

One electron dimple on a thin helium film

Autor(en): **Shikin, V.**

Objekttyp: **Article**

Zeitschrift: **Helvetica Physica Acta**

Band (Jahr): **65 (1992)**

Heft 2-3

PDF erstellt am: **18.04.2024**

Persistenter Link: <https://doi.org/10.5169/seals-116496>

Nutzungsbedingungen

Die ETH-Bibliothek ist Anbieterin der digitalisierten Zeitschriften. Sie besitzt keine Urheberrechte an den Inhalten der Zeitschriften. Die Rechte liegen in der Regel bei den Herausgebern.

Die auf der Plattform e-periodica veröffentlichten Dokumente stehen für nicht-kommerzielle Zwecke in Lehre und Forschung sowie für die private Nutzung frei zur Verfügung. Einzelne Dateien oder Ausdrucke aus diesem Angebot können zusammen mit diesen Nutzungsbedingungen und den korrekten Herkunftsbezeichnungen weitergegeben werden.

Das Veröffentlichen von Bildern in Print- und Online-Publikationen ist nur mit vorheriger Genehmigung der Rechteinhaber erlaubt. Die systematische Speicherung von Teilen des elektronischen Angebots auf anderen Servern bedarf ebenfalls des schriftlichen Einverständnisses der Rechteinhaber.

Haftungsausschluss

Alle Angaben erfolgen ohne Gewähr für Vollständigkeit oder Richtigkeit. Es wird keine Haftung übernommen für Schäden durch die Verwendung von Informationen aus diesem Online-Angebot oder durch das Fehlen von Informationen. Dies gilt auch für Inhalte Dritter, die über dieses Angebot zugänglich sind.

ONE ELECTRON DIMPLE ON A THIN HELIUM FILM

V.Shikin. Institute of Solid State Physics, Academy of Sciences,
142432 Chernogolovka, Moscow district, USSR

Conditions of existence of one-electron dimples on a thin helium film are discussed. It is shown that the dimples cannot exist if the helium film thickness goes to zero.

A problem concerning properties of one-dimensional dimples on a thin helium film has been considered theoretically in detail. We have in mind the first variational calculations for dimples provided by Monarkha [1] in the limit of zero temperature, introduction of temperature into the problem of dimples on a thin helium film [2],[3], the studies of the dynamic properties of these dimples [4] etc. Different approaches to construction of such a theory for 2-D dimples are in a good fit with each other and lead to a general qualitative conclusion that as a helium film d decreases, the coupling energy W increases monotonically and rather sharply (asymptotically $W(d) \sim d^{-4}$).

However the general conclusion about monotonic increase of the dimple energy with decrease of d is, in fact, incorrect. The aim of the given note is to formulate and to prove the fact that in the limit $d \rightarrow 0$ formation of one-electron dimples on a thin helium film becomes energetically unfavoured.

In order to formulate the problem about existence of a dimple we need to make some determinations. A variational calculation from [1] gives the following relations for the energy W and the localization length l

$$W = -\frac{F^2}{4\pi\alpha} \left(\ln \frac{1.3}{k_1} - \frac{1}{2} \right), \quad \tilde{k}^2 = \frac{\rho \tilde{g}}{\alpha}, \quad \tilde{g} = \frac{3\Delta}{\rho d^4}, \quad k_1 \ll 1 \quad (1)$$

$$l^2 = 4\pi\alpha\hbar^2/(mF^2), \quad F = \Lambda_s/d^2, \quad \Lambda_s = \frac{e^2(\epsilon_s - 1)}{4(\epsilon_s + 1)} \quad (2)$$

Here α is the surface tension of liquid helium, ρ is its density, g is the effective acceleration due to Van der Waals force. Δ is the Van der Waals constant, F is the force pressing electrons against the free helium surface in the limit $d < \gamma_\infty^{-1}$ which is of interest for us, ϵ_s is the dielectric constant of the substrate, $\gamma_\infty^{-1} = 4(\epsilon+1)\hbar^2 / [me^2(\epsilon-1)]$ is the length on which the electron is localized due to its interaction with the substrate, ϵ is the dielectrical constant of liquid helium.

Using the definitions (1), (2) it is easy to understand the statement about a monotonic dependence of W on d . Indeed, the combination $\tilde{k}l$ entering into the argument of logarithm in (1) with allowance for F from (2) turns out to be independent of d

$$\tilde{k}^2 l^2 = 12\pi\Delta\hbar^2 / (m\Lambda_s^2) < 1 \quad (3)$$

Therefore the energy W is negative and increases monotonically as d decreases according to a law $W \sim d^{-4}$.

Now we note that the definition F (2) is not accurate. It is only valid in a region $\gamma_\infty^{-1} > d \gg \gamma_d^{-1}$, where γ_d^{-1} is the localization length for an electron above the helium film due to the action of the sublayer image force. In the case $d < \gamma_d^{-1}$ the law $F \sim d^{-2}$ ceases to be valid and the combination $\tilde{k}l$ begins to depend on d . Schematically this effect can be presented as (first the effect of saturation dependent on $F(d)|_d$ was mentioned in [5])

$$F = \frac{\Lambda_s}{(d + \gamma_d^{-1})^2}, \quad \tilde{k}^2 l^2 \sim \frac{(d + \gamma_d^{-1})^4}{d^4} \begin{cases} 1 & d\gamma_d > 1 \\ \gg 1 & d\gamma_d < 1 \end{cases} \quad (4)$$

According to (4) the parameter $\tilde{k}l$ in the range $d\gamma_d < 1$ begins to grow as $\tilde{k}^2 l^2 \sim d^{-4}$. If $\tilde{k}l > 1$ the localization energy W (1) becomes positive which corresponds to destruction of a dimple.

1. Yu. Monarkha, Low. Temp. Phys., 1, 1975, 526.
2. S. Jackson, P. Platzman, Phys. Rev. B24, 1981, 499, Phys. Rev. B25, 1982, 4886.
3. O. Hippolito, G. Farins, N. Studart, Surf. Sci. 113, 1982, 394.
4. M. Saitoh, Surf. Sci. 142, 1984, 114; J. Phys. C16, 1983, 6983.
5. M. Paalanen, Y. Iye, Phys. Rev. Lett. 55, 1985, 1761.