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Thermopower Factor Measurement of Single Nanowires: On the Diameter Modulation to the Seebeck Coefficient and Electrical Conductivity

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Nanowire materials have shown great potential as efficient thermoelectric materials with greatly reduced thermal conductivities. Further enhancement on the thermopower factor ($S^2\sigma$, with S as Seebeck coefficient and σ as electrical conductivity) would lead to more improvements on the overall performances. Although there have been theoretical predictions for the advantage of nanowire in decoupling the inversely correlated S and σ, the corresponding experimental supports are still lacking.

Here, we present the setup of thermopower factor measurement of single nanowires and investigate the size effect with gradually varied diameter. With VLS grown Si nanowire as example, the related parameters of S and σ were measured and their inverse correlation in the case of nanowire was clearly revealed. To gain further insights on the size modulated thermopower factor, the diameter of nanowire was then continuously reduced from over 70 to ~10nm by an isotropic wet chemical etching method on the same Si nanowire. The results indicated a magnified role of surface at smaller diameters, stemming from either the improper surface contamination (carrier depletion) or electrical surface scattering events. These effects may limit the electrical conductivity significantly but contribute little to the increasing of Seebeck coefficient, which consequently will hinder most of the efforts on improving the overall thermopower factor.

Our results therefore highlighted the importance of surface care when investigating thermoelectric nanowires. The diameter modulation methodology may also gain application in other research fields of sensors and electromechanical devices.

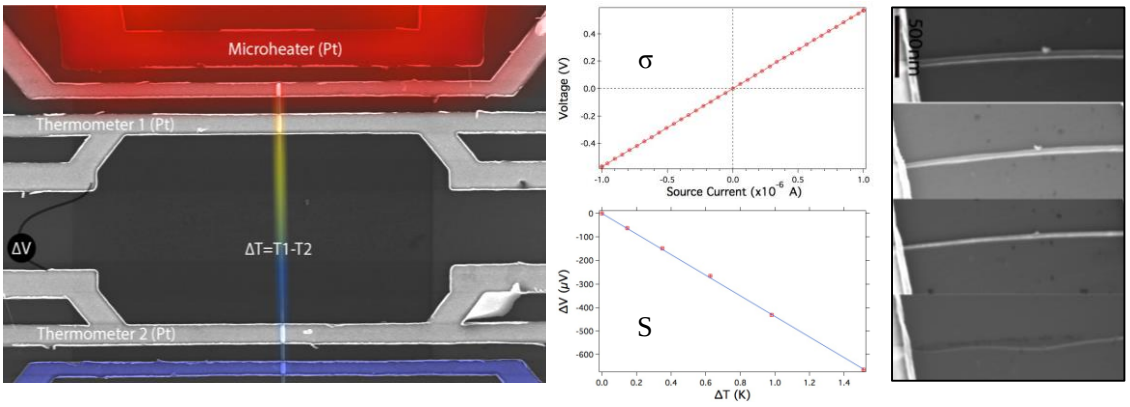

Figure 1. Image of a characterizing device for the thermopower factor measurement of single nanowire, with the σ and S derived from respectively the linear 4-terminal I-V curve and ΔT~ΔV relationship; a demonstration of on-device diameter modulation for the same Si nanowire.