Anomalous Effects in Deuterium/Metal Systems

Long Heqing, Sun Sihai, Liu Hongquan, Xie Renshou
Institute of Sichuan Material and Technology
Zhang Xinwei, Zhang Wushou
Institute of Applied Physics and Computational Mathematics
P.O.Box 8009, Beijing 100088, PRC

Abstract

Stable and high yield of neutron had been measured repeatedly in the glow discharge process of the flowing rare deuterium gas in a Deuterium / Metal system consisted of Pt, Nb, W, Cu, Mo, Ag or Fe with D respectively.

A layer of metal film which was deposited on the inner surface of glass reaction bulb in the glow discharge process and insulated from electrodes played key action on inducing anomalous effects repeatedly. Neutrons had been measured by activation detector (^{115}In, ^{193}Ir) and recoil proton neutron spectrometer; there was a continued spectrum in the energy range from 0.5Mev to 11Mev; The average neutron energy was 3.55Mev; different heights of peak appeared at (0.5–1.0)Mev, (3.0–3.5)Mev, (5.0–5.5)Mev, (8.0–8.5)Mev (9.0–9.5)Mev and (10.0–10.5)Mev; but the neutrons of (2.0–2.5)Mev interesting to people appeared in a valley of the energy spectrum and their yield was only 7–8% of the total yield of neutrons. The highest yield of neutron appeared in D / Pt system, the lowest appeared in D / Fe system, the highest average yield of neutron was 8.3×10^3n / s in D / Nb system (observed time 470min.), the yield of neutron burst was $(0.26-6.2) \times 10^6$n / s(time interval 0.1s).

Intense gamma–ray emission had been detected at same time, the average activity was 3.1×10^4Bq (detected time 175min.). There was a continued gamma spectrum in the energy range from tens Kev to > 20Mev, different heights of peak appeared at tens Kev(point a), 3.4Mev (b) and 5.8 Mev(c),The peaks of energy>7Mev were not quite certain.

The similar experiments were conducted many times with hydrogen or helium gas instead of deuterium but no neutron over background was detected.

Keywords

Deuterium / Metal systems, neutron spectrum, gamma spectrum, activation method, anomalous nuclear effect.

1. Introduction

Since the announcement of cold fusion by Fleishmann and Pons[1], there have been a lot of research works on D / Pd or D / Ti system in the world, Eiichi Yamaguchi[2] had presented gigantic neutron bursts of $(1-2)\times 10^6 n/s$ in Mn–o / Pd: D / Au system, but no average yield and spectrum of neutron.

As for the neutron emission in anomalous nuclear effects, there were only yield of neutron burst and rough energy range but no stable neutron emission and energy spectrum in past papers. The reasons were <1> rate of neutron emission was low, <2> anomalous nuclear effects couldn't be controlled and repeated, so the neutron energy spectrum (NES) and gamma spectrum couldn't be measured exactly, our works have been getting on aiming these questions.

2. Experiments

As having presented[3], we had reached $\sim 10^2 n/s$ of average neutron yield in a D / Pd system by the dynamic low pressure gas discharge method. But it was far away for measuring NES and neutron activation. At latest, it was found by Long Heqing that there had been intense neutron and gamma–ray emission in Deuterium / Metal systems consisted of Deuterium with some Metals (as Pt, Nb, W···) except Pd or Ti. At present, high yield of neutron emission ($\sim 10^4 n/s$ averaged) could be lasting as you want. The features of this method are <1> electrode is made of Pt, Nb, W··· etc., <2> a film of metal (same as metal of electrode) is deposited on the inner surface of the reaction glass bulb and insulated from electrodes, <3> low pressure deuterium gas flow is supplied, <4> the parameters are suitable for glow discharge. When the applied voltage is greater than 17KV there will be intense neutron and gamma–ray emission to be observed.

The apparatus used in this work have been discribed in previous publication[3], but the measuring systems will be introduced in detail.

2.1 NES measurement

NES was measured by a recoil proton fast neutron scintillation spectrometer, it had low response for gamma–ray. The counts rate of gamma–ray, which emitted from ^{60}Co and its energy > 0.5Mev, was only 0.05%. It was interference–free efficicently. NES was transformed from proton–recoil spectrum measured in the experiments, the inverse matrix F^{-1} could be calculated from proton–recoil spectrum of ^{238}Pu–Be Neutron Source and its NES[4] so the neutron spectrum is given by

$$N = F^{-1} M \tag{2.1}$$

where M is column matrix of proton–recoil spectrum.

