Nuclear Physics Approach

About Nuclear Coulomb Barrier and The Electron Over-Concentration

Dan Chicea
Physics Dept., University "Lucian Blaga", Str. Dr. Ion Ratiu 5-7,
Sibiu, 2400, Romania; email: chicea@sibiu.ro

Abstract

When a conductor is the subject of a negative electric potential an electron concentration increase, located very near the surface occurs. A simple model for computing the increase of electron concentration on a grainy metal surface caused by an applied negative potential is presented and used in calculating the excess electron concentration and the size of the electric charge layer. The screening effect caused by the high negative electric charge density is considered for assessing the transparency of the nuclear Coulomb barrier at low incident energies. The results are discussed in connection with the processes grouped in the Cold Fusion class [1].

Introduction

When a conductor is the subject of an applied electric potential, it receives an excess electric charge proportional to the potential value. It is stated in the literature [2] that the charge in excess is located on the conductor surface. If the electric potential is negative, an excess of electrons will be located on the conductor and if the potential is positive, uncompensated positive ions will exist. The electrons in excess can not be outside the conductor in case of a negative potential because once expelled, they will be repelled by the Coulomb force and they will not contribute to the negative potential, therefore they must be located in a layer right under the surface.

The size of the shell and the excess electron concentration are calculated hereafter.

The Electron Excess Concentration

When a fluctuation of the electron concentration, consisting of a layer of electrons escaping from a layer of positive ions occurs in a plasma, the size of the displacement can be calculated from the condition that the electric interaction energy equals the thermal kinetic energy. The size of the displacement, called the Debye length [3], is given by:

$$l_D = \sqrt{\frac{\varepsilon_0 \cdot k \cdot T}{n_0 \cdot e^2}} \qquad (1)$$

where ε_0 is the free space constant, k is Boltzman's constant, T the temperature (K), e is the electron electric charge and n_0 the ion concentration in a plasma.

The hypothesis of the model is that the gradient of the electron concentration near the metal surface is equal to n_0/l_D [4], which leads to a linear increase of the electron excess concentration towards the surface. Defining the electron excess concentration n_e as the difference between the actual electron concentration, n, and the free electron concentration in the absence of the applied electric potential, n_0, and forcing the border condition that the electron excess concentration must be zero at a radius r=R-D, n_e is given by:

$$n_e(r) = \frac{n_0}{l_D}\cdot(r - R + D) \quad \text{for } r \in [R - D, R]$$
$$n_e(r) = 0 \quad \text{for } r \in [0, R - D] \qquad (2)$$

If we consider a grain on the metal surface with a negative electric potential U, having a spherical shape of radius R (figure 1), then the total electric charge on the grain, Q, located under the surface in a layer with the thickness D, is connected to the value U through (3) where ε is the permittivity of the substance the conductor is located in.

$$U = \frac{Q}{4\cdot\pi\cdot\varepsilon\cdot R} \qquad (3)$$

Considering an average value of the excess electron concentration to be half of the maximum value with respect to the linear variation with the radius, and with the observation that D is comparable with the Debye length which is much smaller than the radius of the grain, the condition that Q should be located in the layer can be written:

$$\frac{1}{2}\cdot\frac{n_0\cdot D\cdot e}{l_D}\cdot 4\cdot\pi\cdot R^2\cdot D = 4\cdot\pi\cdot\varepsilon\cdot R\cdot U \qquad (4)$$

therefore D can be expressed as:

$$D = \sqrt{\frac{2\cdot\varepsilon\cdot U\cdot l_D}{e\cdot R\cdot n_0}} \qquad (5)$$

and the average electron excess concentration as (6):

$$n_m = \sqrt{\frac{\varepsilon\cdot n_0\cdot U}{2\cdot l_D\cdot e\cdot R}} \qquad (6)$$

The computed values of the electron excess concentration, for three values of the radius, 0.01 μm (upper curve), 0.1 μm (middle curve) and 1 μm (lower curve) respectively, (values consistent with the grain sizes mentioned in [5]), are plotted versus the negative electric potential in figure 1, the conductor being placed in free space.

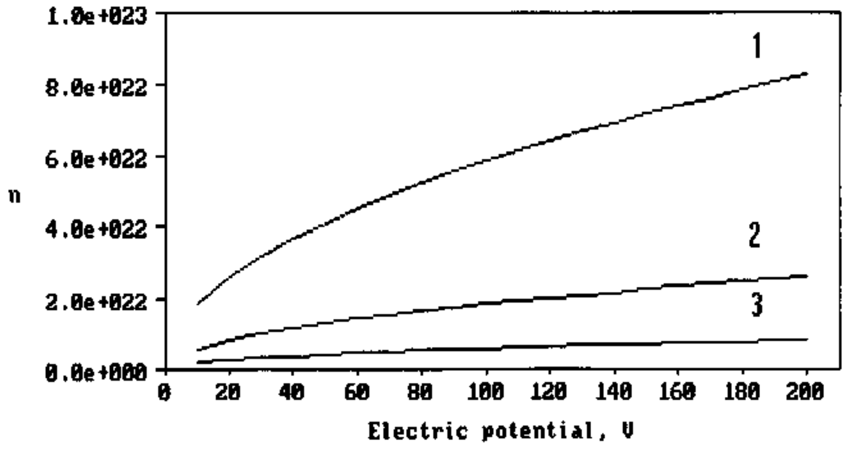

Figure 1: Electron excess concentration (cm^{-3}), for three values of the radius, 0.01μm (1), 0.1μm (2) and 1 μm (3).

