•Theoretical Calculation of the Hydrogen, Deuterium, Tritium and Muonium Negative Ionization Probability on the Low Work Function Surfaces

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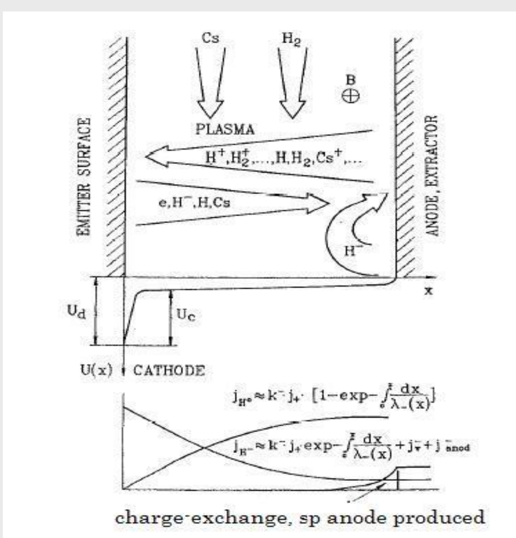
ABSTRACT

In this work is calculated the probability of negative ionization of hydrogen, deuterium, tritium and muonium on low work function metal surfaces, an important parameter for the field of the surface plasma negative ion sources. We present the theoretical model for the computer calculation of the negative ionization probability. The key feature of our model is that the affinity level of the hydrogen atom is set constant near the surface, hence the calculated ionization probability does not heavily depend on the initial atom-surface distance.

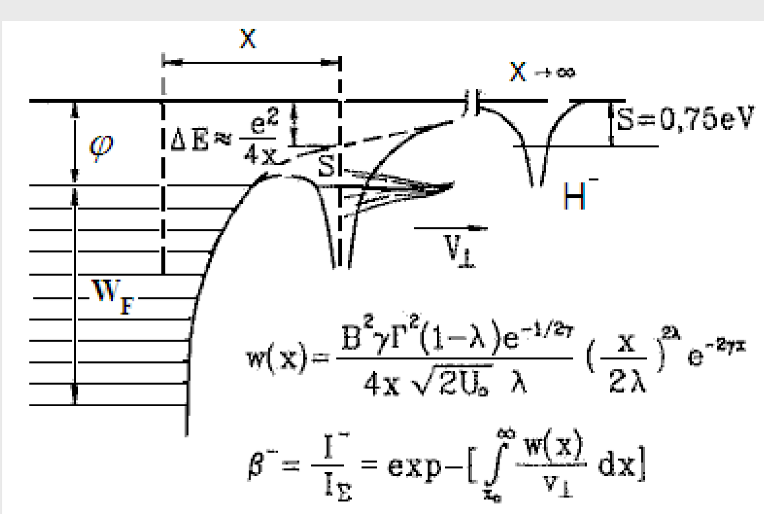
Atomic units $m_e = e = \hbar = 1$ l – 0.53 Å; E – 27.211 eV; t – 2.419·10^{-17} s; v – 2.188·10^{8} sm/s

INTRODUCTION



General diagram of the Surface-Plasma Generation of negative ions in a gas discharge

BACKGROUND



The shifting of affinity levels for particles approaching the surface due to the interaction of electrons with the metal has a decisive influence on the result of the interaction of particles with the surface. The shift of electron affinity level relative to the Fermi level of the metal was approximated by action of an image potential.
the center of this region is lowered relative to the electron affinity level of free particles S by an amount ΔS = e 2 /4x

Rate equation for calculation of negative ionization probability

$$\frac{dP^-}{dt} = -\Gamma_{loss}(z)\cdot P^- + \Gamma_{capture}(z)\cdot(1-P^-)$$

$$\Gamma_{loss}(z) = g_{loss}\cdot\Gamma(z)\cdot F_{loss}$$

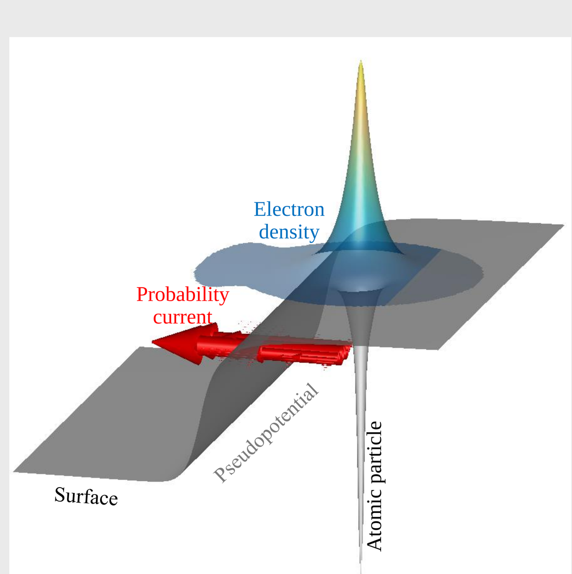
$$\Gamma_{capture}(z) = g_{capture}\cdot\Gamma(z)\cdot F_{capture}$$

