TNCF Analysis of Tritium Generation from Ceramics in Glow Discharge with D2 Gas

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Synopsis

Experimental results of tritium measurements in a discharge system with ceramics cathodes by Romodanov et al. were analyzed with the TNCF model. A consistent interpretation of the whole results is given. The adjustable parameter in the model n_n, the density of the trapped neutron, was determined as $n_n \sim 10^5$ cm^{-3} in the experiments where tritium was measured.

1.Introduction

The TNCF model for the cold fusion phenomenon has been used to explain various cold fusion events measured in materials containing hydrogen isotopes with a great success[1-3]. There have been, however, too many experimental data to treat in a short time since the development of the model about two years ago. We are going to analyze the remaining excellent data obtained in these 8 years after the discovery of this phenomenon using the TNCF model. In a previous paper[4] we have analyzed experimental data of tritium generation from a metal cathode in glow discharge by Romodanov et al.[5,6]. In this paper we have taken up the data obtained by Romodanov et al.[7] using ceramics cathodes.

2.Experimental results

Romodanov and his collaborators have been working with discharge systems using various materials for the cathode to measure tritium. The data with a Mo cathode had been analyzed successfully by the TNCF model[4] to give a reasonable explanation for the tritium generation in the cathode occluding a large amount of deuterium[5,6]. In this paper we will take up one with a ceramics cathode[7] VC, TiC, ZrC and ZrN from their experiments to provide an explanation consistent with the others.

2-1. Ceramics

The ceramics cathodes used in the experiment[7] and analyzed in this paper are tabulated in Table 1. The ceramics all have a crystal structure of NaCl type and their lattice constants *a*, size of the

Table 1: Cathode materials and their lattice constants *a* and sizes of the cathodes.

Material	a(Å)	Size (mm$\phi \times$ mm)	Volume (cm^3)
TiC	4.326	25 × 10	4.91
VC	4.167	25 × 10	4.91
ZrC	4.691	25 × 10	4.91
ZrN	4.573	40 × 20	25.12

Table 2: Cathode material, Discharge current I (A), Cathode temperature T (K), Gas pressure P (Pa), Measuring time (h), Tritium generation rate (/s) and the parameter n_n determined by the data.

Cathode	I (A)	T (K)	P ($\times 10^3$ Pa)	Time (h)	t ($\times 10^6$ /s)	n_n ($\times 10^5$ cm^{-3})
TiC	2.3	2020	20	56	1.6	2.5
	2.3	1910	10	34	1.2	1.9
VC	2.1	2030	20	52	1.6	2.2
VC	2.1	1935	12	39	2.6	3.7
ZrC	2.0	2060	29	60	16	31
ZrC	1.8	1580	7	72	1.2	2.7
ZrN	2.5	2030	30	44	4.2	7.7
ZrN	2.5	2240	20	48	3.6	6.3
ZrN	2.4	1900	10	66	2.7	5.1

cathodes with disc shape and their volume are listed in this table.

2-2. Tritium measurement

High current glow discharge with D_2 gas of pressures 10 ~ 30 Ps was conducted with the disc cathode of the ceramics at voltages of 200 ~ 1000 V and currents of 2 ~ 2.5 A for 30 ~ 80 hours. Tritium content of the gas was measured during the experiment giving values 10^6 ~ 10^7 t/s. Typical data were tabulated in Table 2.

The tritium generation in these experiments were with good reproducibility w in the case of the metal cathodes analyzed before[4-6].

3. Analysis of the Data by the TNCF Model

Using the recipe described in the preceding papers[1-3], we could explain[4] the data of the tritium generation obtained by Romodanov et al.[5,6] The TNCF model assumes existence of the trapped thermal neutron with a density n_n in a sample as an adjustable parameter.

The trapped thermal neutron can induce a reaction with a deuteron especially in the surface layer (trigger reactions):

$$n + d = t\,(6.98\ \mathrm{keV}) + \gamma(6.25\ \mathrm{MeV}).\quad(1)$$

The cross section of this reaction for the thermal neutron is 5.5 x 10^{-4} barn.

