Ultrafast dynamics of topological material probed under pressure

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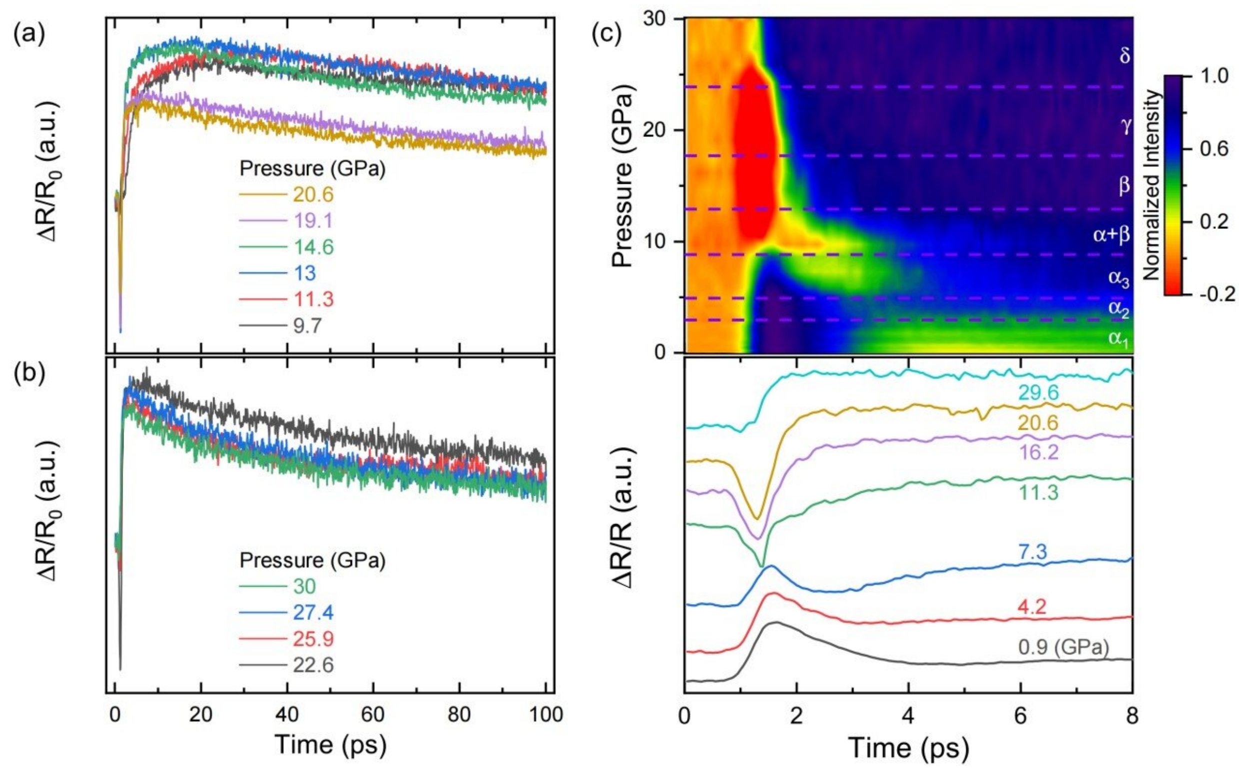

Transient reflectivity spectra of Sb2Te3 at different pressures. Credit: Su Fuhai

A team led by Prof. Su Fuhai from the Hefei Institutes of Physical Science (HFIPS) of the Chinese Academy of Sciences (CAS), together with researchers from the Aerospace Information Research Institute, and the Center for High Pressure Science and Technology Advanced

Research has investigated the nonequilibrium electron and phonon dynamics of the topological insulator Sb_2Te_3 under pressure and explored the ultrafast photophysics across the electronic topological and lattice structure transitions.

Relevant results have been published in *Physical Review B*.

Ultrafast spectroscopy can record the evolution of excited states with femtosecond time resolution, and then allow direct access to the ultrafast dynamics involving the hot electrons cooling, coherent phonons, electron-phonon couplings, etc. Pressure modulation using a diamond anvil cell (DAC) provides a simple and clean way to continuously adjust the lattice and electronic structures in materials, resulting in different phase transitions. In high pressure phase materials, pressure-induced electron topological transitions (ETTs) without lattice abruption are often critical for thermal electronic properties and superconductivity. However, investigating the electron-phonon interactions on ETT remains challenging.

In this work, using femtosecond optical pump-probe spectroscopy (OPPS) in combination with DAC, the researchers investigated the ultrafast photocarrier dynamics of the Sb_2Te_3, one of prototypical topological insulators.

OPPS was employed to track the nonequilibrium relaxations of the hot electron and coherent acoustic phonon in the time range of 100 picoseconds under hydrostatic pressure up to 30 GPa. Supported by Raman spectroscopy, the researchers identified the ETT and semiconductor-semimetal transition around 3 GPa and 5 GPa from the pressure dependence of phonon vibrations, relaxation time constants and coherent phonons.

Intriguingly, OPPS revealed a hot phonon bottleneck effect at low pressure, which was found to be effectively suppressed along with the onset of ETT. This phenomenon was interpreted in terms of the abrupt increase in the density of state and the number of Fermi pockets, according to the calculated electronic and lattice structures.

Furthermore, they found that the pressure dependence of the photocarrier dynamics could also exactly reflect the lattice structure transitions including α-β and β-γ phase changes, even the mixed phase.

This work not only develops a new understanding of the interactions between electron and lattice in Sb_2Te_3, but also may provide an impetus to assess the pressure-induced topological phase transitions based on the ultrafast spectroscopies.

More information: Kai Zhang et al, Nonequilibrium electron and lattice dynamics of Sb_2Te_3 under pressure, *Physical Review B* (2022). DOI: 10.1103/PhysRevB.105.195109

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