$Cu_2ZnSnSe_4$ photovoltaic thin film: A potential large-area THz emitter

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Abstract—**An efficient terahertz (THz) emission from sol-gel grown $Cu_2ZnSnSe_4$ (CZTSe) film is evaluated using THz time domain spectroscopy. Comparing the polarity of THz emission waveforms of CZTSe and GaAs, we suggest the acceleration of photo-carriers in the surface accumulation layer of CZTSe to be the dominant mechanism of radiation emission.**

I. INTRODUCTION

Large-area THz surface emitters receive increasing interest due to their rubastness, and higher damage threshold with better output efficiency, however, such device is either grown by molecular beam epitaxy (MBE) or metal-organic vapor phase epitaxy (MOVPE). These fabrication methods require strict operating environments, while exhibiting extremely low growth rates. To date, it remains a challenge to realize highly cost-effective materials adapted for large-area surface THz emitters.

In this work[1], we report the observation of efficient THz radiation from the surface of a $Cu_2ZnSnSe_4$ (CZTSe) thin film grown via low-cost sol-gel method. The THz temporal waveform is measured using a THz time-domain spectroscopy (THz-TDS) setup. In addition to the structural and electrical characterization, the mechanism of THz emission from the CZTSe thin film is revealed.

II. RESULTS

The temporal waveform of THz radiation from CZTSe pumped with a femtosecond laser (800 nm, 80 fs pulses, and 82 MHz rep. rate) is shown in Fig. 1(a), and the corresponding spectrum is shown in Fig. 1(b).

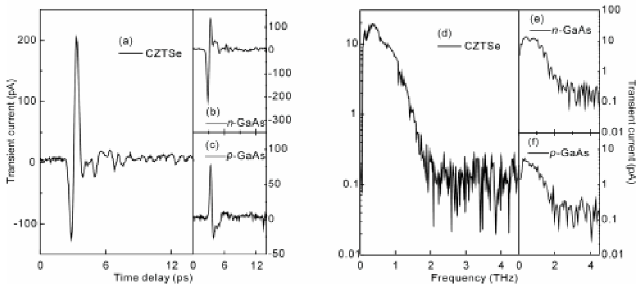

Fig. 1 (a),(b),(c) refers to the THz waveform of CZTSe, *n*-GaAs, and *p*-GaAs, (d),(e), (f) refers to the THz spectrum of CZTSe, *n*-GaAs, and *p*-GaAs,respectively.

The radiation bandwidths of CZTSe is close to 2 THz with a 40 dB dynamic range (the peak-to-noise level ratio of the power spectrum), as is comparable to GaAs under the same excitation power. The energy band bending directions (upward or downward) determine that the surge current direction of p-type semiconductor is opposite to that of n-type material. GaAs exhibits distinct THz polarity dependence due to its surface depletion layer so as to be an ideal reference emitter. As shown in the Fig. 1(b) and Fig. 1(c), n-GaAs exhibits a distinct positive peak THz waveform, while p-GaAs exhibits distinctly a valley THz waveform. The CZTSe shows the same THz polarity as n-GaAs.

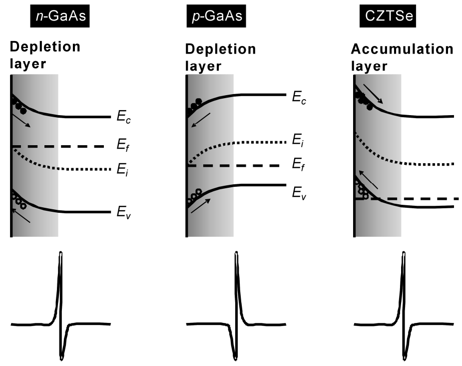

Fig. 2. Diagram of the relation between THz polarity and the surface band bending of GaAs as well as CZTSe thin film.

Such a phenomenon indicates that the band bending direction at the surface of p-type CZTSe is more similar to the n-GaAs rather than p-GaAs. Actually, the surface band of p-type semiconductor is likely to bend upward when the edge of valence band is closer to the Fermi-level at surface area. For upward band bending, negative charges exist at the surface, and holes accumulate in the CZTSe near surface, causing an accumulation layer[2]. The accumulation layer in p-type semiconductor causes the band bending upward but downward in n-type semiconductor.

III. SUMMARY

In summary, a prominent THz radiation is observed in CZTSe photovoltaic thin film excited by femtosecond laser pulse. The mechanism of THz generation from CZTSe thin film is dominated by acceleration of photocarriers in accumulation layer at the surface of CZTSe. The CZTSe is found to be a potential cost-effective large area THz emitter.

REFERENCES

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