宙吊りグラフェン上に形成した非対称ナノメッシュによる熱整流作用

Thermal rectification based on asymmetric nanomesh formed on suspended graphene

○(P)F. Liu[1], M. Muruganathan[1], 小川 真一[2], 森田 行則[2], 郭 嘉裕[1], M. Schmid[1], 水田 博[1,3]

北陸先端大[1], 産総研[2], Hitachi Cambridge Lab.[3]

E-mail: fayong@jaist.ac.jp

The thermal rectifier is one of the basic units for thermal engineering, in which the heat transfer from the preferred direction is much larger than that from the opposite direction. The conventional mechanism is based on the combination of two different materials with opposite κ-T dependence (κ: thermal conductivity, T: temperature) [1]. However, there are many critical obstacles on the way forward to the practical applications for thermal information processing. One is that most of the reported thermal rectifier has a low recertification ratio just around 10-20% [2]. Another is that it is quite difficult to measure the κ separately for two different nanomaterials. The last but the most is that both the diffusion and ballistic transport of the phonons should be considered if the device scale is smaller than the phonon main free path. In this case, the κ-T dependence method is losing efficacy to explain and guide the thermal rectifier development in advanced nanomaterials. In this work, we use suspended graphene and graphene-nanomesh (GNM) combined structure as a simplified 2D platform to investigate the mechanism of thermal transport. We report that the thermal rectification phenomenon is observed with up to 60% thermal rectification ratio at 150 K. The GNM was patterned by the helium ion beam milling (HIBM) technique with sub-10 nm diameter periodical nanopores [3]. The thermal transport properties from the two directions were characterized by the "differential thermal leakage" method [4]. Both the neck (nanopore edge to edge) dependence and the environmental temperature dependence of the thermal rectification ratio are investigated. Based on the results, the "nanomesh phonon filter model" is proposed, which may provide a new way to design and improve the thermal rectifier beyond the conventional thermal conductivity method.

Acknowledgment:

The authors acknowledge T. Iijima and H. Ota for the usage of the HIM at the AIST SCR station for the helium ion irradiations. This work was supported by the Grant-in-Aid for Scientific Research No. 18H03861, 19H05520 from the Japan Society for the Promotion of Science (JSPS).

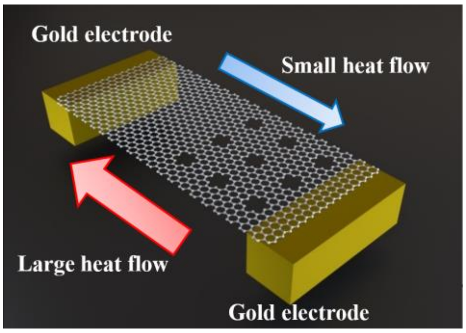

Fig.1: Schematic illustration of the suspended GNM device

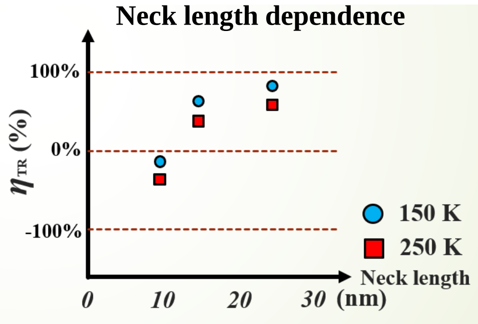

Fig.2: The thermal rectification ratio from three GNM devices with different neck length

Reference:

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