Some progress on the new kind of IR &THz detectors

Junhao Chu[1,2]
[1] Key laboratory of polar materials and devices, East China Normal University, Shanghai, China
[2] National Laboratory for infrared physics, Shanghai Institute of Technical Physics, CAS, Shanghai, China

***Abstract*—Based on novel effects due to the development of materials preparation technology and the new construction of materials, some new kind of IR & THz detectors have been developed recently, and new concepts for IR detectors appear too. The talk includes three parts: trends of IR detector technology, new concept IR & THz detectors, and intelligence application of IR & THz detectors.**

I. INTRODUCTION

The IR detectors have been deeply investigated recent some ten years. The general purposes are to prepare very large scale focal plane arrays, multi-color detectors, to enlarge the spectra-response to longer wavelength range even THz range, to raise the working temperature to range of the semiconductor cooling system, and to develop sensitive un-cooled IR detectors working at room temperature [1]. For all the purposes new infrared sensitive materials and constructions are investigated in addition to narrow gap semiconductors such as HgCdTe.

II. RESULTS

A new kind of IR detector is based on the wavelength upgrade transformation techniques which combine the quantum well IR detector with the LED device. Liu *et al.* proposed an innovative device that integrated the photoconductor (QWIP) with a light emitting diode (LED) which can convert long-wavelength infrared radiation into near-infrared or visible light [2]. An n-type QWIP-LED device is operated at a forward constant bias and illuminated by long wavelength infrared radiation, the electrical current injected into LED segment will increase, which in turn leads to an increase of near-infrared emission from the LED. The infrared detection process could be transformed to using Si CCD to test visible or near infrared light from LED which has been influenced by weak electron signal from QW detector. Further studies are going well in NLIR.

Same principle is also used to realize the wavelength upgrade transformation detector by a Metal-Ferroelectric thin film-semiconductor (MFS) structure. When the p-type semiconductor is at inversion states in a MFS structure, the inversion states changes as the infrared light illuminates the ferroelectric thin film due to the polarization change. Therefore the optical constants changes, resulting the visible reflectance change. By using the Si CCD to test the visible reflection variation signal, it detects infrared light.

A new type of infrared detector, which utilize amplification of the tunneling current via controlling the interface of the ferroelectric tunnel junction (FTJ) reaches a critical condition (Fig. 1). The PVDF ultrathin films act as the barrier layer in the FTJs were fabricated by Langmuir-Blodgett (LB) deposition technique. The thickness of every transfer layer is ~2.2 nm and we control the thickness of the PVDF LB films at 2.2 and 4.4 nm [3,4]. As the incident infrared radiation reaches to the surface of the FTJ, the rising temperature will induce the change of the ferroelectric polarization, which leads to variation of the tunneling current across the junction. As a result, the FTJ can act as an infrared detector with a bolometer-like method. Furthermore, we can precisely design the structure of the FTJ with an ingenious critical state, where the tunneling only occurs after the incident infrared radiation. In other words, the FTJ maintains high resistance state without the infrared radiation, but transfers to low resistance state under the infrared radiation. And the quantum amplification can be realized by the FTJ. Indeed, it is difficult to design and fabricate such a delicate structure, however, it is reasonable to realize the quantum amplification of infrared detection by the FTJ devices.

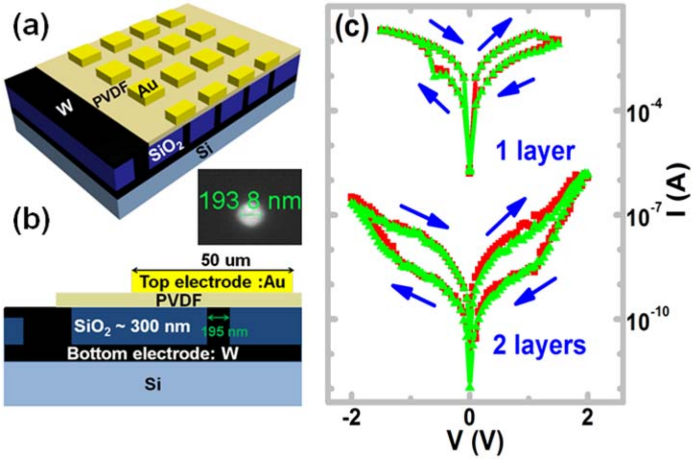

Fig. 1. Sketch and current versus voltage (I-V) characterization of the PVDF FTJs.

A novel effect of carries gathering from metal to semiconductor due to the interaction of THz field with narrow gap semiconductor MSM structure was found by Huang et al. [5]. When THz wave incidents on the MSM structure the carries will gather into semiconductor region from Metal. The Au/HgCdTe/Au structure is used in the experiment. This is in turn to detect THz light. This is a new kind of room temperature THz detector. The same effect is also observed in Au/InSb/Au structure. The results suggest a way to generate carriers by photons without adequate excitation energy and will have great significances in terahertz detection.

In order to develop very sensitive IR &THz detectors the quantum enhanced effect in tunneling structure can be used. Several structures and possibilities for very sensitive IR detector are presented for discussion.

