Electronic Supplementary Material (ESI) for Nanoscale.

Supplementary Data 1: Mathematical equations used for modeling

(1) Umklapp phonon-phonon scattering events[1]:

$$\tau_{Umklapp}^{-1} = 2\gamma^2 \frac{k_B T \omega^4}{\mu V_0 \omega_D} \tag{1}$$

where γ is Gruneisen anharmonicity parameter, μ is shear modulus, V_0 is volume per atom, ω_D is Debye frequency, T is ambient temperature and ω is phonon angular frequency.

(2) mass-difference impurity scattering[2]:

$$\tau_{defect}^{-1} = \frac{nV^2\omega^4}{4\pi v_s^3}\left(\frac{\Delta M}{M}\right)^2 \tag{2}$$

where v_s is an averaged phonon group velocity, n is the dopant concentration is denoted, V is the volume of the host (silicon) atom, M is the silicon atomic mass, and ΔM is the difference between the host and impurity atomic masses.

(3) Phonon to grain boundary scattering[3] :

$$\tau_{grain}^{-1} = \int_0^d \frac{v_s}{d_g(z)}\left(\frac{1-p_{tr}}{1+p_{tr}}\right)dz \tag{3}$$

where $d_g(z)$ is the grain size at thickness z, p_{tr} is the probability of specular transmission ($0 \le p_{tr} \le 1$).

(4) Segregated dopants induced scattering[4]:

$$\tau_{segragated\ dopants}^{-1} = \int_0^d \frac{2v_s}{\pi d_g(z)}\left\{1+\left[e^{\left(\frac{\pi}{2}\right)^2\delta(\omega,z)}-1\right]^{-1}\right\}^{-1}dz \tag{4}$$

where $\delta(\omega,z)$ is the grain boundary scattering strength.

Table S1 The parameters used for simulation

Temperature (K)	**Doping concentration (cm^{-3})**	**Maximum grain size (nm)**	**Minimum grain size (nm)**
300	$3*10^{19}$	400	100

Supplementary Data 2: Measurement setup of thermal electric properties of poly-Si

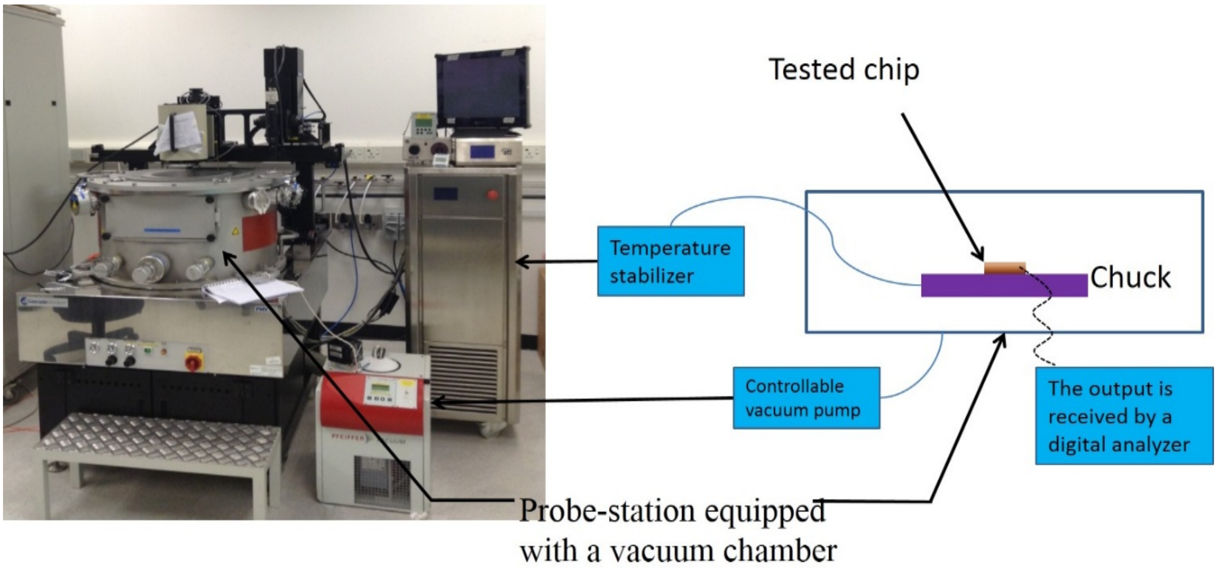

Figure.S1 Testing setup for the measurement of thermoelectric properties of poly-Si.

The measurement is conducted with a probe-station (Cascade Microtech, PMV200) equipped with a vacuum chamber, which can provide vacuum level at 10^{-3} mbar, to eliminate the influence of the thermal conductance due to air. The Chip is clamped onto a metal chuck, which acts as a large heat sink. The temperature of the chuck is controlled by a temperature stabilizer to maintain a constant temperature. The output signal can be readout by the probe and received by a semiconductor parameter analyzer (Agilent technology, 4156C)

Supplementary Data 3: Characterization results of the test key

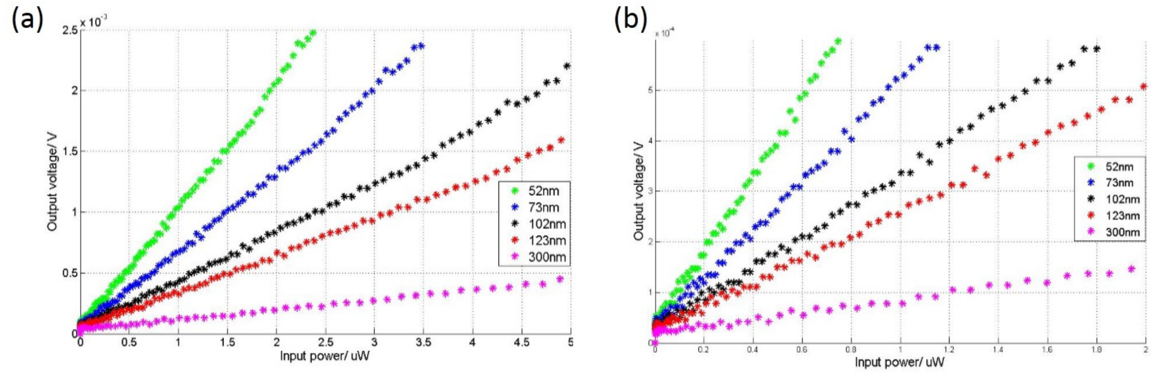

Figure.S2 The characterization with input power vs. output voltage of n-type poly-Si (a) and p-type poly-Si (b) test-key at room temperature.

As shown in this figure, the output is quite linear to the input power which suggests the contact between the Al and poly-Si is quite good and the temperature rise caused by the micro-heater do not influence the performance of thermocouple obviously.

[1] Mingo, N. Calculation of Si nanowire thermal conductivity using complete phonon dispersion relations. *Physical Review B*, *68*(11), 113308(2003).

[2] Zou, J., & Balandin, A. Phonon heat conduction in a semiconductor nanowire. *Journal of Applied Physics*, *89*(5), 2932-2938(2001).

[3] McConnell, A. D., Uma, S., & Goodson, K. E. Thermal conductivity of doped polysilicon layers. *Microelectromechanical Systems, Journal of*, *10*(3), 360-369(2001)..

[4] Goodson, K. E. Thermal conduction in nonhomogeneous CVD diamond layers in electronic microstructures. *Journal of Heat Transfer*,*118*(2), 279-286(1996).