Neutron emission during the mechanical treatment of titanium in the presence of deuterated substances

A. G. Lipson, D. M. Sakov, V. A. Klyuev, B. V. Deryagin, and Yu. P. Toporov
Institute of Physical Chemistry, Academy of Sciences of the USSR

(Submitted 27 April 1989)
Pis'ma Zh. Eksp. Teor. Fiz. **49**, No. 11, 588–590 (10 June 1989)

Neutron emission has been observed during the mechanical treatment of titanium in the presence of several deuterated substances: D_2O, LiD, and polypropylene (D_6).

We have shown previously[1,2] that a neutron emission is observed during the shock loading of several solids containing deuterium (heavy ice, D_2O, and LiD). This neutron emission is evidence that individual DD nuclear reactions occur in the fracture zone. Reports of the observation of DD reactions during the saturation of titanium, palladium, and certain other transition metals with deuterium make it worthwhile to check the effect of mechanical treatment on titanium in the presence of objects containing deuterium, in order to learn whether nuclear fusion reactions can also be caused in these systems by mechanical treatment.

We selected for study titanium shavings (of commercial purity), D_2O, deuterated polypropylene PP(D_6), and lithium deuteride (LiD). The experiments on the mechanical treatment of the titanium were carried out on an M-35 laboratory eccentric vibration mill at a frequency of 50 Hz and an amplitude of 5 mm (at an energy level ~ 10 W/g). The titanium shavings were mixed with the deuterated objects in certain proportions and placed in a steel drum with a hermetically sealed cover, which was filled two-thirds full with steel balls 6 mm in diameter.[3,4] As a control, we crushed the titanium shavings and also the D_2O, the LiD, and the PP(D_6) separately.

The neutrons were detected by an array of seven NWI-62 proportional counters, immersed in an oil-filled tank lined with sheet cadmium. The array of detectors was positioned 15 cm from the working drum of the vibration mill (Fig. 1). The signals from the counters were fed to an AI-256-6 pulse-height analyzer with digital printout. The efficiency of a detector was calibrated with the help of a Po-α-Be neutron source with an intensity of 200 neutron/s. This source was placed in the cell of the vibration mill in place of the working drum (curve 1 in Fig. 2). At certain time intervals, we also recorded the natural (cosmic-ray) neutron background with the working drum removed from the cell.

The experiments showed that when only the titanium shavings were dispersed, or when the components containing deuterium were dispersed separately, there is no increase above the natural neutron background (0.05 count/s). Upon the dispersion of titanium shavings along with 10% heavy water or 4–5% deuterated polypropylene (D_6), and also with the two components together, the neutron count rate exceeds the cosmic-ray background count rate by a factor of five to six (the detected efficiency is being taken into account here). The maximum neutron count rate is observed for the

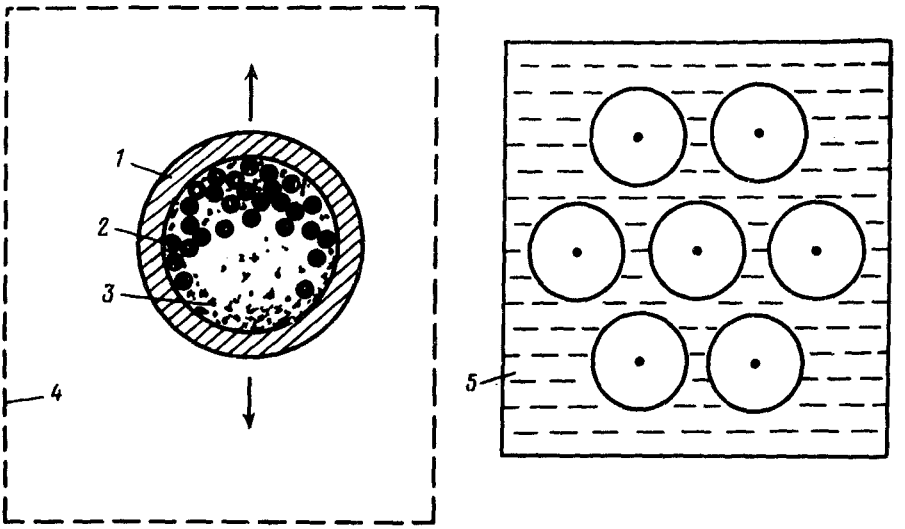

FIG. 1. Experimental apparatus. 1—Working drums; 2—steel balls; 3—titanium shavings with deuterated components; 4—wall of vibration mill; 5—neutron detection unit.

system Ti + 10% D_2O + 4% PP(D_6) (Fig. 2, curve 2); this maximum rate is 0.31 ± 0.03 count/s in the dispersion process. Approximately the same increase above the background level is observed for 8–10 min after the mechanical treatment of the given system is terminated (0.30 ± 0.13 count/s). The maximum effect in the system Ti + 10% D_2O + 4%PP(D_6) is detected when the working drum is frozen in liquid nitrogen in 3–6 min after the termination of the mechanical treatment; this maximum effect is 0.40 ± 0.14 count/s. After three or four cycles of the vibration dispersion, in three-min sessions, the neutron count rate falls off and becomes indistinguishable from the natural neutron background. It is not restored during a subsequent mechanical treatment. Effects with a lower count rate were also observed in a system in which LiD was the deuterium source instead of PP(D_6), which were dispersed with the titanium shavings. In this case the increase above the background was far weaker, and the neutron count rate was 0.14 ± 0.06 count/s. In this case again we observed an increase above the background level after the termination of the mechanical treatment and when the working drum was frozen in liquid nitrogen.

