From the Guest editors

NANOTHERMODYNAMICS FOR MATERIALS, ENERGY, AND ENVIRONMENTAL SCIENCES

by

Rou-Xi CHEN [a,b]***, Ji-Huan HE*** [a,b*]***, and Ling LIN*** [c]

[a] National Engineering Laboratory for Modern Silk, College of Textile and Clothing Engineering,
Soochow University, Suzhou, China
[b] Ningbo Key Laboratory for Advanced Textile Technology and Fashion CAD,
Zhejiang Fashion Institute of Technology, Jiangbei District, Ningbo, Zhejiang, China
[c] Nantong Textile Institute, Soochow University, Nantong, China

Nanoscale flow and heat transfer are widely observed in modern industry. The nanoeffect in nanothermodynamics is generally 5 to 7 orders of magnitude higher or lower than its macro partner.

Key words: *nanofibers, nanoeffect, bubble-electrospinning, solvent evaporation, nanoporous fibers*

Introduction

We begin with a cubic meters of charcoal, which can be burned in air slowly. Now if the charcoal is decomposed into nanoparticles, the combustion efficiency increases tremendously due to the remarkably high surface-to-volume ratio. Nanothermodynamics is to study the thermal property of materials and objects with sizes of 1 to 100 nm.

So what sort of properties change as objects get smaller? A lot of material properties begin to change in nanoscales. The combustion efficiency, for example, in nanoscales is 5 to 7 orders of magnitude higher than that for any observable scales. The phenomenon is always called as the size-effect or nanoeffect [1].

A perfect example of this can be seen looking bubble lifetime. What a bubble lifetime is when it tends to a nanoscale one? Consider a macroscopic bubble with diameter of 1 cm and a nanobubble with diameter of 10 nm. The bubble lifetime linearly depends upon its size, that is [2]:

$$\frac{L_1}{L_2}=\frac{d_1}{d_2}=\frac{1\ \text{cm}}{10\ \text{nm}}=10^6 \tag{1}$$

where L_1 and L_2 are lifetimes for the macroscopic bubbles and nanobubbles, respectively. Theoretically predicted bubble lifetime for a bubble with diameter of 1 cm in water is about 1 s, that means the bubble lifetime for the nanobubble is as short as 10^{-6} s.

Taleyarkhan *et al.* found that under suitable experimental conditions, temperature in a broken nanobubble rose to as high as 1,000,000 K [3]. This temperature is high enough for deuterium nuclei to undergo fusion reactions. Though there are many debates on this experi-

---

[*] Corresponding author; e-mail: hejihuan@suda.edu.cn

mental phenomenon [4], it is astonishing that nanoeffect can make anything impossible in Newton's mechanics possible when it tends to nanoscales.

A thinner layer of ZrO_2 microfibrous membrane is transparent to pass heat flow, however, when the fibers tend to nanoscales, the membrane has excellent heat insulating property. The thermal resistance (the inverse of heat conductivity) can be expressed as:

$$\eta = \eta_0 + \frac{\beta}{d^\alpha} \tag{2}$$

where η_0 is the thermal resistance of the bulk material, β – the material constant, d – the fiber diameter, $\alpha > 0$ – a scaling exponent, in [1] we recommend $\alpha = 1/2$ for qualitative analysis:

$$\frac{(\eta - \eta_0)_{\text{micro}}}{(\eta - \eta_0)_{\text{nano}}} = \sqrt{\frac{10\ \mu\text{m}}{100\ \text{nm}}} = 10 \tag{3}$$

If the heat conductivity of a microfibrous membrane is 0.2 W/mK, then the heat conductivity of the nanofibrous membrane becomes 0.02 W/mK. That means if the microfibrous membrane can resist temperature of 100 degrees, its nanopartner can resist temperature of 1000 degrees.

This issue focuses on nanofibers fabrication, energy and environmental flow in nanoscales, both experimental and theoretical papers are considered.

Acknowledgments

The work is supported by Priority Academic Program Development of Jiangsu Higher Education Institutions (PAPD), National Natural Science Foundation of China under grant No.11372205 and Project for Six Kinds of Top Talents in Jiangsu Province under grant No. ZBZZ-035, Science & Technology Pillar Program of Jiangsu Province under grant No. BE2013072, Ningbo Natural Science Foundation under grant Nos. 2011A610111 and 2013A610011, and Ningbo Science and Technology Innovation Team Foundation under grant No. 2012B82014.

References

[1] He, J. H., *et al.,* Nano-Effects, Quantum-Like Properties in Electrospun Nanofibers, *Chaos, Solitons and Fractals, 33* (2007), 1, pp. 26-37

[2] Craig, V. S. J., Very Small Bubbles at Surfaces the Nanobubble Puzzle, *Soft Matter, 7* (2011), 1, pp. 40-48

[3] Taleyarkhan, R. P., *et al.*, Evidence for Nuclear Emissions during Acoustic Cavitation, *Science, 295* (2002), 5561, pp. 1868-1873

[4] Brumfiel, G., Bubble Fusion Dispute Reaches Boiling Point, *Nature, 416* (2002), 6876, pp. 7

[5] He, J.-H., *et al.,* Review on Fiber Morphology Obtained by Bubble Electrospinning and Blown Bubble Spinning, *Thermal Science, 16* (2012), 5, pp. 1263-1279

Paper submitted: July 1, 2014
Paper accepted: July 2, 2014