UDC 533.9.004.14; 621.039.6

Eugene B. Gordon

Institute of Problems of Chemical Physics RAS, Chernogolovka 142432, Russia
E-mail: Gordon.eb@gmail.com

# Thermal stability of metallic nanowires and microspheres

Quantized vortices in superfluid helium are the perfect one-dimensional template, imposing growing the product of condensation of any impurities suspended in HeII only along the core of the vortex. Nevertheless, we have demonstrated that it is impossible in the case of metal to prepare the chain of single atoms or molecules.

**Key words:** superfluidity, impurity nanotubes

Евгений Б. Гордон

**Термическая стабильность металлических нанопроволок и микросфер**

Квантованные вихри в сверхтекучем гелии являются идеальным одномерным шаблоном для роста продуктов конденсации каких-либо примесей, взвешенных в HeII только по сердцевине вихря. Тем не менее мы продемонстрировали невозможность в случае с металлом подготовки цепочки отдельных атомов или молекул.

**Ключевые слова:** сверхтекучесть, примесь, нанопроволка.

Евгений Б. Гордон

**Металды наносымдар мен микросфералардың темиялық тұрақтылығы**

Асқынаққыш гелийдегі квантты құйындар кез келген қоспаның өсуіне идеалды үлгі болып табылады. Дегенмен, біздің зерттеуіміз бойынша жекелеген атомдар мен молекулаларда бұл тізбектің орындалмай қалуын көрсеттік.

**Түйін сөздер:** асқынаққыштық, қоспа, наносым.

Quantized vortices in superfluid helium are the perfect one-dimensional template, imposing growing the product of condensation of any impurities suspended in HeII only along the core of the vortex. Nevertheless, we have demonstrated that it is impossible in the case of metal to prepare the chain of single atoms or molecules. Even in HeII possessing a uniquely high thermal conductivity the collision of small metal particles leads to their self-melting, which resulted in a spherical shape of product cluster. And only starting from their certain size the metal clusters begin to coalesce into a nanowire. The thickness of these nanowires depends on the thermo-physical properties of the metal and varies from 8 nm for the low-melting indium to 3 nm for refractory platinum.

However, for practical use these grown at low temperature nanowires should be stable at reasonably high T. Our studies of thermal stability of nanowires made of many metals and alloys demonstrated rather unexpected results. In particular, at room temperature nanowires of indium possessing melting point Tm = 1570C exhibit long term stability, while the silver nanowires (Tm = 9600C) fall to «dotted line» of clusters in few hours after their heating up to T = 300K. All results are consistent with the following unusual mechanism of thin metal nanowires decay. In order to destroy the nanowire it is not necessary to bring it to melt. One can achieve that simply moving the atoms along the surface and at a distance slightly greater than interatomic spacing. The motion of atoms on the surface is much less activated than that causing the melting. Therefore, a radical change in the shape of nanowires can occur at temperatures much lower than the melting temperature. However for the destruction of the nanowire by surface mobility a bean-like shape of nanowire should be more energetically favorable than cylindrical one. That is true for metals such as silver, where the surface tension increases rapidly with decreasing radius of the nanowire, and they are destroyed long before their melting. In metals such as indium and platinum, this effect is weak, and they exhibit an enviable thermal stability. The use of alloys can significantly extend the temperature range of metal nanowire stability.

Completely different effect determines the stability of spherical particles, when even melting cannot change their shape. These particles are commonly obtained by cooling the molten metal droplets in a liquid, and a large negative pressure arises inside them during cooling and solidification. Our studies have shown that under weak damage to the integrity of their surface, they break up, ejecting a plurality of nanoparticles.