Hot electron nano-imaging and real-space energy dissipation of operating microelectronic devices at room-temperature

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There's of fundamental importance to understand electron transport and real-space energy dissipation when a system is driven out of equilibrium. Especially as the specific size of modern electronic and optoelectronic devices goes down to the nanoscale, the electrons can dissipate their excess energy nonuniformly within the device. However, to experimentally characterize nanoscale hot electron distributions and energy dissipations are extremely challenging. Most of present studies are limited to measure time-resolved current noise by making use of ohmic contacts, and no spatial information can be obtained.

Here, we show the first experimental realization of direct hot electron imaging by locally probing excess noise[1]. The basic idea is that, when a device is driven out of equilibrium by applied bias, local current fluctuations can generate fluctuating electric and magnetic fields bound on the surface. The fluctuating evanescent fields are then scattered by an approached tip in the near-field[2], and sensed by a sensitive terahertz (THz) detector[3] placed in the far-field domain, as illustrated in Fig. 1.

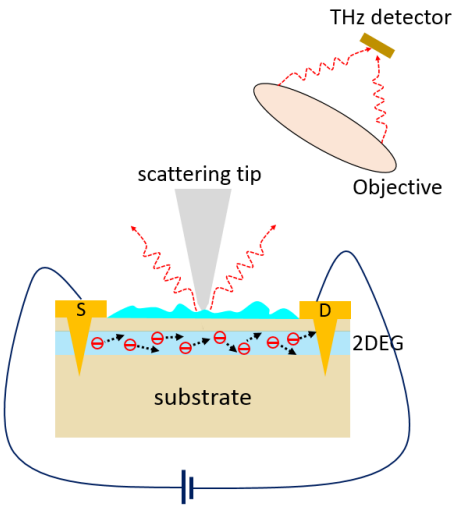

Fig. 1. Near-field nanoscopy for hot electrons on 2DEG devices at room-temperature.

We perform the study on a GaAs/AlGaAs two dimensional electron gas (2DEG) system at room temperature. The device is fabricated into nanoscale by electron-beam lithography and wet-etching, as shown in Fig. 2. High electric-field is generated in the narrow constriction when applying a large voltage on the device. Therefore, hot electrons with specific temperatures much higher than the lattice can be generated in the high-field region and releasing their excess energy outside of narrow constriction. Real-space hot electrons and their energy dissipation process are directly imaged for the first time at room temperature (Fig. 2). As a conclusion, we provide a new metrology for nonequilibrium local dynamics with spatial resolution down to the nanoscale.

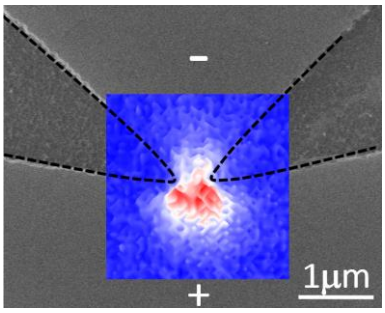

Fig. 2. Real-space hot electron distribution and energy dissipation at room temperature.

Reference:

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