Ultrafast THz Modulation Characteristics of Photo-induced Metal-Insulator Transition of W-doped VO_2 film

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***Abstract*—The ultrafast terahertz modulation characteristic during photoinduced metal-insulator transition (MIT) of W-doped VO2 film was investigated at picoseconds time scale using time-resolved terahertz spectroscopy. The phase transition dynamic process was dramatically suppressed in W-doped VO2 film, which could be ascribed to the lattice distortion and enhanced electron-electron interaction caused by W substitution for V. The transient complex terahertz conductivity of W-doped VO2 film at different pump-probe delay times were extracted and can be well fitted by Drude-Smith model, which provide significant insights into the dynamic properties of MIT in nanogranular VO2 film.**

VANADIUM dioxide (VO2) undergoes a first-order phase transition from tetragonal metallic phase to monoclinic insulator phase (metal-insulator transition, MIT) around 68ºC, accompanied with strong transmission contrast of terahertz (THz) wave between insulating and metallic phase [1-4]. Therefore, VO2 based THz switchers and ultrafast modulators have attracted much attention. For practical application, however, the phase transition temperature of pure VO2 is a little higher than ambient. Fortunately chemical doping can effectively modify the phase transition properties in VO2, such as W, Mo, Nb, etc. Among these W ion is the most effective dopant that can reduce the phase transition temperature by 23ºC/at. % [5]. To the best of our knowledge, most of the current research on VO2 based THz wave modulation is based on pure VO2. Since W-doped VO2 have potential advantages in THz functional devices, it has rarely been investigated at terahertz range, especially for its ultrafast modulation characteristic at picosecond scale[6-8].

In this work, we have investigated the dynamic process of the photoinduced metal-insulator transition (MIT) in W-doped and undoped VO2 film using time-resolved terahertz spectroscopy for the first time. The sample was excited by fs laser pulses and the transient property of the sample were probed by THz pulses at different delay times. Then the complex THz conductivity of W-doped sample was extracted (see Fig. 1). The characteristic properties of photoinduced MIT, such as carrier density N, scattering time τ, were determined by Drude-Smith model. We found that the phase transition process will be dramatically suppressed by W substitution in VO2 film, leading to the response time of ultrafast THz modulation increased more than tens of picoseconds in W-doped film (see Fig. 1). The reason for this should be ascribed to enhanced structure distortion and enhanced electron-electron interaction caused by W substitution for V. And it indicates that W-doped VO2 could be a promising candidate for THz function devices like modulators and switchers.

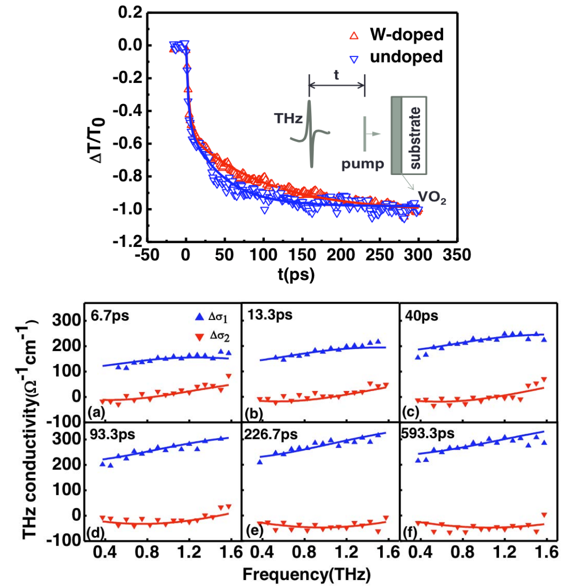

Fig. 1. (Upper) Normalized transient transmittance changes of undoped and W-doped VO2 film. Triangles are the experiment data and solid line is the fitting curve with bi-exponential function. The inset shows the pump-probe process. (Lower) Transient THz conductivity of W-doped sample at different delay times with pump fluence 1.95m J/cm2. Triangles are the experiment data, and solid lines are the best fits with Drude-Smith model.

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