Nuclear Physics Approach

A value of a few hundred volts for a small grain on the surface will make the excess electron concentration to be of the magnitude 10^{23} cm^{-3} which is relatively high compared to the concentration of free electrons in palladium, $6.25*10^{22}$ cm^{-3}. If the conductor is placed in a substance with the relative electric permittivity ε_r over-unity, or if the surface is covered with oxide, as mentioned in [6], the electron excess concentration increases as many times as the square root of ε_r, accordingly to (6).

The Screened Coulomb Barrier

In order to describe the screening of the Coulomb barrier a Thomas-Fermi-like effective interaction potential V(r) between two ions has been used [7]; the screening length has been considered to be l_D, the Debye length.

$$V(r) = \frac{e^2}{4 \cdot \pi \cdot \varepsilon \cdot r^2} \cdot \exp\left(-\frac{r}{l_D}\right) \qquad (7)$$

The barrier penetration probability P has been numerically integrated for the values of the Debye length corresponding to several electron concentration, using the WKB approximation. The (decimal) logarithm of the probability is plotted versus the (decimal) logarithm of the electron concentration (m^{-3}), for three values of the incident deuterium ion energy, in figure 2 (5 eV lower curve, 50 eV the middle and 500 eV the upper curve).

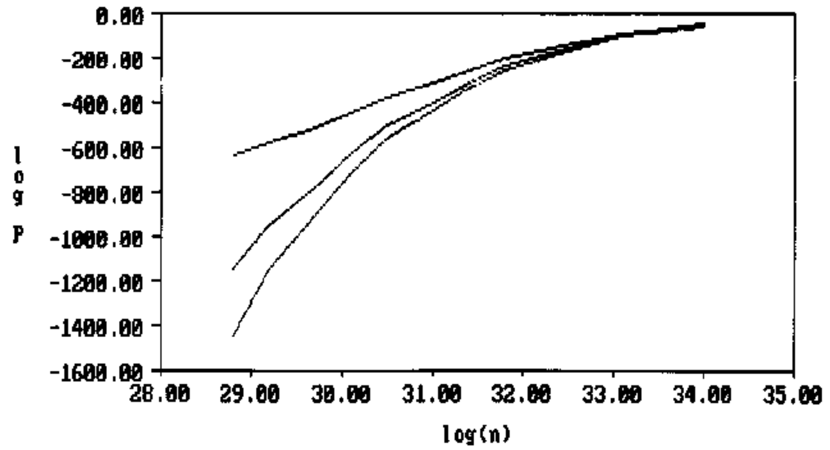

Figure 1: The Coulomb barrier penetration probability versus the electron concentration (m^{-3}), for three values of the deuteron energy, 5 eV lower curve, 50 eV the middle and 500 eV the upper curve.

If we consider the volume rate of the fusion reaction W [8] of two deuterons to be (8):

$$W = \frac{1}{2} n_D^2 < \sigma v > \qquad (8)$$

were σ is the nuclear reaction cross-section, n_D is the concentration of the deuterons trapped in a metal's lattice, like in palladium, of the magnitude of 10^{22} cm^{-3} for a high loading ratio and $W_{min}=10^{-3}$ $cm^{-3}s^{-1}$ the minimum detectable reaction rate [8], and if we write the cross section of the reaction as $\sigma=\sigma_0 P$ with $\sigma_0 = 10^{-24}$ cm^2 [8], assuming an average velocity of 10^8 $cm \cdot s^{-1}$ [8], if the deuterons are considered to be flowing resonantly through the palladium lattice [9], we find a minimum detectable value of 10^{-30} - 10^{-32} for P, which is far too high to be achieved by means of electron screening in the absence of an acceleration mechanism [10].

Conclusion

The simple model described in this paper was used to calculate the increase of the electron concentration near the grainy metal surface. The values of the "free" electron concentration can double themselves for a negative electric voltage of the magnitude of a hundred volts and can increase further more if the surface is covered by oxide. The increase of the deuterium nuclear fusion reaction cross section produced by the electron screening, can not represent the only possible explanation for the processes involved in the heat excess described in many experimental works.

Acknowledgments

I fully acknowledge Dr. Gheorghe Vasaru and Dr. Peter Glück for their help, encouragement and fruitful discussions.

References

[1] M. Fleischman, S. Pons, Phys. Lett. A 176, (1993), 118.
[2] Hudson A., Nelson R., University Physics, 2nd ed. (Sounders College Publishing, 1990)
[3] Linhart J.G., Plasma Physics, (EURATOM, 1969).
[4] Chicea D., Vasaru Gh., Submitted to Surface Science Letters.
[5] Reifenschweiler O., Phys. Lett. A 184 (1994), 149.
[6] Chatterje L. & all, Ind. J. of Pure and Appl. Phys., 65, No. 2, (1993), 265.
[7] Ichimaru S., Rev. Mod. Phys., 65, No.2 , (1993), 265.
[8] Goldanskii V.I., Dalidchik F.I., Phys. Lett. B 234, no. 4, (1990), 465.
[9] Bush R., Fusion Technology 19 (1991), 313.
[10] Chicea D., "Cold Fusion" No. 14, (1995), 2.