Forest of Silicon Nanowires for Thermoelectrics

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Thermoelectric modules interconvert thermal gradients for power generation through Seebeck effect. Restricted by its low efficiency, measured by a dimensionless parameter ZT (function of Seebeck coefficient, electrical and thermal conductivities), it finds niche applications. Nanomaterials allow tailoring of the interdependent parameters, which opens up new avenues to enhance efficiency. Low thermal conductivity with a wide range of density of states and phonon electron scattering in nanomaterials make them ideal for thermoelectric applications [1]. When the dimensions of the material are comparable to the mean free path of the phonons, the thermal conductivity drops significantly due to surface scattering mechanism. Nanowires with modulated-diameter would further decrease the thermal conductivity substantially as the corrugations would act as a trap for phonons and reduce transmitivity [2].

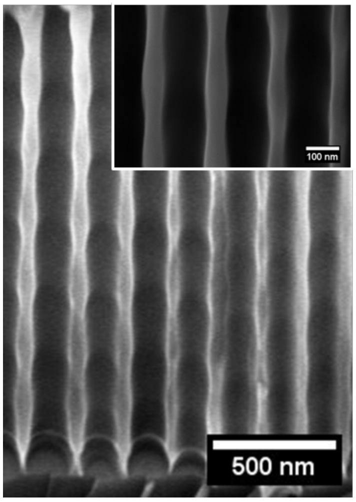

Fig. 1 – Nanoporous alumina fabricated through pulse anodisation.

In this work, dense forest ($10^9/\text{cm}^2$) of diameter-modulated silicon nanowires will be grown through template-assisted Chemical Vapor deposition (CVD). Nanoporous alumina, commonly used as templates, is fabricated by anodizing aluminum in acidic electrolytes. The diameter and porosity of the template depend largely on the applied voltage. In order to fabricate porous template with modulating pore diameter, method of pulse anodisation is employed which consists of periodic potential surges. Structural engineering along the film growth direction is achieved by deliberately designing the potential pulse sequences (Figure 1 shows cross-section of highly ordered alumina template with modulated pore diameter. The inset shows the symmetry of modulation in the pores). The arrangement of the pores on the surface is improved by the use of nanoimprint lithography and double anodisation method. The resulting highly ordered and dense structure of modulated pore diameter is suitable as templates for growing nanowires. The diameter of the Si nanowire segment is predefined by the internal pore structure of alumina. Growth of Si nanowires is underway through CVD. Sensitive 3-omega measurements will be carried out on the forest of nanowires to confirm the reduction in the thermal conductivity of Silicon.

1. Boukai, A., Xu, K., Heath, J.R., *Size-Dependent Transport and Thermoelectric Properties of Individual Polycrystalline Bismuth Nanowires*, Advanced Materials 18, 864–869, 2006.

2. Zianni, X., Chantrenne, P., *Thermal Condutivity of Diameter-Modulated Silicon Nanowires Within a Frequency-Dependent Model for Phonon Boundary Scattering*, Journal of Electronic materials, 42(7), 1509–1513, 2013.