The nuclear products generated in these trigger reactions can induce reactions (breeding reactions) with nuclei in the sample:

$$t\,(6.98\ \mathrm{keV}) + d = {}^4\mathrm{He}\,(3.5\ \mathrm{MeV}) + n\,(14.1\ \mathrm{MeV}),\quad(2)$$

$$n\,(14.1\ \mathrm{MeV}) + d = n + p + n,\quad(3)$$

$$\gamma(6.25\ \mathrm{MeV}) + d = p + n.\quad(4)$$

The cross sections of these reactions are

3.04×10^{-6}, 1.77×10^{-1} and 2.0×10^{-3} barn, respectively. Also, the 14.1 MeV neutron can accelerate deuterons by elastic collisions with them making possible d-d reactions:

$$n\,(14.1\ \text{MeV}) + d = n' + d'\ (e), \qquad (5)$$
$$d\,(\varepsilon) + d = t\,(1.01\ \text{MeV}) + p\,(3.02\ \text{MeV}), (6)$$
$$= {}^{3}\text{He}\,(0.82\ \text{MeV}) + n\,(2.45\ \text{MeV}). (7)$$

The cross section of the elastic collision (5) is about 1 barn.

The number of the reactions (1) (generating t and γ) is calculated by the following relation:

$$\text{Nt} = \text{Ng} = 0.35 n_n v_n \text{n}_d V \sigma_{nd} \xi \qquad (8)$$

where $0.35 n_n v_n$ is the flow density of the thermal neutrons per unit area and time, n_d is the density of deuterium in the volume, σ_{nd} is the fusion cross section for reaction (1) and is 5.5×10^{-1} barn for the thermal neutrons. The numerical factor ξ related with stability of the trapped neutron in volume is taken as 1 in the surface layer and 0.01 in volume[8,9].

Using these relations (8) between the observed quantities of the number of events N's and n_n, we can calculate n_n for each event. In the analysis we assume the excess heat is inevitably accompanied with nuclear products according to the reactions (1), (2), (6) and (7), though we assume all the liberated energy is thermalized in the system.

The careful investigation of tritium generation in the discharge system with the ceramics cathodes is tabulated in Table 2 for each cathode. The maximum tritium generation was 1.6×10^{7} /s. The densities of the trapped neutrons calculated from the experimental data are also shown in Table 2. In the calculation, it was assumed that the density of deuterium in the ceramic cathodes was constant and one half of the metal ion (Ti, V, Zr): D/Ti (V, Zr) = 0.5.

The result tabulated in Table 2 shows that the average density of the trapped neutron in the ceramics cathode used in the above experiments are in a range of $10^{6} \sim 10^{7}$, which is an order of magnitude lower than the value determined in Mo cathode

4.Discussion

In the more than eight years after the discovery of the cold fusion by Fleischmann et al.[10], there have been many evidences of nuclear reactions in solids. Most of materials used in cold fusion experiments were transition metals: Pd, Ti and Ni. Ceramics and oxides have been used also as materials which occlude or include hydrogen isotopes. The work analyzed in the preceding section[7] was a rare case in which ceramics were used as a cathode in discharge and tritium generation was observed in them. This experiment has shown that tritium had been generated not only in metal but also ceramic cathode of discharge experiment with D_2 gas. Nuclear reactions in solids with a hydrogen isotope is not restricted to metals (Mo, V, etc.[6] but include ceramics[7], i.e. cold fusion is more a general phenomenon occurring in a wide variety of materials than was at first considered by its pioneers[10].

We, therefore, have to seek a cause (causes) of the cold fusion phenomenon in more general properties of solids containing not only deuterium,but also hydrogen[11-13].

The TNCF model is a trial in this line of theoretical investigation and has provided a consistent interpretation of various events of the cold fusion phenomenon. The authors have to say, unfortunately, that there is a shortage of quantitative information caused by the patent barrier by those wishing to protect their priority in getting a patent. Such an important discovery as the cold fusion should be a commonwealth of mankind to save the future of the earth. We hope that the patent barrier will be lowered and the cold fusion research will be a common work of mankind.

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