2.2 Activation

Activation was the most reliable neutron measurement method in a high electromagnetic interference environment. ^{115}In and ^{193}Ir active pieces were placed in paraffine slowing–down layer (7.5cm thick, it is 15cm from the center of reaction bulb) and irradiated for several hours, then measuring the activity by α, β measuring apparatus with low background.

2.3 Neutron burst

Neutron burst was defined of maximum counts in 0.1s in the experiments, the mono–channel output of spectrometer was linked with the entrance of computer (IPC–610) accross counting board, it could show the counts of every time interval (0.1s).

2.4 Gamma–spectrum measurement

A NaI scintillation counter was used as the gamma–ray spectrometer, the measurement efficiency was 0.8% for the gamma–ray emitted from ^{60}Co, the counts of background was 13CPS after shielding.

3. Results

3.1 Neutron yield

<1> Relative yield of neutron

Relative neutron yield of different D / M systems are shown in Table 1, these metals were chosen at random and neutron emission could be measured in all of D / M systems, the relative order was Pt, Nb, W, Pd, Ag, Cu, Mo and Fe.

<2> Activation

For scaling active pieces, similar experiments were conducted with ^{238}Pu–Be Neutron Source instead of the reaction bulb, the ^{238}Pu–Be Neutron Source was placed in "center of the reaction bulb" and irradiating for 20min., then neasuring the β activity of active pieces, the results are shown in Table 2. The effective distance in Table 2 was deduced from point source formula.

In experiments, the active pieces were bare ^{115}In pieces, ^{115}In pieces wraped by cadmium (Cd) and bare ^{193}Ir pieces, the results of D / Nb system are shown in Table 3, the average yield of neutron calculated from the average fluence rate was $2.64 \pm 0.36 \times 10^3$n / s. The results of D / Pt system are shown in Table 4, the average yield of neutron calculated by same method was $1.24 \pm 0.51 \times 10^4$n / s.

The measuring half life period of ^{116}In (53.03 ± 5.5min) and ^{194}Ir (19.6 ± 1.6hour) consisted well with standard value 54.1min and 19.4hour respectively.

The result of ^{115}In piece which wraped by cadinum and had been irradiated for 4 hours was background level.

<3> NES method

Less understanding of neutron distribution in anomalous nuclear effects, we assumed neutrons were emitted from a "point source" and the effective distance $R_{eff} = 8.7$cm was deduced from ^{238}Pu–Be Neutron Source instead of the reaction bulb at same condition.

The fluence rate of D / Nb system is shown in Table 5. The average neutron yield was $6.1 \pm 1.6 \times 10^3$n / s, the maximum average neutron yield was 8.3×10^3n / s (observed time 470min.). Comparing results of the two methods, it is consistent in 40% relative deviation.

3.2 Neutron Spectrum

From the NES of ^{238}Pu–Be Neutron Source[4] (shown in Fig.1) and the measured proton–recoil spectrum by our spectrometer. We calculated inverse matrix F^{-1} with formula(2–1) (Energy interval was chosen of $\Delta E = 0.5$Mev), the detection efficency of energy interval was calculated from the proton–recoil spectrum with the NES and is shown in Figure 2.

We had scaled the spectrometer by a 2.45Mev monoenergitic neutron source, the channel was as same as of the ^{238}Pu–Be Neutron Source.

NES of D / Nb system is shown in Figure 3 (980min.) and Figure 4 (470min.). The results of Figure 3 was accumulation of that of Figure 4, their shape and peaks are consistent with each other. Because of low yield of neutron in D / Pd system, there was only NES of $E < 6.0$Mev in Figure 5. NES of D / Pt system is shown in Figure 6. NES of $E < 6.0$Mev of three systems are similar.

For D / Nb system, the interval of neutron energy was from 0.5Mev to 11.0Mev, the average energy was $\bar{E}_n = 3.55$Mev, five different heights of peak appeared at (3.0–3.5)Mev, (5.0–5.5)Mev, (8.0–8.5)Mev, (9.0–9.5)Mev and (10.0–10.5)Mev. But the spectrum of D / Pt system was broken off in the interval of (8.5–10.5)Mev, it seemed that there were higher energy neutrons ($E >$ 10.5Mev), there were five peaks too. The neutrons of (2.0–2.5)Mev interesting to people appeared in a valley of the energy spectrum and their yield was only 7–8% of the total yield of neutrons.