Wave-packet propagation (WPP) method

$$i\frac{\partial\Psi(\mathbf{r},t)}{\partial t} = \left[-\frac{\Delta}{2} + V_{e-ion}(\mathbf{r}) + V_{e-surf}(\mathbf{r})\right]\Psi(\mathbf{r},t)$$

Atomic particle occupation for the "dynamical" problem $P(t) = |A(t)|^2$

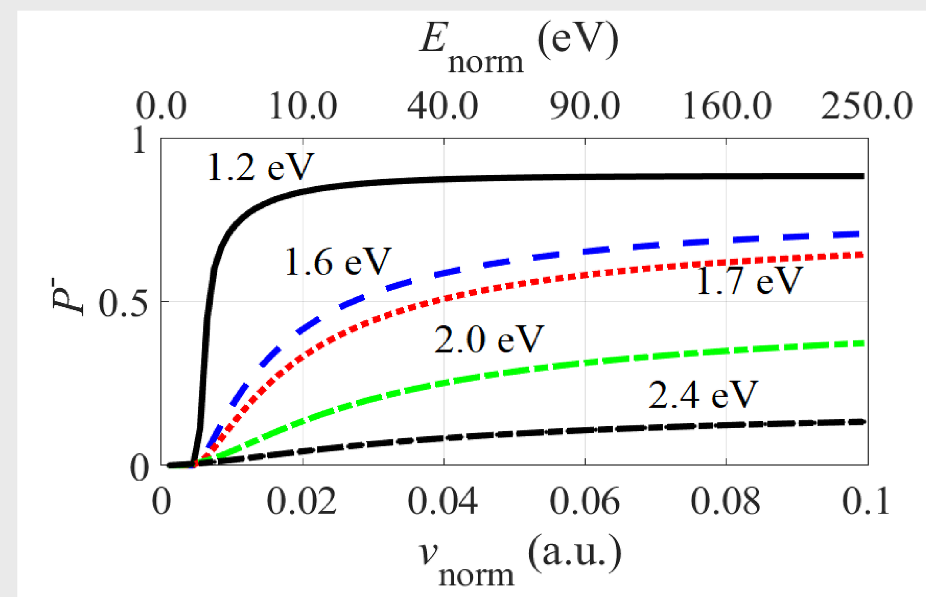
Autocorrelation function $A(t) = \langle\Psi_0(\mathbf{r})|\Psi(\mathbf{r},t)\rangle$



- Theoretical model has been presented for the negative ionization probability calculation:

In this work, the regularities of the formation of negative ions of hydrogen, deuterium, tritium and muonium were studied, which are practical interest for developing of negative ion sources for thermonuclear fusion and for accelerators.

