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Supporting Information

Directional architecture of graphene/ceramic composites with improved thermal conduction for thermal applications

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Details of the thermal evolution study (Figure 5)

All the samples had same starting temperature of ~28 °C tuned by air conditioning before measurement. Then, the samples were placed on a heating plate with constant temperature of 70 °C, temperature distribution images of these samples were recorded by a thermal imager (SC305, Flir system USA). A photo shot was taken every 1 second interval by the thermal imager to record the thermal evolution of the samples. Therefore, the heating rate depended on the thermal conductivity of the samples.

Detailed description of the thermoelectric application

In the cooling system, thermoelectric cooling can be achieved by inputting a direct current through a pair of n-type and p-type semiconductor materials, and electrons and holes carry heat to the same direction of the device, eventually resulting in cooling. The cooling capability of a thermoelectric material is dependent on a combined effect of the material, which includes electrical resistivity, Seebeck voltage and thermal conductivity over the temperature range between the cold and hot end.[S1] The cooling performance of a conventional thermoelectric cooler is generally expressed by the characteristics as follows: the maximum temperature difference established across the cold and hot sides, ΔT_{max}, coefficient of performance, Z_D, and the heat pumping capacity, Q_c.[S2]

$$\Delta T_{\max} = \frac{Z_D T_c^2}{2} \tag{1}$$

$$Q_c = K\left(\Delta T_{\max} - \Delta T\right) \tag{2}$$

$$\eta_0 = \frac{T_c}{T_h - T_c} \bullet \frac{\left(Z_D\, T_c + 1\right)^{1/2} - T_h / T_c}{\left(Z_D\, T_c + 1\right)^{1/2} + 1} \qquad (3)$$

where T_h and T_c are temperatures of the hot and cold ends, respectively; $\Delta T_M=(T_h+T_c)/2$ is the mean temperature; $\Delta T=T_h-T_c$ the temperature difference; $K=\lambda(A/l)$ the thermal conductance; Z_D is the figure-of-merit of the thermocouples and is given by

$$Z_D = \frac{\alpha_{NP}^2}{RK} \qquad (4)$$

We derictly evaluate the efficiency of the cooling device according to the temperature of the cold end under a constant current and voltage. The cooling capability of the device is improved by fixing a heat sink to quickly dissipate the heat to the envirenment and futher reduce the temperature of the cold end. The G-Ni/PCD-WA composite was fixed on the device, as shown in Figure S4. This experiment was carried out at temperature of ~28 °C tuned by air conditioning. Under a constant current and voltage, a cooling device which can transfer heat faster from the hot end to the environment can keep thermal equilibrium at a lower temperature.

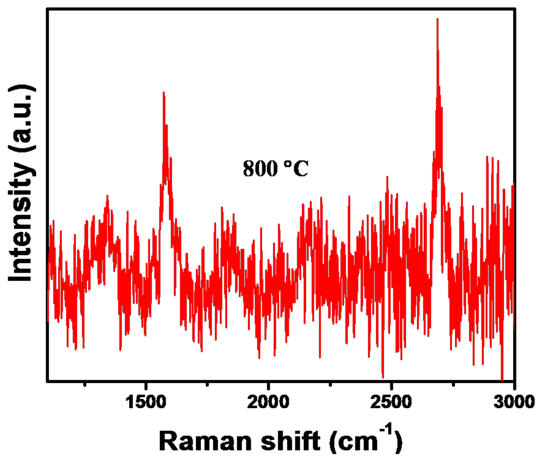

Figure S1. Raman spectrum of graphene grown on Ni/sapphire at 800 °C.

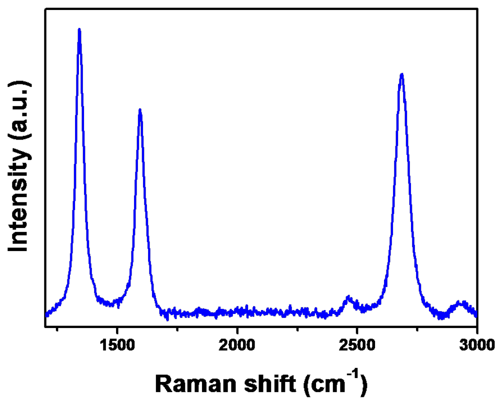

Figure S2. Raman spectrum of graphene grown on AAO at 1200 °C.

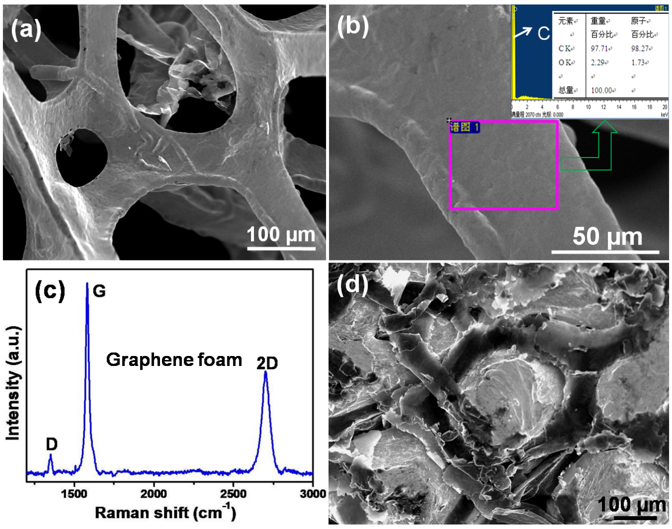

Figure S3 (a) & (b) SEM images of graphene foam and the EDS of the grpahene foam (inset). (c) Raman spectrum of graphene foam. (d) SEM image of G-Ni/PCD/GF composite composited with WA.

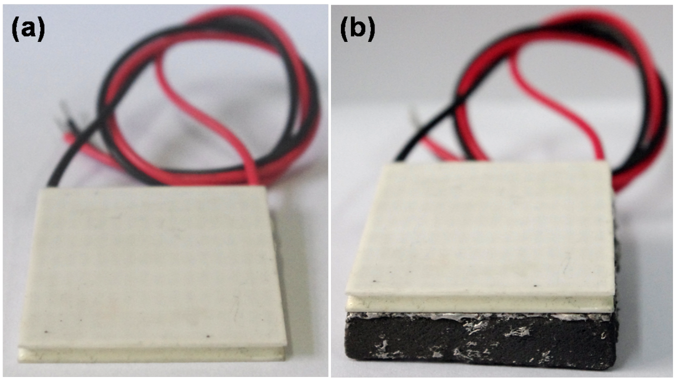

Figure S4 (a) & (b) The photographs of cooling device and cooling device fixed with heat sink of G-Ni/PCD-WA composite.

References

S1. S. B. Riffat, X. Ma, *Appl. Therm. Eng.* 2003, **23**, 913.
S2. G. Min, D. Rowe, Solid State Electronic. 1999, **43**, 923.