Local overheating under physical and chemical processes in superfluid helium

Eugene B. Gordon

Institute of Problems of Chemical Physics RAS, Chernogolovka 142432 Russia

It was accepted that the coagulation of any guest particles in superfluid helium was controlled by their diffusion and therefore was rather slow. It was also believed that the uniquely high thermal conductivity of He II eliminates any local overheating, so any processes between these particles proceeded strictly isothermally. We have shown that both of above mentioned "obvious" statements are fundamentally wrong. First, the presence of quantized vortices in He II provides very fast mechanism of coagulation which products are not spherical clusters but long thin filaments. Second, at least at the initial stage of coagulation the local overheating is as high as few thousand K.

It was accepted for a long time that the rate of mutual collisions for any guest particles introduced into superfluid helium was controlled by their diffusion, and therefore the coagulation of these particles was comparatively slow. It was also believed that the uniquely high thermal conductivity of He II eliminates any local overheating resulting from the physical and chemical processes between these particles, and therefore the processes proceeded strictly isothermally. Our recent studies have shown that both of above mentioned "obvious" statements are fundamentally wrong.

Firstly, the presence of quasi-1D quantized vortices in He II, which resulted in concentrating any foreign particles in their core, provides a specific mechanism of coagulation which rate is much faster than the rate of normal, diffusion controlled condensation. Besides the coagulation products are not spherical clusters, but the long thin filaments [1, 2] . That allowed to propose and to realize the universal techniques for metallic nanowires bottom-up design [3 – 5]. Secondly, the structure and thickness of nanowires grown of different metals in He II by this method evidenced that nanowires were formed from the previously melted nanoclusters [6]. In other words, it was assumed that, at least at the initial stage of coagulation, the local overheating is as high as few thousand Kelvins.

To prove that unusual and important fact we have performed the experiments on monitoring in the visible range the thermal radiation, accompanying the coagulation of metallic atoms in He II. For all investigated metals such as Tungsten, Molybdenum, and Platinum, with natural exception of fusible Indium, such emission was reliably observed and investigated [7]. It means that the huge local overheating may appear during the most of physical and chemical processes inside such "perfect cooler" as He II.

These circumstances should be taken into account in any study of the guest particles embedded into the superfluid helium. Of course, this kind of effects must be clearly expressed also in the experiments with cold helium nanodroplets, the first evidence of this was already published [8]. These results are as well challenging for theorists, evidence may be find in the recent work [9]. The prospects for the developing further experiments will be analyzed too.

E-mail: gordon.eb@gmail.com

References

[1] E.B. Gordon *et al.* 2007 *JETP Lett.* **85,** 581.

[2] E.B. Gordon *et al.* 2012 *Chem. Phys. Lett.* **(519–520)** 64.

[3] E.B. Gordon *et al.* 2009 *Low Temp. Phys.*,**35,** 209.

[4] E.B. Gordon *et al.* 2010 *Low Temp. Phys.*,**36,** 590.

[5] P. Moroshkin *et al.* 2010 *EPL.*,**90,** AN 34002.

[6] E.B. Gordon *et al.* 2011 *JETP*, **112,** 1061.

[7] E.B. Gordon *et al.* 2017 *Low Temp. Phys.*, accepted.

[8] L.F. Gomez *et al.* 2016 *J. Chem. Phys.*,**145,** 114304.

[9] D. Mateo, *et al.* 2015 *J.Chem.Phys* **142**, 064510.