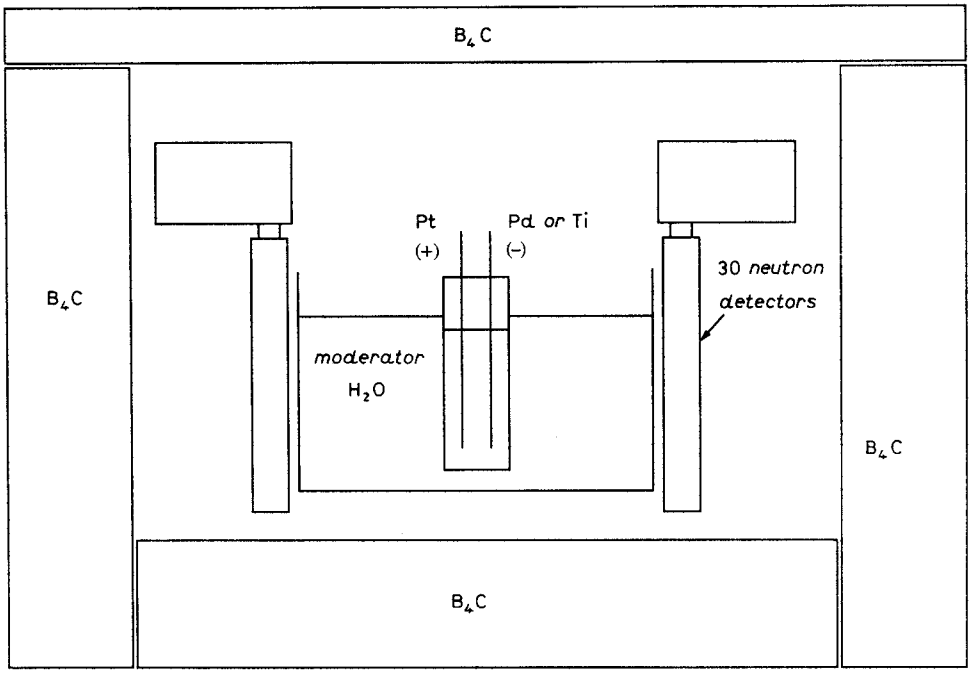

Fig. 1. – Scheme of the experimental apparatus.

completely surrounded by B_4C shields (20 cm thick) in order to reduce the ambient neutron background. Using a calibrated neutron source we measured an efficiency $\varepsilon \approx 1\%$. To try to better extract neutron signals during the electrolytic process we performed one hour cycles with the electrolytic current cell on and off alternatively. Five minutes counting time was used during cycles and the results reported in fig. 2 are the average of a 24 hours run. The horizontal line represents the background level ≈ 2 counts/min. As we already noted with the fusion rate reported in relation (2) it would be impossible to observe above background neutrons coming from possible fusion processes. Nevertheless in fig. 2 we note signals merging above background at certain stages of our working cycles particularly at the end of deuterium charging process and at the beginning of the resting period. We cannot exclude that we have a neutron counting rate higher than what predicted by relation (2). The Pd charging process with deuterium through electrolysis is a nonequilibrium thermodynamic process and, from the analysis of fig. 2, we rise the question if there could be particular nonequilibrium processes able to better catalyze D-D fusions. We note that palladium charged with deuterium exists in two different crystallographic phases α and β [4]. In both phases the system retains its f.c.c. configuration but

[4] F. A. LEWIS: *The Palladium Hydrogen System* (Academic Press, London and New York, N. Y., 1967).

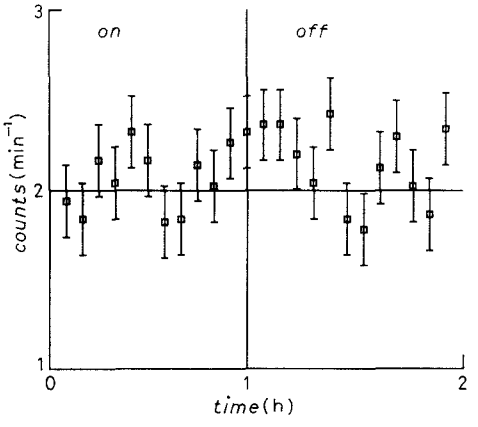

Fig. 2. – Neutron counts during 1 hour cycles with the electrolytic current cell on and off alternatively. Each point corresponds to 5 min measuring time. The horizontal line is the background level.

with 3% larger lattice parameter in the β phase. The two phases are also characterized at equilibrium by very different deuterium concentration, $D/Pd \approx 0.01$ for the α phase, and $D/Pd \approx 0.6$ for the β phase. A sudden $\beta \Rightarrow \alpha$ transition could create the physical conditions to enhance the D/D fusion processes.