3.3 Gamma–ray

Gamma spectrometer was scaled by ^{22}Na, ^{60}Co and ^{137}Cs gamma–source. The results are shown in Table 6. But the spectrometer had some response for ^{241}Am gamma–source (0.05957Mev), so the data of low energy in Table 6 couldn't be used.

Gamma–spectrum of D / Nb system is shown in Figure 7. The interval of energy is from tens Kev to $>$20Mev, the peaks of $E < 7$Mev are obvious, they are tens Kev(point a) , 3.4Mev(b) and 5.8Mev(c).The peaks of high energy are less clear because of low intensity, notably the yield of gamma–ray was about ten times of neutron.

3.4 Contrasted Experiments

The similar experiments were conducted with hydrogen gas and helium gas instead of deuterium but no neutron over background was detected.

The neutron counts for 70 minutes are shown in Figure 8 and Figure 9, there are 0.3CPM interference counts in 44–90 channel (corresponding 0.5–1Mev) because of 17–24KV high voltage appied in the experiments, it could be neglect.

4. Discussion and conclusion

4.1 Gas discharge process

In the dynamic low pressure gas discharge process, a lot of atom or atom cluster would be sputting from electrodes and depositing on the inner surface of reaction bulb to form a metal film. Plasma was formed in major part space between electrodes; in addition, there would be a accelerating field on the inner surface of metal film, it made $D^+(D_2^+)$ moving to the metal film. Other wise, the density of Deuterium was low in the electrodes because of high temperature on it. So the anomalous effects were caused by the metal film mainly but not the electrodes.

4.2 Contribution of Beam–Target neutron

As a result of calculating, the neutrons caused by beam–target effect were less than 100n / s, it was less than 2% of total neutrons. If there were a lot of neutrons caused by beam–target effect there would be a peak of (2.0–2.5)Mev in the NES, just the opposite, there was no and the neutrons in there were only 7–8% of total neutrons.

Another fact was if the deuterium gas pressure added to 27–50Pa the counts of neutrons did not reduce obviously.

4.3 High energy neutrons

It seemed that there had been high energy neutrons in NES of D / Pt and D / Nb systems, because of our spectrometer limitation, the high energy neutrons (E > 11Mev) couldn't be determined. It needs advance research.

4.4 The action of metal

The metals in experiments were chosen at random, they don't take part in the primary reaction in anomalous nuclear effect at least, but the secondary reaction maybe, the coulomb barrier between deuterons may be reduced by metal help, so the reaction possibility rises notably. The peaks in NES and gamma–spectrum may be relate multi–body fusion. But simulation indicate, only multi–body fusion can't explain the peaks[5].

Acknowledg ments

The authors express their thanks to Mr. Wu sheng, Wu DongZhou, Zhou Ruyan for their discussion and supporting, thanks to members of taking part in the experiments for their combining and helping, especially thanks are due to Prof. Li Xinzhong for his help and support.

References

(1) M.Flieshmann, S.Pons and H.Hawkins, J.Electronal. Chem. 261, 301(1989)

(2) Eiichi, Yamaguchi et al., Jpn. J.Appl. Phys. 29, L666(1990)

(3) Long Heqing et al., The anomalous nuclear effects inducing by the dynamic low pressure gas discharge in D / Pd system (to be publishing in this proceeding)

(4) S.Block et al., Health Phys, 13, 1027(1967)

(5) Zhang Xinwei and Zhang Wushou et al.,(to be published)

Table 1 Relative neutron yield of different D / M systems

system	P_t–D	Nb–D	W–D	Pd–D	Ag–D	Cu–D	Mo–D	Fe–D
voltage (KV)	17–21	17–21	17–21	17–21	16–18	17–21	17–21	17–21
relative neutron yield	10.1	8.2	5.2	3.7	2.8	1.6	1.6	1.0

Table 2 Scaled results of ^{115}In active pieces

sample	half life (min.)	decay rate when stop irradiating (Bq)	fluence rate × 10^{-3} ($n/m^2 \cdot s$)	ratio of hot neutron fluence rate over activity $n \cdot m^{-2}s^{-1}Bq^{-1}$	effective distance (cm)	measuring apparatus
1*	52.03 56.60	158.8 162.2	4.91 4.98	3.09×10^5 3.07×10^5	11.9 11.9	BH–1216 LB–1900
2*	54.03 56.40	114.5 122.6	3.7 4.01	3.28×10^5 3.27×10^5	13.7 13.2	BH–1216 LB–1900
average value	54.8 ± 1.8	139.5 ± 21	4.41 ± 0.54	$3.18 \pm 0.10 \times 10^5$	12.7 ± 0.8	—