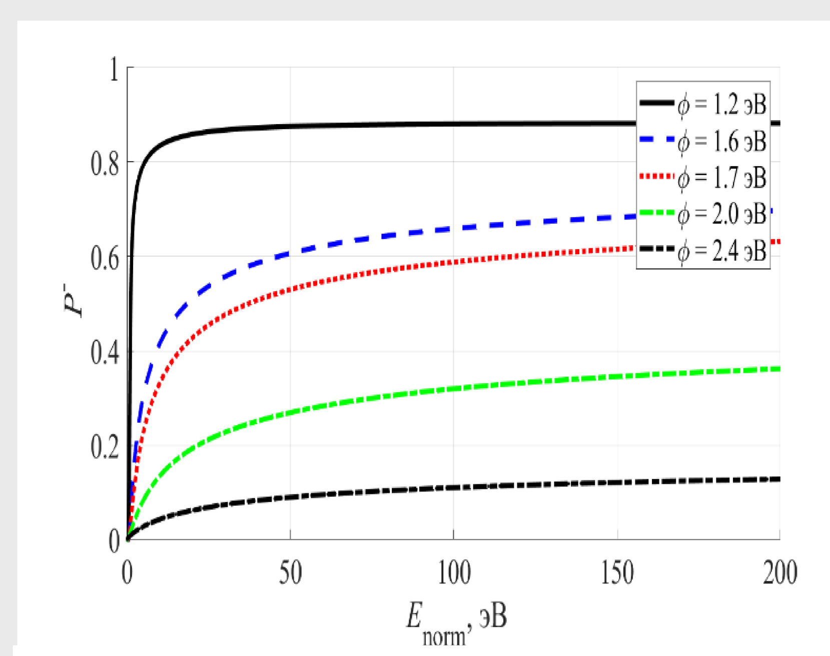
Main factors, influencing the P^-



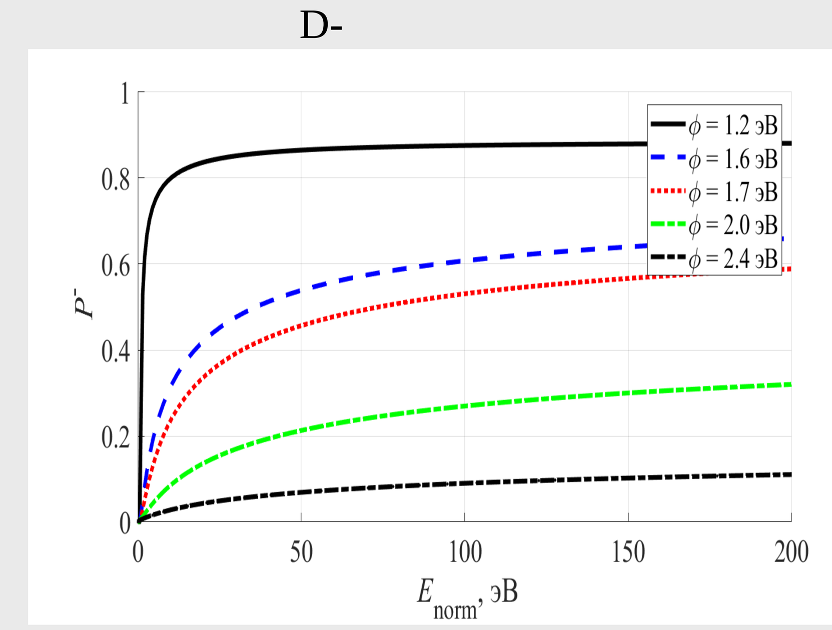
Influence of surface work function on negative ionization probability. Figure shows the negative ionization probability of hydrogen as function of initial normal exit energy/velocity for different work functions.

Negative ionization probability mainly depends on surface work function and ion velocity