To create particular nonequilibrium conditions we decided to warm up the Pd wire charged in the β phase. The deuterium concentration was monitored by the cathode weight change. The Pd cathode placed in an empty glass container, similar to that used for the electrolytic process, was subjected to a current burst of 10 A for 1 minute. We did not measure accurately the temperature reached by the Pd wire and we can only estimate from a thermocouple badly in contact with it that the temperature was higher than 100 °C. In fig. 3*a*) we report three different experiments selected among different runs. The neutron counts were accumulated every minute and the vertical arrows refer to the beginning of one minute current bursts. All the measurements show that with a delay of nearly 2 minutes signals well above background are detectable. Considering our efficiency ($\varepsilon \approx 1\%$), we have, for the highest peak of fig. 3*a*), about 800 fusions/minute, under the hypothesis that these are related to fusion processes, we have with 6 g of Pd used in this case

$$\lambda_f \approx 1.3 \cdot 10^{-21} \text{ fusions/deuteron pair/second}. \tag{3}$$

This value is 2 orders of magnitude higher than that reported by Jones (see relation (2)).

A similar result has been obtained for a Ti cathode charged with deuterium in a similar manner but obtaining a very low concentration, $D/Ti \approx 0.03$. The results are reported in fig. 3*b*).

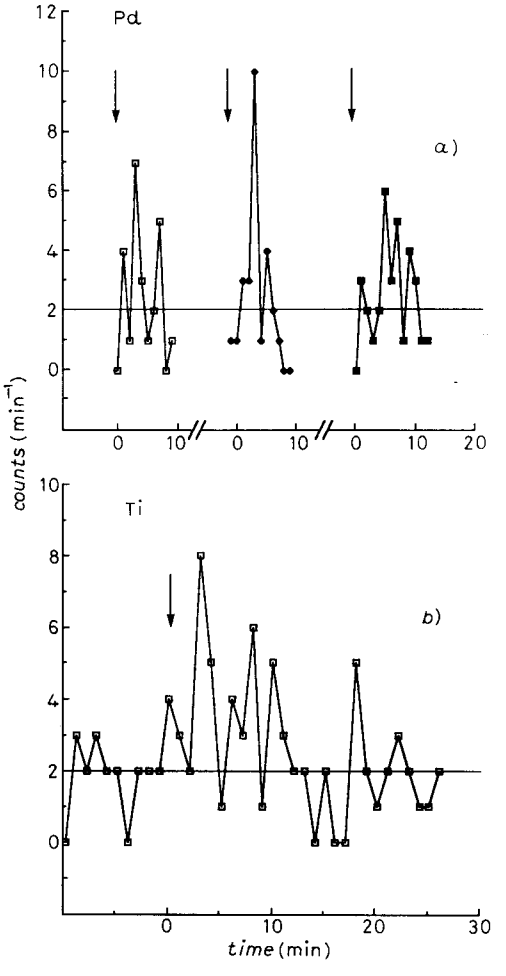

Fig. 3. – *a*) Neutron counts accumulated every minute for three different experiments performed on palladium charged with deuterium and subjected to one minute current bursts. The arrows refer to the beginning of heating. *b*) Same for the deuterium-charged titanium.

From our experiments we note that the production of neutrons is present in Pd or Ti charged with deuterium when they are subjected to a thermal treatment. Since in ref. [1] the observation of neutrons having the exact energy predicted by reaction (1) has been reported we also favour the interpretation that the neutrons we observe are due to possible fusion processes, even if we cannot exclude at the moment that they are due to other unknown mechanisms. We note also that in our case the effect is not peculiar of the electrolyte since it is observed when the cathode is removed from the electrolytic solution. Temperature changes ((50 ÷ 300)°C) of Pd(Ti) seem to be a quite practical way to induce a $\beta \Rightarrow \alpha$ transition which in turn could remove local dislocations and

catalyze fusion or other processes. Work is in progress to answer all these questions.

* * *

We wish to acknowledge all the personnel of our institute for the stimulating discussions and for the help given to reach the results so quickly. In particular we acknowledge S. Rinaldi and F. Zuccaro for the mechanical support.