A weak neutron emission (10–30 neutron/s) is thus observed during the mechanical treatment of titanium in the presence of deuterated substances and for a certain time after the treatment is ended. This emission is evidently a consequence of DD reactions as the particles of the mechanically crushed titanium become saturated with deuterium. The mechanism for the effect in this case may be a mechanochemical decomposition of the deuterated components[4] with a diffusion of deuterium across the freshly formed titanium surface into the crystal lattice of the titanium in the case in which there is a significant contact pressure during the vibrational dispersion. Since titanium absorbs up to 200% deuterium, and the deformation of the lattice can corre-

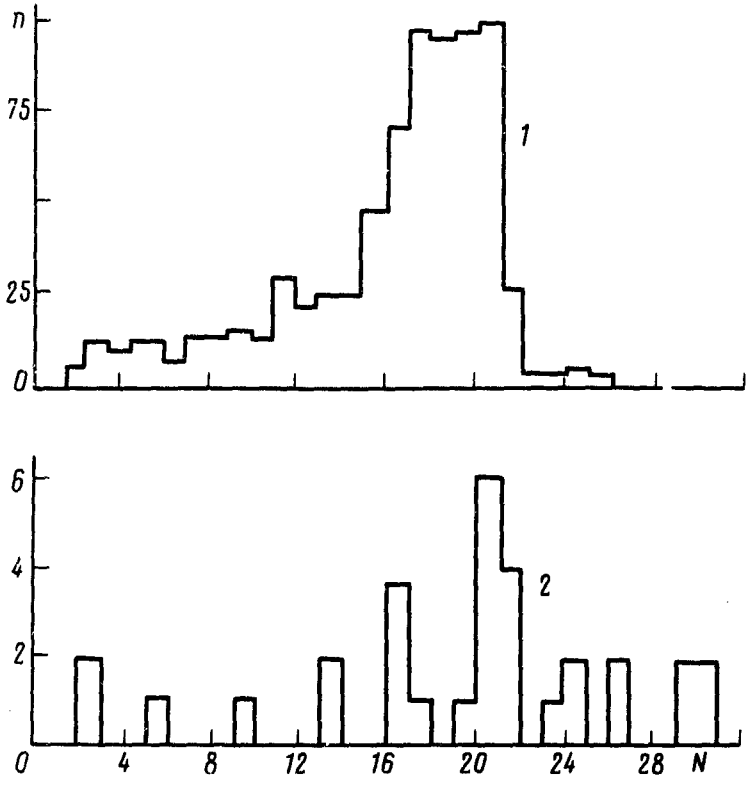

FIG. 2. Histograms of the distribution of counts among the channels of the analyzer. 1—From a neutron source; 2—during dispersion of the system consisting of titanium + 10% D_2O + 4% PP(D_6). The exposure time was 1 min.

spondingly reach[5] 25%, the conditions in the lattice will apparently promote an effective decrease in the distance between deuterons in regions with a high energy concentration. Such regions form in the interior of the titanium during the mechanical treatment. Another important point is that when the crystal lattice is destroyed, electric fields $\sim 10^7$ V/cm arise and can substantially lower the Coulomb barrier of the deuterons,[1,2] promoting an increase in the probability for DD reactions.[6] The increase in the neutron count rate when the samples are frozen in liquid nitrogen may also be indirect evidence of "solid-state nuclear reactions" during the absorption of deuterium by the titanium lattice, since we know that the equilibrium phase pressure of hydrogen (or deuterium) decreases with decreasing temperature of the titanium. The decrease is accompanied by an increase in the absorption of deuterium.[5] Furthermore, as was indicated above, the observed depletion of the neutron emission can be explained on the basis that the titanium particles reach a size of less than 1 μm, and in the process their surface is modified by the polypropylene.[3] The effect is to stop the diffusion of deuterium into the titanium lattice, so the neutron count rate approaches the cosmic-ray background level.

Further research is required to determine the nature of the DD reactions in the titanium lattice.

We wish to thank Academician I. M. Frank, Yu. M. Ostanevich, A. V. Strelkov, and E. P. Shabalin for furnishing the apparatus for detecting the neutrons and for several useful pieces of advice.

[1]B. V. Deryagin *et al.*, Kolloid. Zh. **48**, 12 (1986).
[2]V. A. Klyuev *et al.*, Pis'ma Zh. Tekh. Fiz. **12**, 1333 (1986) [Sov. Tech. Phys. Lett. **12**, 551 (1986)].
[3]V. A. Kuznetsov *et al.*, Dokl. Akad. Nauk SSSR **299**, 1170 (1988) (sic).
[4]G. Heinicke, *Tribochemistry*, Akad. Verlag, Berlin, 1984, p. 496.
[5]*Hyrides of the Transition Metals* (Russ. Transl. Mir, Moscow, 1975, p. 311).
[6]L. A. Artsimovich, *Controlled Thermonuclear Reactions*, Gordon and Breach, New York, 1968.

Translated by Dave Parsons