Measurement of 2.5 MeV Neutron Emission from Ti/D and Pd/D Systems

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ABSTRACT

A new set of measurements of neutron emission from gas (D_2 and H_2) loaded Ti and Pd systems has been carried out in the TOFUS experiment. The temperature and pressure controls of the gas loading apparatus were improved. The results concerning the Ti/D system show the presence of a small 2.5 MeV neutron emission, with a signal having a statistical significance of ~ 5σ. The results on the Pd/D system doesn't show a statistically significant signal (less ~ 2σ).

1. Introduction

Since the start of the debate about the occurrence of D-D fusion phenomena in the lattice of some metals like Pd and Ti, the detection of neutrons, in particular 2.5 MeV neutrons, has been considered as the most reliable signature of the effect. In order to clarify this point, a sophisticated neutron detector was designed and built for the TOFUS experiment and in a first set of measurements we observed a small amount of neutron emission following the loading of Ti shavings with gaseous D_2 [4], with a statistical significance of ~ 2.5 σ. After a number of improvements on the heating system of the apparatus a second set of measurements has been performed with a better control of the pressure and temperature of both the metal and the gas [1].

The results shown here concern the Ti/D and Pd/D systems: blank measurement on the Ti/H and Pd/H systems have been performed too, in the same way as those ones with D, in order to avoid possible variations of the performances of the scintillators and detector electronics due to the heating cycles.

2. Experimental set-up and description of the thermal cycles

Concerning the neutron detector, it has been already described in previous papers [1, 2, 3] and we just recall here the performances: the neutrons are detected by two blocks of plastic scintillators NE110 in coincidence (double scattering technique) and their energy is determined using a reconstruction method

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based on the measurement of the neutron Time of Flight (TOF) and of the impact position onto the scintillators.

A cylindrical cell is located in front of the first block and contains the metal: it can be loaded with gaseous D_2 or H_2 and degassed up to a vacuum of 10^{-11} bar. Two K-type thermocouples, the first one embebbed in the metal and the second one lying in the upper internal part of the cell, allow to monitor simultaneously the temperature of the metal and of the surrounding gas. The pressure of the gas is monitored too, by means of a piezoresistive pressure gauge located in the upper part of the cell.

For the Ti measurements, 20 g of high purity Ti sponge supplied by GINATTA TORINO TITANIUM SpA, were used. The operating thermal conditions of the Ti/gas system were chosen with the aim of exploring the dependence of the neutron emission, if any, upon the thermodynamic conditions. After the degasing step, a known amount of D_2 was dosed at room temperature. The Ti/D system was submitted to a number of thermal cycles consisting of a heating step from room temperature (~ 25°C) up to 540 °C at least (called run UP) followed by a cooling step to the room temperature (called run DOWN). During these cycles the gas flowed out and in the metal, as monitored by the increase and decrease of the pressure respectively and phase transitions occur in both UP and DOWN runs. During these repeated cycles, the morphology of the Ti gradually changes from sponge to a powder. This is due to the large strains associated with the hydride formation and phase transformations which cause the formation of internal cracks and fractures and ultimately lead to the crystals fragmentation.

The cycles were performed at two atomic ratios, 0.7 (~ 20% of the total data taking) and 1.8, i.e. near the saturation (~ 80% of the total data taking). For the higher loading runs the cycles in the Ti deuteride phase diagram were such that only the δ phase was concerned and therefore no phase transition was observed.

The duration of a run UP was ~ 100 minutes and the total number of runs UP was 12; an equal number of runs DOWN was performed, each one of ~ 250 minutes, followed by several hours (~ 13) at steady temperature for a total time of 13933 minutes. Also, 4 runs UP and 4 runs DOWN with Hydrogen gas (blank runs) having the same duration of those ones with Deuterium, were performed for a total time of 4631 minutes.

For the Pd measurements we used 54 g of metallic Pd in form of small cylinders, of diameter 1 mm and length ~ 2 mm. The operating thermal conditions were: 6 cycles UP from 20 °C to 350 °C and 6 cycles DOWN from 350 °C to 20 °C through α and β phases, for a total time of 2820 minutes with D_2 and the same with H_2; the atomic ratio was ~ 0.7. At the end of the experiment the small cylinders of Pd resulted to be transformed into small spheres due to the lattice strain release during the α–β phase transition producing the formation of internal cracks and dislocations.