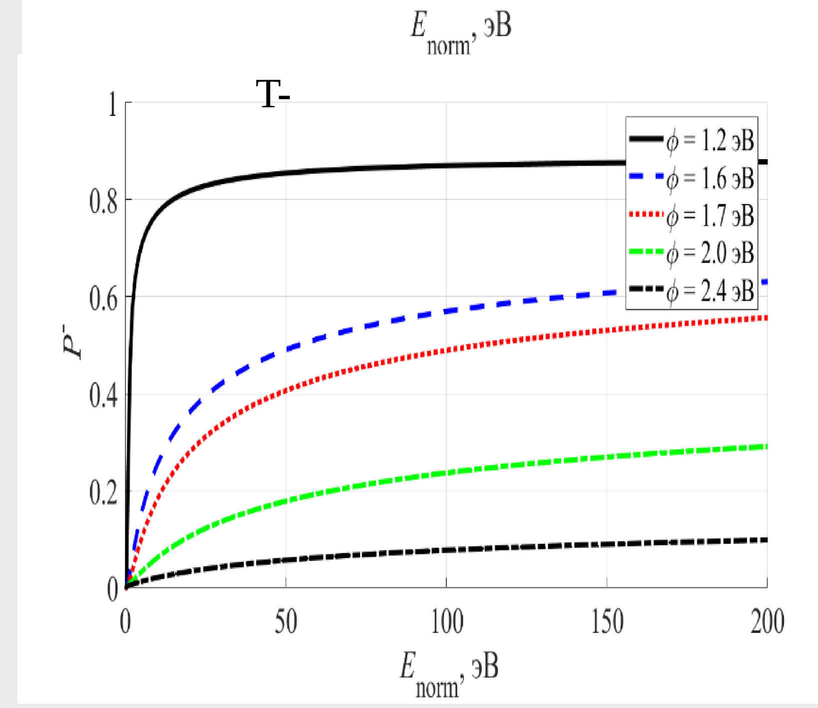
H-



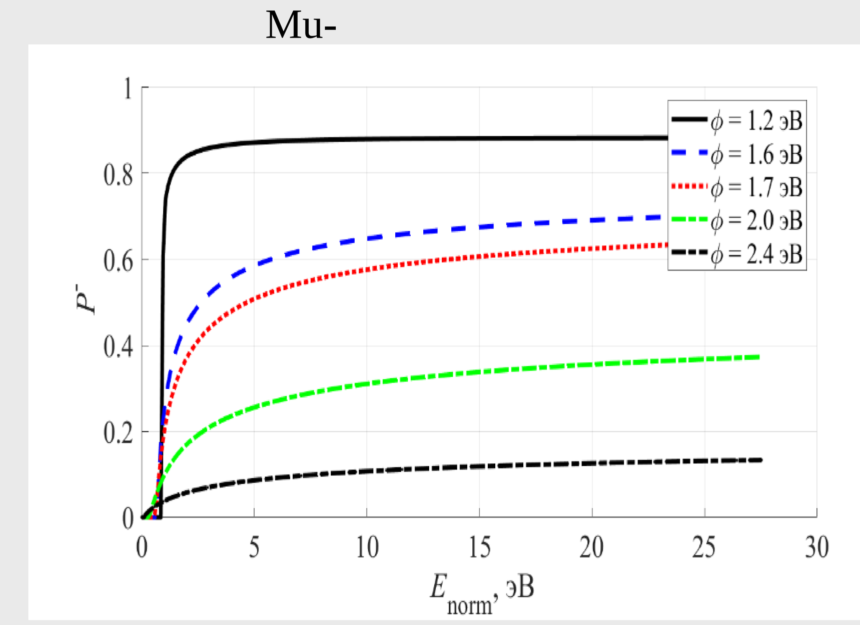
D-



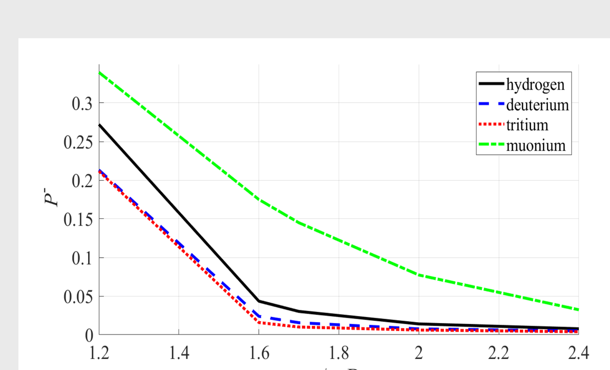
T-



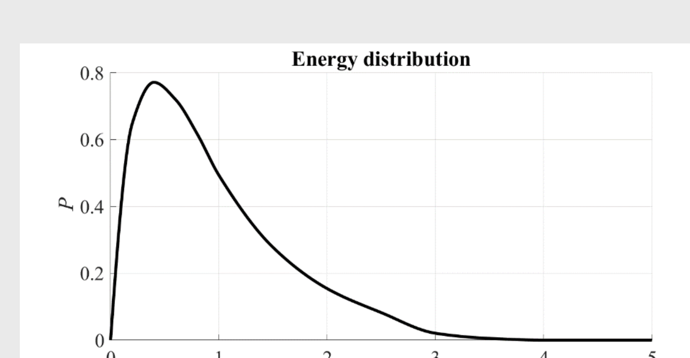
Mu-



Ionization probabilities of hydrogen, deuterium, tritium and muonium



Integral dependence of the yield of various types of negative ions on the work function of the metal surface With atomic energy spectra ion induced desorption shown below



Energy spectra of H- ions computed by to induced desorption by 4 eV atoms

1. Gainullin I K and Dudnikov V G "Theoretical investigation of the negative ionization of hydrogen particles on metal surfaces with low work function", 2020 Plasma Res. Express 2 045007 (2020).
2. Gainullin I.K., Dudnikov V. G., "Theoretical Calculation of the Hydrogen Negative Ionization Probability on the Low Work Function Surfaces ", AIP Conference Proceedings 2373, 070001 (2021).