AUXETICS AS ENTROPY FILTERS – POSSIBLE APPLICATION

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Abstract: In this note a sketch of the idea of applying auxetics to separation of ^{3}He from a mixture of ^{4}He and ^{3}He by using auxetic entropy filters is presented.

Keywords: superfluidity, entropy filters, auxetics, ^{3}He isotope

1. Introduction

Entropic filtration is the first step to increase the concentration of ^{3}He in the ^{4}He-^{3}He mixture [1]. Auxetics, a new class of mechanical metamaterials [2] exhibiting a negative Poisson's ratio [3] and intensively studied recently [4–6], were investigated in the context of filtering at the macro-level [7]. However, recent developments in the auxetic materials indicate that they can be applied also at the nano-level. The idea of auxetic filtering is illustrated in Figure 7 in Ref. [7]. It can be seen there that by stretching an auxetic structure one can tune the holes and select precisely the maximum size of particles which can go through the filter.

At the first look, the idea of filtering glass beads, described in [7], has nothing to do with the filtering of ^{3}He from ^{3}He-^{4}He mixtures. The reason is that the sizes of ^{3}He and ^{4}He are very close to each other. However, it is well known that liquid ^{4}He becomes superfluid at higher temperature than ^{3}He [1]. Thus, in a proper temperature range, *i.e.* below the temperature when the liquid mixture becomes superfluid but above the temperature when ^{3}He becomes superfluid, the situation is as follows. Being not superfluid, ^{3}He is located in the normal component of the fluid mixture, whereas the superfluid component is composed of ^{4}He [1]. Thus, if the filter stops the normal component in a vessel but, at the same time, allows the superfluid component to go through the filter and leave the vessel, the concentration of ^{3}He in the vessel will grow if the mixture of the initial concentration of ^{3}He is continuously introduced to the vessel to fill the leaving

^{4}He volume. This is the role of standard entropy filters [1]. Hence, what would be the advantages of auxetic filters? One of the main advantages is that they could be tuned, *e.g.* to respond properly to the changing conditions in the vessel during the filtration process.

Despite the fact the auxetic filters could be advantageous, there are two obvious obstacles for their application. The first obstacle is that known auxetic membranes, *e.g.* those described in [7], are macroscopic. The second obstacle is that materials typically used to produce filters are not auxetic. Fortunately, recent developments in the auxetics indicate that both these obstacles can be overcome. Namely, it can be expected that soon it will be possible to obtain auxetic structures not only at the macro-but also at the micro-and nano-levels. This can be reached, not only by introduction of defects or "cuts" – examples of such structures have been recently studied by computer simulations by Grima and co-workers [8] and Kim and co-workers [9], respectively – but also by applying proper conditions to materials, as was shown long time ago by Wojciechowski [10]. In particular, it has been shown that by applying negative pressure (isotropic tensile stress) one can reduce the Poisson's ratio of materials what, at proper conditions, should result in reaching auxeticity [10]. Moreover, the extension of the results obtained in [8], performed in [11], shows that auxeticity can be reached also by applying anisotropic stress, *e.g.* stretching defect-free, pure graphene [11]. A similar effect has been earlier obtained for very thin layers of metals [12]. It is attractive to conjecture that similar, auxetic effects can be obtained also by stretching layers of some other materials.

In conclusion, combinations of properly arranged auxetic layers of properly prepared structures should lead to a new class of efficient entropy filters.

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References

[1] Eselson B N, Grigoriev V N, Ivancov V G, Rudavskij E A, Sanikidze D G and Serbin I A 1973 *Solutions of Quantum Liquids* ^{3}*He*-^{4}*He*, Nauka (in Russian)
[2] Grima J N and Caruana-Gauci R 2012 *Nature Materials* **11** (7) 565
[3] Lakes R 1987 *Science* **235** (4792) 1038
[4] Cauchi R and Grima J N 2014 *TASK Quarterly* **18** (1) 5
[5] Lim T C 2015 *Auxetic Materials and Structures*, Springer
[6] Wojciechowski K W, Scarpa F, Grima J N and Alderson A 2015 *Physica Status Solidi* **B252** 1421 see also the references therein
[7] Alderson A, Rasburn J, Ameer-Beg S *et al.* 2000 *Industrial and Engineering Chemistry Research* **39** (3) 654
[8] Grima J N, Winczewski S, Mizzi L, Grech M C, Cauchi R, Gatt R, Attard D, Wojciechowski K W and Rybicki J 2015 *Advanced Materials* **27** (8) 1455
[9] Ho V H, Ho D T, Kwon S-Y, and Kim S Y 2016 *Physica Status Solidi* **B253**
[10] Wojciechowski K W 1995 *Molecular Physics Reports* **10** 129
[11] Ho D T, Kim H, Kwon S-Y *et al.* 2015 *Physica Status Solidi* **B252** (7) 1492
[12] Winczewski Sz, Wojciechowski K W and Rybicki J in preparation