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Hot electrons in carbon - graphite behaves like a semiconductor

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Nanomaterials like carbon possess unique properties, which have led to first applications in novel electronic devices and sensors. These materials are based on ordered, atomically thin layers of carbon atoms, for example in the form of a single layer as so-called 'graphene,' or rolled-up in carbon nanotubes. The electronic properties of such structures are closely related to those of graphite, which consists of a stack of graphene sheets. Despite intensive research in the past, the fundamental behaviour of electrons in this material are not fully understood and still controversially debated.

Markus Breusing, Claus Ropers and Thomas Elsaesser, three scientists from the Max-Born-Institute in Berlin, have now investigated the behaviour of electrons in thin graphite films in real time. As they now report in Physical Review Letters (Volume 102, Issue 08, 086809/1-4, 2009), they recorded the dynamics of electrons with an unprecedented temporal resolution of only 10 femtoseconds (one femtosecond is a millionth of a billionth of a second). Electrons were excited to high energy states with ultrashort laser pulses, and their return to equilibrium was observed. The individual steps of this process are temporally resolved, and the momentary distribution of electrons in the material is identified. Within 30 femtoseconds, electrons form a hot gas with temperatures of 2500 C, which cools down to about 200 C in only 500 femtoseconds. The energy dissipated in this process is transferred to the crystal lattice. After this process, the electrons slowly return to their initial states. For the first time, the study shows conclusively that, on ultrashort time scales, graphite behaves like a semiconductor, such as silicon or gallium arsenide, and not like a metal.

The observed dynamics have significant consequences for electrical transport, such as currents flowing through the material at high frequencies. The results are of fundamental importance for future electronic devices based on carbon, in which high electrical fields or frequencies are processed.