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Calculation of Resonance Frequencies of Electrons Present in the Contact Area of Two Semiconductors

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Abstract—Two multielectron atoms with valence bond have been considered. Oscillations of the valence electron were determined with due regard for the influence of two nuclei and electron gas. The resonance frequencies were determined with due regard for the gradient induction forces of electric field. The electric equivalent circuit has been found. The causes of the changing polarity of the electromotive force (emf) depending on the frequency of the monochromatic electric field applied to the contact are explained.

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INTRODUCTION

General statement of the problem. The main element in semiconductor devices intended for various purposes is contact [1]. The electrophysical and mechanical properties of the contact depend on parameters of the connecting semiconductors [2].

It is natural that electrons in the contact area react to an external action in a different way. Hence, for example, if the applied field is alternating with cyclic frequency ω, this results in the occurrence of forced oscillations. First of all, the bound covalent electrons experience the specified effect. The behavior of such electron depends on many factors, such as bond type, rigidity, coefficient of elasticity, and dielectric constants of semiconductors.

Let us consider a relatively simplified variant of contact. Let us assume that two multielectron atoms are in contact. The electron gas is present in the region of contact. We assume that an electron found itself somewhere inside such system. This electron shall be called test one. Based on the laws of interaction we shall determine the field intensity or potential energy of the electron.

Different atoms having almost equal concentrations (the specifics of the charge affinity between the two media) are present at contact surfaces. Let us designate positive charges of the atoms as Z_1e and Z_2e. All the electrons in the contact form the electron gas. The distance between the centers of two "nuclei" shall be called the contact width. It will be designated as R. Outside the limits of the contact area a depleted layer may appear. Its influence will be neglected in our subsequent calculations [3].

The coordinate system required for calculations is selected as shown in Fig. 1, where R_1 and R_2 are the radii of the first orbits, R_g is the width of electron gas. Hence, it can be seen that $R_g = R - R_1 - R_2$. Let us determine the Coulomb potential of two nuclei and the potential of electron gas. The latter can be determined by solving the Thomas–Fermi equation [4]. Coordinates of the stable state of the test electron are fixed at distance r_m from nucleus Z_1e. Then this electron is at distance $R - r_m$ from the second nucleus.

The test electron is in the scalar electrostatic field created by both the Coulomb and Thomas–Fermi potentials. In addition, this electron is under the exposure to the induced gradient field, the force density of which is determined by the following formula [5]:

$$f_e = \varepsilon_0(\varepsilon - 1)E|\nabla E|V_0, \quad (1)$$

where ε_0 is the electric constant, ε is the relative dielectric constant of semiconductor, V_0 is the classical volume of electron, ∇E is the field intensity gradient, $E = -\text{grad}\varphi$ (magnetic component is disregarded), φ is the field potential. Having determined the forces applied to the test electron we can draw a dynamic equation of small oscillations in the form: