# Noncontact interface potential estimation on $VO_2$/Si heterojunction with temperature variation

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## 1. Introduction

Vanadium oxide ($VO_2$) exhibits a phase transition from an insulating monoclinic phase (M) to a conductive rutile phase (R) around 340 K[1]. Owing to the unique phase transition close to room temperature, $VO_2$ has been focused on the research of tunable terahertz (THz) devices, such as THz modulators, absorbers, and metamaterials. On the other hand, the THz emission properties from the $VO_2$-based structures have not been systematically studied. The relationship between the THz emission amplitude and the temperature conditions is quite essential to estimate the electric properties of the $VO_2$-based devices and deeply understand the influence of the phase transition on the properties of the $VO_2$/Si interface, which will contribute to the development of the THz devices based on the $VO_2$. In this study, we focus on the THz emission properties from $VO_2$/Si heterojunction under different temperature conditions. Meanwhile, we discussed the influence of the doping conditions of the Si substrate on the THz emission properties and estimated the work function variation across the phase transition.

## 2. Experiment and set-up

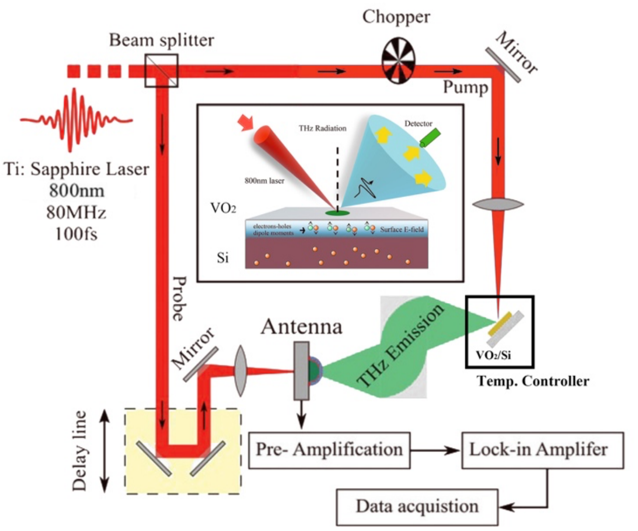


Fig. 1 Diagram of the TES system for testing THz emission from the $VO_2$/Si samples with different temperatures.

In the experiment, the $VO_2$ film was deposited on the Si substrate with different doping conditions by using pulse laser deposition (PLD). We used undoped, low-doped n-type, and high-doped p-type Si as the substrate. The TES system was performed to measure the waveforms and amplitudes of the THz emission from the $VO_2$/Si heterojunction, as shown in Fig.1. The samples were excited at 80 MHz using an 800-nm source at an incident angle of 45°[2]. The sample was arranged in the vacuum condition of 1E-4 pa and a temperature controller was used to adjust the temperature of the sample ranging from 300 K to 400 K. We set the 5 mW for the probe laser power and 600 mW for the pump.

## 3. Results and discussion

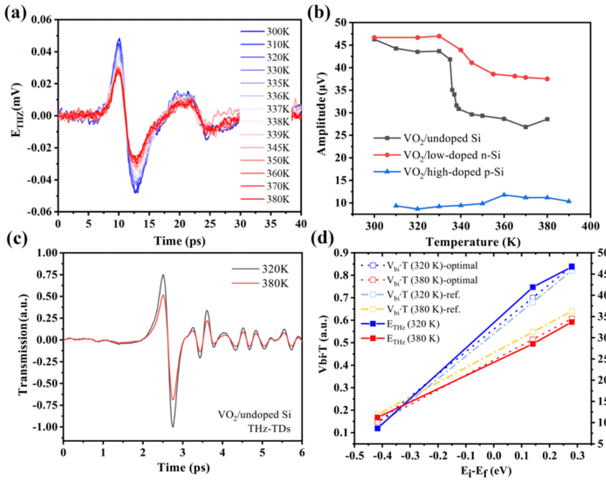

Fig. 2 The THz emission waveform from the $VO_2$/undoped Si with temperature increase from 300 K to 380 K.(b) he temperature dependence on the THz emission amplitude from $VO_2$/Si with different doping conditions. (c) The time-domain THz transmission waveform of the $VO_2$ film at 320 and 380 K measured by THz-TDs system, which exhibited 34% intensity loss from 320 to 380 K. (d) The comparison between the measured THz emission amplitude ($E_{THz}$) and the calculated interface barrier ($V_{bi}$) considering the transmission intensity loss factor (T).

Figure.2(a) and 2(b) show the THz emission waveform and temperature dependence on the THz emission amplitude from $VO_2$/Si heterojunction with undoped, low-doped n-type, and high-doped p-type Si substrates from 300 K to 390 K. The THz emission is extremely sensitive to the interface electric field. Due to the work function difference between $VO_2$ and Si substrate, the band bending occurs at the interface and accelerates the photocarriers to generate ultra-fast photocurrent, and excites the THz emission from the interface[3]. When the phase transition occurs, the electric properties of $VO_2$ are largely changed, such as the work function[4], which can be reflected by the THz emission properties. We also consider the transmission variation due to phase transition, as shown in Fig.2(c). Based on these results, the estimation of $VO_2$ work function can be achieved as 5.17–5.25 eV for temperature increase from 320 to 380 K, as shown in Fig.2(d), which makes the TES to be a potential noncontact estimation method of the materials properties.

## References

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