The most popular application of IR & THz detectors is to get objective image in dark environment and to get the temperature

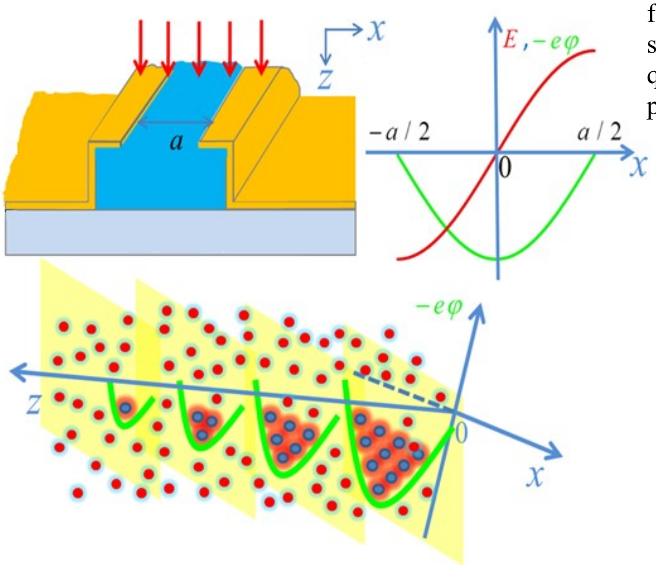

Fig. 2. Photocurrent by the wave nature of photons.

distribution of objective. However, the intelligence application of IR & THz detectors should be widely developed to get more information from the spectroscopic data and ellipso-spectroscopy data.

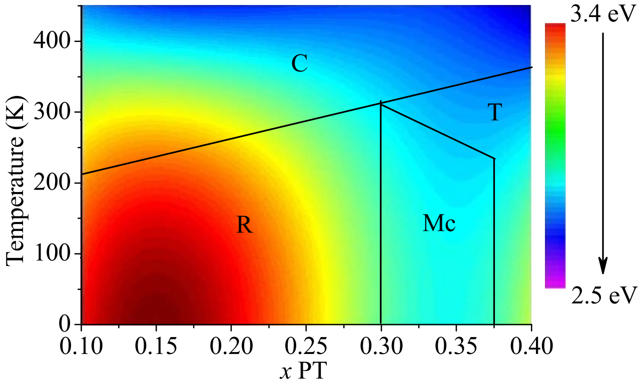

Fig. 3. The phase diagram for PMNT single crystals derived from temperature and composition dependences of band gap variation

We present the interesting results on optical properties from PMNT, PIMNT single crystals and (PbLa)(ZrSnTi)O_3 (PLZST) ferroelectric ceramics using variable-temperature (200-750 K) spectroscopic ellipsometry (SE) technique [6-9]. By the standard critical-point (SCP) model, some typical interband transitions can be observed from the second derivative of dielectric functions. It was found that the discontinuous evolution from the second derivative of dielectric functions can be corresponding to phase transition patterns. It indicates that these characteristic changes can be readily accounted for the ferroelectric order. Based on the interband transitions, the phase diagram of PMNT (Fig. 3), PIMNT, PLZST oxides (Fig. 4) can be significantly improved. Moreover, a peculiar incommensurate antiferroelectric state has been found to exist above the temperature of the normal commensurate antiferroelectric tetragonal structure for PLZST ceramics. It reveals an intrinsic relationship between fundamental bandgap and phase transition of ferroelectric oxides, which pioneers an effective methodology to explore the phase transition of ferroelectric. Also, the present results provide important supports for the theoretical model, which can establish a quantitative relationship between the electronic transition and phase transformation for ferroelectric oxides.

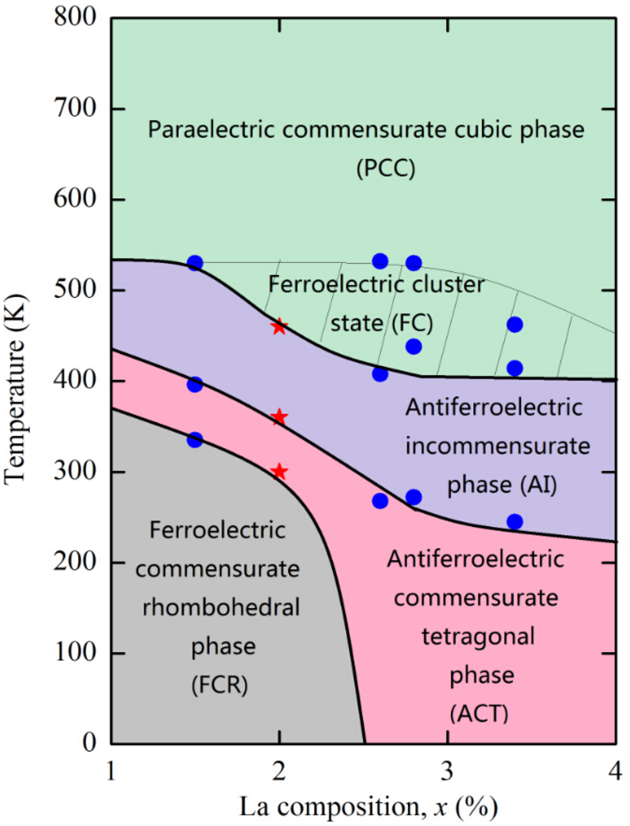

Fig. 4. The phase diagram for PLZST ceramics derived from temperature and composition dependences of band gap variation

III. SUMMARY

We have reported the recent developments of some new kind of IR & THz detectors and new concepts for IR detectors. A prediction of the trends on IR detector technology and intelligence applications of IR & THz detectors have also presented in the talk.

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