Table 3 Results of activation of D / Nb system

sample	half life	pure count rates (CPS)	decay rate (Bq)	fluence rate × 10^{-4} ($n/m^2 \cdot s$)	detecting limit (Bq)
1* 2* 3*	53.03 ± 5.5 min.	$2.60 \pm 0.46 \times 10^{-2}$ $2.44 \pm 0.49 \times 10^{-2}$ $2.43 \pm 0.43 \times 10^{-2}$	0.100 0.094 0.094	1.48 1.48 1.15	0.025 (BH–1216)
4**	—	0	—	—	0.025 (BH–1216)
5***	19.6 ± 1.6 hours	$3.12 \pm 0.39 \times 10^{-2}$	0.104	1.10	0.025 (BH–1216)

* ^{115}In (Φ30 × 0.087mm)

** ^{115}In (Φ30 × 0.087mm) wraped by Cd (0.5mm thick)

*** ^{193}Ir (Φ40 × 0.2mm)

Table 4 Results of activation of D / Pt system

sample	pure count rates (CPS)	decay rate (Bq)	fluence rate× 10^{-4} ($n/m^2 \cdot s$)	detecting limit (Bq)
1+	$6.93 \pm 0.80 \times 10^{-2}$	0.231	3.60	0.025 (BH–1216)
2+	$3.29 \pm 0.20 \times 10^{-1}$	0.658	8.67	0.020 (LB–1900)

\+ ^{115}In (2× Φ50 × 0.087mm)

Table 5 Results of NES method of D / Nb system

Sample	1	2	3
fluence rate × 10^{-4}($n/m^2 \cdot s$)	4.83	8.73	5.64

Table 6 Scaled results of energy–channel

gamma source	energy E_γ (Mev)	corresponding channel(n)	$\Delta E_\gamma / \Delta n$	$\Delta E_\gamma / \Delta n$
^{22}Na	1.274	217	0.0220	0.0237 ± 0.0012
^{60}Co	1.253	216	0.0246	
^{137}Cs	0.662	192	0.0245	

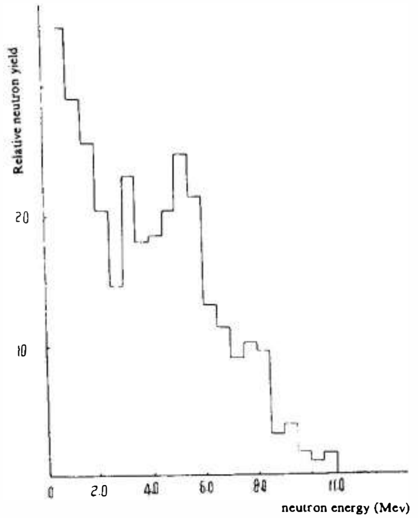

Fig.1 ^{238}Pu–Be Source neutron spectrum

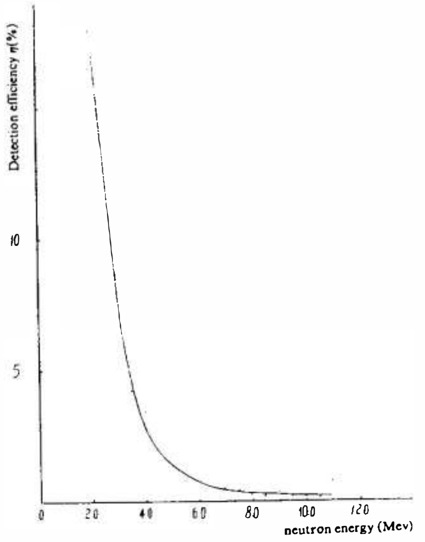

Fig.2 Detection efficiency of fast neutron spectrometer neutron curtain in energy interval

