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THE POSSIBILITY OF USING OF METAL-METAL CONTACT EFFECT TO PREVENT THE ESCAPE OF HYDROGEN FROM METAL*

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The effect of metal-metal contact on charged particles has been considered. It was shown that when hydrogen exists in metal in the form of positive ions, i.e. protons, one should expect a directional action of the contact on hydrogen transport. The possible applications of such effects are pointed out, one of which is the possibility of the prevention of hydrogen escape from reactor materials.

1. Introduction

The metal-hydrogen systems are materials attractive for research workers because of their significance in studies of the physical and chemical properties of solids and their applications. Recently, besides such traditional applications of these systems as the obtainment and storage of pure hydrogen, as well as deuterium and tritium, they are used as reactor materials.

One of the important problems connected with the use and study of metal-hydrogen systems is how to prevent the escape of hydrogen from metal. In this paper the physical grounds for using metal-metal contact effects for this purpose are presented.

2. The energetic barrier on metal-metal contact

When two metals, say metal A and metal B, contact, the difference between maximum kinetic energies of their free electrons causes a partial passage of electrons from the metal with the higher energy, say from metal A, to the other metal. A double electrical layer forms at the contact surface producing potential difference, U_{AB}, the so called Galvani

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potential. Thus, for a charged particle moving in metal-metal contact region this potential difference produces an energetic barrier, D_{AB}. If q denotes the particle charge, the barrier is equal to

$$D_{AB} = qU_{AB}. \tag{1}$$

If μ_A and μ_B denote the bulk interior chemical potentials of the particle, relative to the mean electrostatic potentials, in metal A and metal B, the total energetic barrier, Φ_{AB}, for the particle at the metal-metal contact is given by the formula

$$\Phi_{AB} = -D_{AB} - \mu_A + \mu_B. \tag{2}$$

For negative values of Φ_{AB}, the contact should enable the particle to pass only from metal A to metal B unless the energy of the particle in metal B exceeds μ_B more than $-\Phi_{AB}$. Assuming that the potential difference, U_{AB}, is equal to the difference between potentials U_A and U_B connected with dipole layers at respective metal-vacuum boundaries one can obtain for Φ_{AB} the expression

$$\Phi_{AB} = \Phi_A - \Phi_B, \tag{3}$$

where

$$\Phi_A = -\mu_A - qU_A \tag{4}$$

and

$$\Phi_B = -\mu_B - qU_B \tag{5}$$

can be treated as the particle work functions for metal A and metal B, respectively.

The theoretical estimation of the positron work functions for metals [1, 2] indicate that the energetic barrier determined by formula (3) may be for this particle of an order of several eV, i.e., its magnitude may be enough to allow thermal positrons to diffuse through it in one direction only. Studying the angular distributions of photons emitted as a result of positron annihilation in thin layer bimetallic samples, Świątkowski et al. [3] and Świątkowski [4] have found that the distribution for each of the samples is more similar to the distribution characteristic for one of the sample components than should be expected from its content in the sample. These results indicate that thermalized positrons pass before their annihilation, as a result of their diffusive movement, from one metal to the other. The contact allows them to penetrate only in one direction. The directions of positron passage through metal-metal contact resulting from these observations are in good agreement with signs of the respective barriers, Φ_{AB}, determined on the basis of positron work functions calculated by Hodges and Stott [1].

In the case of transition metals, the binary metal-hydrogen systems have some properties similar to those of metals, for example, high thermal and electrical conductivity. These properties, as well as the magnetic properties of these systems, are explained by theories which assume that hydrogen exists in metals in form of protons. The reliability of such assumptions is confirmed also by results from studies on the direction of electrolytic hydrogen transport in metals (e.g. [5]). One may then expect, in the case of two transition metals being in contact, that the energetic barrier appearing at the contact should act directionally on the diffusive transport of hydrogen. Of course, the bulk chemical potentials for protons — "the heavy positrons" — may be different from the respective chemical potentials for positrons, but the differences should not be significant. For example, it follows from the calculations connected with hydrogen chemisorption made by Smith et al. [6] that the surface binding energy of protons, which is determined by similar therms as is the proton work function, has for tungsten a value of 9 eV which differs only slightly from the positron correlation energy for this metal (10.2 eV) calculated by Nieminen and Hodges [2].

3. *Final remarks*

The above considerations indicate that in some cases there is a real possibility of the directional action of metal-metal junctions on the diffusive transport of hydrogen dissolved in metals. This means that proper bimetallic layers covering some materials should allow one to fill the materials with hydrogen through the cover. The cover would prevent the escape of hydrogen from the materials. Such covers, in the case of reactor materials, would have the advantage of reactor materials usually used as covers which do not allow hydrogen to pass through them. The proper bimetallic membranes would appear to be more effective than palladium which is usually used in the process of pure hydrogen obtainment. It seems, therefore, that the realisation of measurements of hydrogen diffusion through metal-metal contact would give results essential both to practical applications and to the theory of metal-hydrogen systems.

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