Electron and optical phonon temperatures in electrically biased graphene

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Graphene is characterized by remarkably large room-temperature carrier mobilities (> 10^5 cm^2Vs^{-1}) [1], as well as by its ability to sustain high current densities (> 10^8 A/cm2) [2, 3, 4, 5]. Recent investigations of high-field transport in graphene indicate a critical role for coupling of energetic carriers with the high-energy optical phonons [4, 5]. The distribution of energy within and among the charge carriers, the strongly coupled optical phonons, and the other phonons in graphene has, however, not yet been established.

Here, we examine the intrinsic energy dissipation steps in electrically biased graphene channels. By combining in-situ measurements of the spontaneous optical emission with a Raman spectroscopy study of the graphene sample under conditions of current flow, we obtain independent information on the energy distribution of the electrons and phonons [6]. The electrons and holes contributing to light emission are found to obey a thermal distribution (see Fig. 1), with temperatures in excess of 1500 K in the regime of current saturation. The zone-center optical phonons are also highly excited and are found to be in equilibrium with the electrons. For a given optical phonon temperature, the anharmonic downshift of the Raman G-mode is smaller than expected under equilibrium conditions, suggesting that the electrons and high-energy optical phonons are not fully equilibrated with all of the phonon modes.

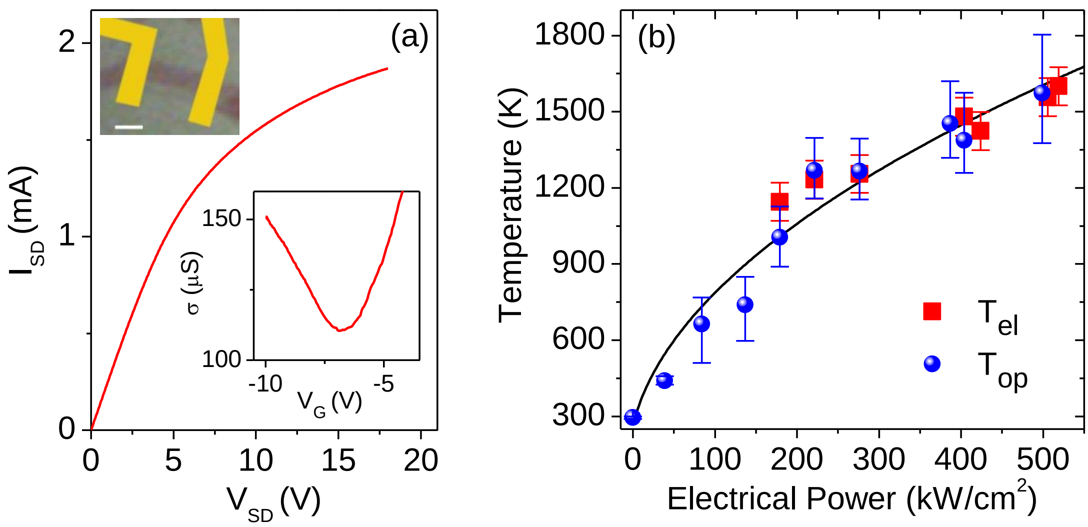

Figure 1: (a) Source-drain current-voltage characteristics at zero gate bias of the 3.6 x 1.6 μm^2 graphene channel shown in the top inset (the scale bar is 2 μm). The lower inset shows the back-gate dependence of the channel conductivity (σ). (b) Electronic (T_{el}, squares, deduced from the spontaneous optical emission spectra) and optical phonon (T_{op}, circles, deduced from Raman measurements) temperatures as a function of the dissipated electrical power. The dashed line is a guide to the eye, based on a scaling of the temperature as $P^{1/2}$.

References

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