Electronic Supplementary Material (ESI) for Nanoscale.

Supplementary Information

High Temperature Thermal Management with Boron Nitride Nanosheets

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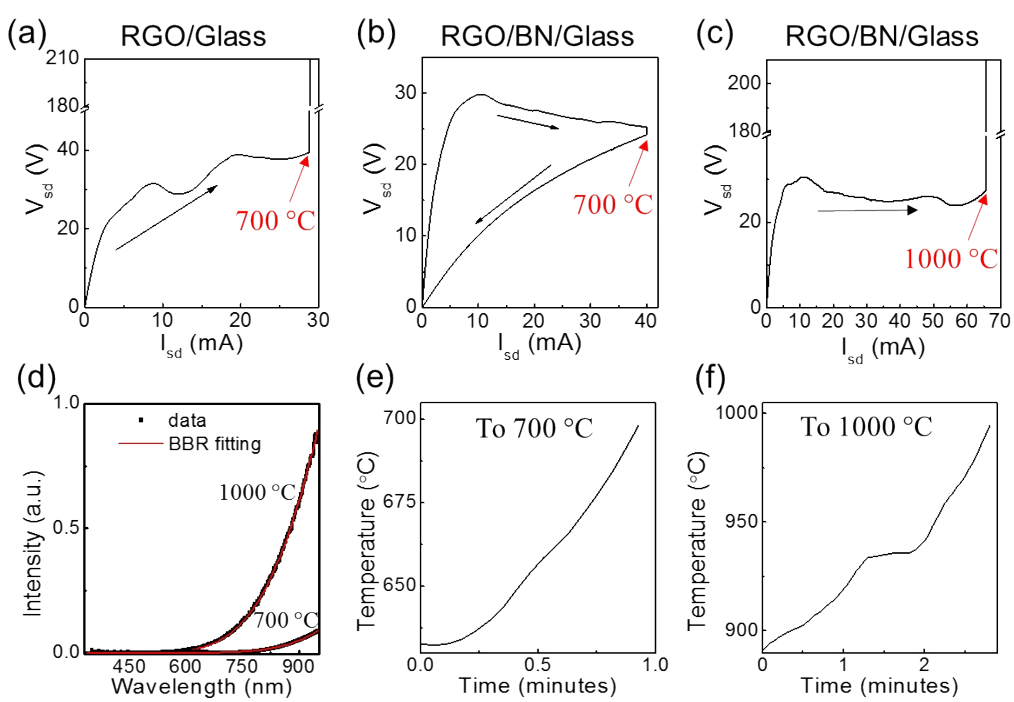
1. Device characteristics

Figure S1 provides the device characteristics during operation. There is a clear sign, where the voltage suddenly increases to the maximum limit of the power supply, when the device suddenly fails for RGO/Glass at 700 °C (Fig. S1(a)) and RGO/BN/Glass at 1000 ºC(Fig. S1(b)). The RGO/BN/Glass device was still operable when the device was held at 700 °C for 30 minutes and the voltage was steadily decreased as the current was lowered back down (Fig. S1(c)). The hysteresis between the I-V curves of increasing or decreasing current is due to the resistance change of the RGO thin film caused by further reduction at 700 °C. The emission spectra of the heated devices were recorded in a real-time manner when applying current through the devices. The spectra were fitted to Planck's law of black-body radiation: $I_\lambda(\lambda,T) = \frac{2hc^2}{\lambda^5}\frac{1}{e^{\frac{hc}{\lambda k_B T}}-1}$, to reveal the



operation temperatures of the devices.

Figure S1: (a-b) Source and drain I-V curve for (a) RGO device on Glass and (b) RGO device on BN/Glass up to a temperature of 700 °C. (c) Source and drain I-V curve for RGO device on BN/Glass up to a temperature of 1000 °C. (d) Spectral radiance measurements of RGO devices heated to 1000 ºC and 700 °C, and the corresponding blackbody radiation (BBR) fittings. (e-f) The temperature of (e) RGO device on Glass and (f) RGO device on BN/Glass as a function of time before the devices break.

2. Effect of h-BN film thickness on the thermal management performance

A finite element model in ANSYS was built to demonstrate the heat dissipation performance of BN film with different thickness on glass substrate when the BN/glass composite is exposed to local heat source for thermal management applications. In the simulation model, top surface of BN/glass composite is exposed to constant heat source, which is used to mimic active device power dissipation in the system. The lower temperature at the center of glass substrate marks the better thermal management performance of BN film and thus leads to higher reliability of the entire system. The ambient environment was set at 25 °C with consideration of natural convection effect from hot surface to ambient. The local heat generated from the device body is transferred through the BN film to the glass substrate. During the heat transfer process from local heat source to glass substrate, the thermal conductivity of the BN film plays a vital role to maintain thermal reliability of both device and substrate. High in-plane thermal conductivity of BN film (14 W/mK) contributes to unimpeded heat dissipation from the heat source to the environment (high heat flux). On the other hand, relative low cross-plane thermal conductivity of BN film (0.4 W/mK) effectively blocks the excess heat to reach glass substrate beneath the BN film. From the results of simulation, thicker BN film exhibits better thermal management performance, which is indicated by lower maximum temperature at the center of BN/glass composite with thicker BN film thickness, as shown in Figs. S2(a) and (b). A BN film thickness *vs* maximum temperature of glass substrate underneath the local heat source is plotted in Fig. S2(c), where the maximum temperature of the glass substrate under the same local heat decreases as the BN thickness increases. These simulation results indicate the thicker BN film thickness better benefits the thermal management performance.

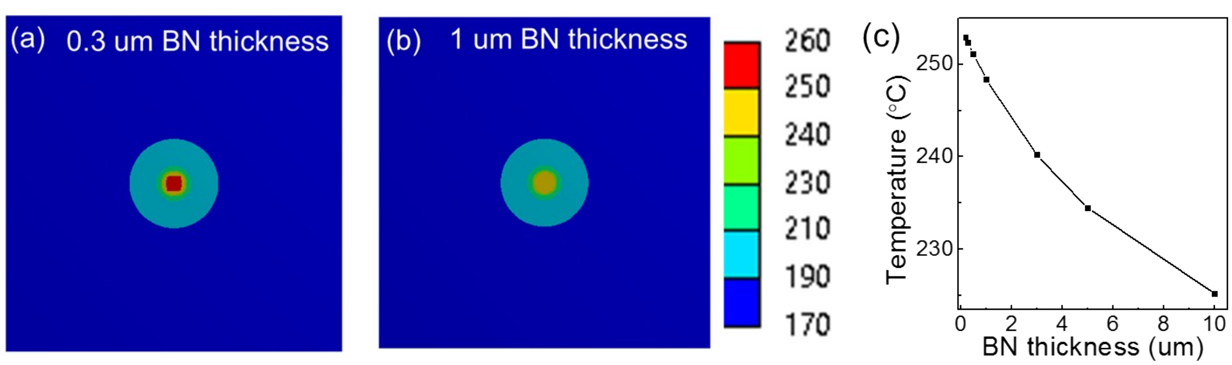


Fig. S2: (a-b) Temperature distribution on a BN/glass composite under the same local heat source for (a) 0.3 um BN thickness and (b) 1um BN thickness. (c) The maximum temperature of the glass substrate underneath the same local heat as a function of the BN thickness.