If an emission of 2.5 MeV neutrons from the cell occurs, one expects that, by subtracting the spectra observed during the blank runs from those ones observed during the runs with D (all properly normalized in time) some excess should appear in the energy region around 2.5 MeV: in fact, looking at the Fig 1, where such a subtraction is reported, one sees that the energy channel between 2 and 3 MeV contains an excess of ~ 377 counts with a significance of about 3.9 standard deviation. Another way of searching for neutron excesses is that of subtracting from each run with D_2 filling the total spectrum obtained with H_2 filling, properly normalized in time. The counts in each channel were then obtained as the weighted mean of the values obtained for each D_2 run and the error was calculated as the standard deviation. The result is shown by Fig.2 and no substantial difference is apparent between the two methods, apart the reduction of

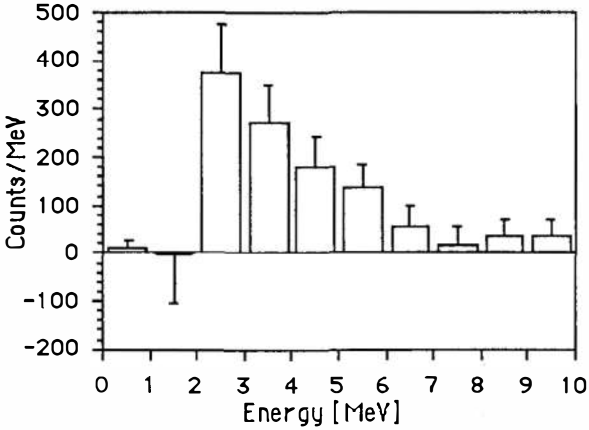

Fig.1 Difference between the neutron emission spectra observed in Ti/D and Ti/H systems: the error bars refer to the statistical error only and must be intended plus and minus.

the errors. The channel between 2 MeV and 3 MeV is again the most populated, at a 5.4σ level. As a further confirmation that the signal in this channel is not due to the subtraction method, such a procedure has been applied also to two halves of the total background measurements chosen at random obtaining a statistical fluctuation consistent with zero. An estimate of the neutron production per unit mass and time

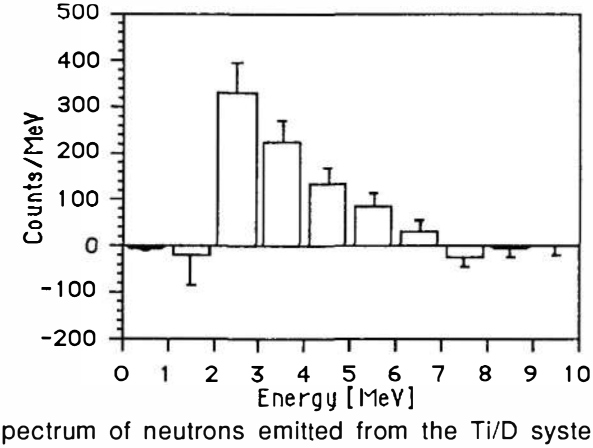

Fig.2 Spectrum of neutrons emitted from the Ti/D system (single runs analysis, as described in the text).

was made assuming that the neutron production rate was independent from time: on this basis a result of 0.11±0.03 neutrons g^{-1} s^{-1} has been obtained.

As a final remark we point out the total absence of neutron bursts in our measurements, never detected at the trigger level nor by the fast counters.

Concerning the measurements on the Pd/gas system, the total time for the data acquisition was considerably lower for both D_2 and H_2, with respect to the Ti:

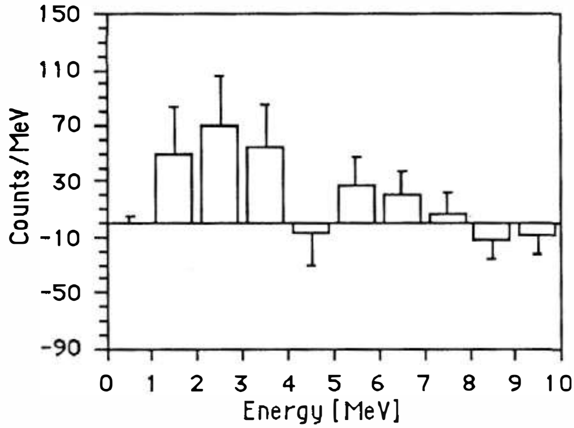

Fig.3 Difference between the neutron emission spectra observed in Pd/D and Pd/H systems: error bars as in Fig.1.

this was due to the decision of stopping the cycles when the Pd metal morphology showed to be highly modified with respect to the initial situation.

The same analysis applied to the Ti data was applied to the Pd runs and the result is shown by Fig.3: also in this case a small signal of ~ 70 events appears in the channel between 2 and 3 MeV, with the typical smearing on the nearest channels, but the statistical significance is small, less than 2 standard deviations. The neutron emission rate would be 0.02±0.01 neutrons $g^{-1}s^{-1}$. Of course no burst has been counted.

3. Conclusions

In conclusion, we have confirmed with a greater statistical significance (5σ), the emission of 2.5 MeV neutrons from a Ti/D system submitted to thermodynamic cycles. No such a significant neutron emission was observed for the Pd/D system, again submitted to thermodynamic cycles corresponding to a crossing between the α and β phases. However, the neutron rate observed in this experiment is one order of magnitude lower than that observed in a previous experiment. We attribute this difference to the different nature of Ti metal used in the two experiments and we plan to repeat with the improved cell and with a further improvement in the neutron detector the measurement with the Ti shavings.

4. References

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