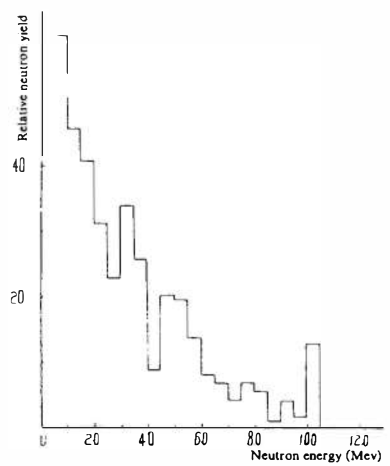

Fig.4 Neutron spectrum of D / Nb system

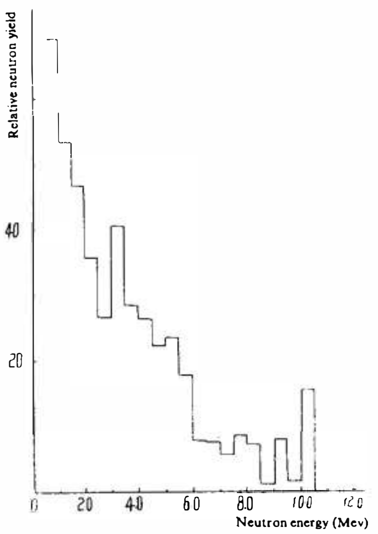

Fig.3 Neutron spectrum of D / Nb system

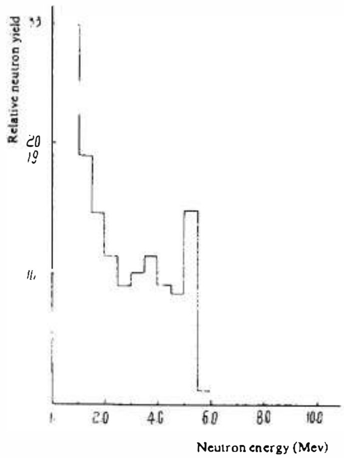

Fig.5 Neutron spectrum of D / Pd system

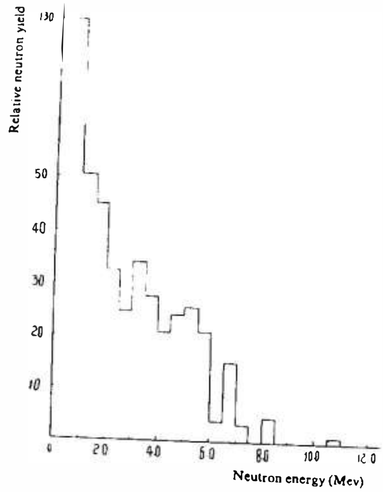

Fig.6 Neutron spectrum of D / Pt system

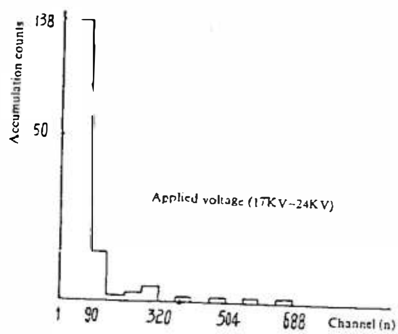

Fig.8 Counts of 70min. of H / Nb system

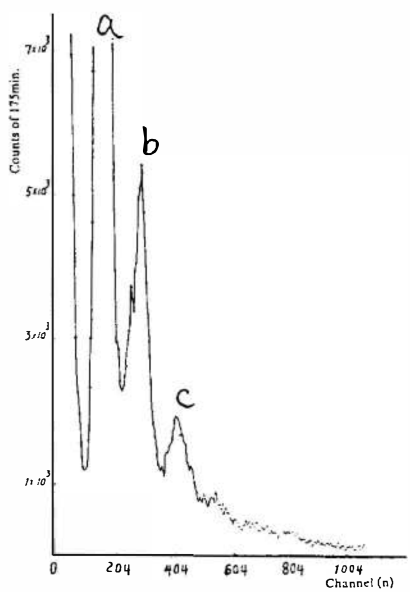

Fig.7 Gamma-spectrum of D / Nb system

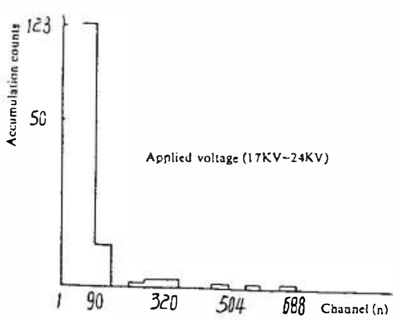

Fig.9 Counts of 70min. of He / Nb system