Direct observation of photo-induced spin-density-wave gap closing and recovery in $(TMTSF)_2PF_6$ by terahertz time-domain spectroscopy

Shinichi Watanabe[1], Ryusuke Kondo[2], Seiichi Kagoshima[2], and Ryo Shimano[1]
[1] *Department of Physics, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo, 113-0033 Japan*
[2] *Department of Basic Science, University of Tokyo, 3-8-1 Komaba, Meguro-ku, Tokyo, 153-8902, Japan*
Email: shimano@phys.s.u-tokyo.ac.jp

Ultrafast photo-induced phenomena of the symmetry broken (insulating) ground states in organic conductors have attracted much attention recent years. In particular, the non-thermal modification of the conducting properties mediated by photo-excited states [1] would be promising for efficient and ultrafast optical switching devices. In order to understand the photo-excited dynamics in such systems, a direct probe of the order parameters would be crucial. Here we demonstrate ultrafast optical pump and terahertz probe measurement to study the ultrafast photo-excited dynamics of spin density wave (SDW) ground state in $(TMTSF)_2PF_6$ with ps time resolution.

The single crystal $(TMTSF)_2PF_6$ sample is grown by electrochemical oxidation, in which the metal-to-insulator transition accompanied with the SDW formation is confirmed below 12 K by dc-conductivity measurement. The change of conductivity spectra in THz frequency range at T=4 K and 3 ps after an ultrafast laser pulse excitation are summarized in Fig. 1. Without the laser pulse excitation, the peak as well as the suppression of the conductivity at and below ~65 cm^{-1} occurs due to SDW gap opening [2]. When the optical excitation density increases, the conductivity peak shifts to the lower energy, indicating a closing of the SDW gap. Such a closing of the gap can be attributed to the non-equilibrium distribution of quasi-particles as predicted in superconductors [3]. The recovery dynamics of the gap shows a strong temperature dependence, which indicates that the quasi-particle recombination rates depend on the temperature dependent energy gap, as predicted by the theory [4].

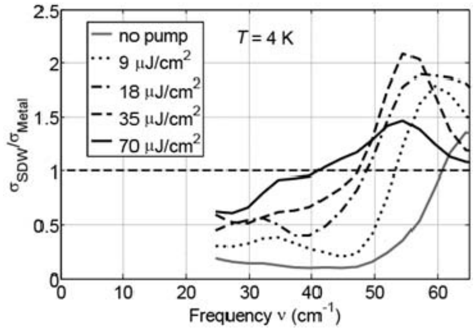

Fig. 1: Conductivity spectra of $(TMTSF)_2PF_6$ at T = 4 K and 3 ps after an ultrafast laser pulse excitation (λ=800 nm, ~30 fs in pulse width) with the indicated excitation densities. The conductivity is normalized by the metallic conductivity at T = 15 K.

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[4]V. V. Kabanov *et al.*, PRB **59**, 1497 (1999).