The Characterization and Fabrication of Pyroelectric Infrared Sensor and Application of Thermal Image Array

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Abstract

The pyroelectric infrared (PIR) sensor with the lead-titanate (PbTiO3) thin film has been successfully fabricated. A RF planar magnetron sputter was used to deposit $PbTiO_3$ thin film. A perovskite thin film can be obtained. From the properties measurement we can obtain the remanent polarization Pr = 20.8 $\mu c/cm^2$ and coercive electric field Ec = 79.365 kV/cm. The pyroelectric coefficient of 1.09 $\times 10^{-5}$ C/m^2 K at 50 °C was measured as a function of temperature. In addition, the fabricated PIR sensor properties is RV = 600 (VW^{-1}) when chopper frequency is 0.3 Hz. D* = 7.3×10^5 cm $Hz^{1/2}$ W^{-1} for a modulation frequency of 0.5 Hz. In this experiment, the 4 $\times$ 4 array for PIR sensor is also constructed and tested.

***Key Words*:** Pyroelectric Infrared Sensor, Pyroelectric Coefficient, Polarization

1. Introduction

Infrared light and thermal radiation has been known for many years. Block and Wien had proposed corresponding theories about infrared. Any object has temperature will radiate the infrared. Infrared sensor will detect the infrared radiation from the object. Since the infrared radiation is commonly encountered in many substances, IR sensor is one of the most useful sensors.

Infrared sensor can be classified into two major types including thermal type and photon type. The photon type sensors often need to be cooled to the cryogenic temperature to obtain a better performance. They are wavelength selective. On the other side, there are many advantages about thermal IR sensor such as no need for cooling equipment, no radiation harmful, low cost, and easily integration.

In this experiment, a thermal type $PbTiO_3$ (PT) pyroelectric infrared sensor (PIR) is investigated. Furthermore, the fabricated PIR sensor is constructed as a 4 $\times$ 4 matrix to be a image sensor-array. In addition, for thermal insulation of the pyroelectric infrared (PIR) sensor and PIR 4 x 4 array sensor, backside etching for silicon substrate is used to minimize conductive heat loss.

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2. Experimental

The PIR sensor with the PT thin film has been successfully fabricated. The pyroelectric detector is fabricated on silicon chip. A microelectro-mechanical-system (MEMS) technique is used to have a back side etching to achieve thermal isolation and minimize conductive heat loss. The structure diagram is shown in Figure 1.

In addition, a RF planar magnetron sputter was used to deposit PT thin film. The PT thin film annealed at 550 ℃ for 15 minutes to obtain better structure quality [1]. In this experiment, a field emission scanning electron microscopy (SEM, Hitachi S4100) with emission voltage of 15 kV and current of 10 μA is set to investigate the surface

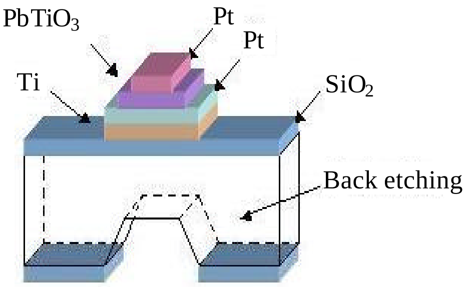

Figure 1. The structure of PIR Sensor.

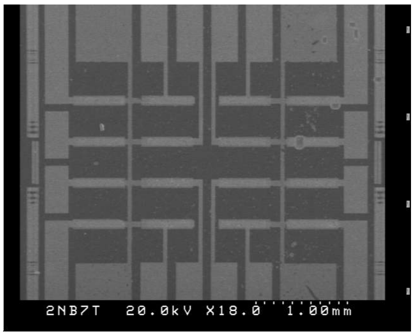

Figure 2. The top view of the PIR array device.

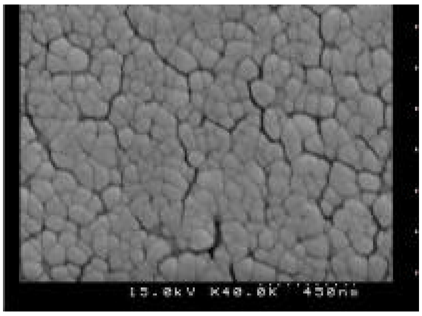

Figure 3. The surface morphology of the $PbTiO_3$ thin film.

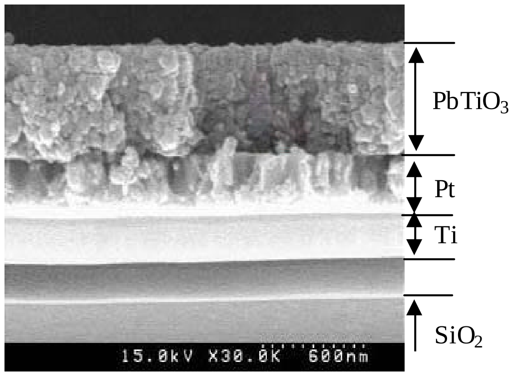

Figure 4. The cross section of $PbTiO_3$ /Pt/Ti.

morphology and cross section of the deposited thin film.

The X-ray diffraction (XRD) pattern is used to check the deposited thin film structure. The pyroelectric coefficient and the P-E properties of the deposited thin film is also measured. The quality of the finished PIR sensors is evaluated by the specific detectivity (D*) measurement. In addition, a 4 × 4 PIR image sensor is also tested for IR image measurement. The top view of the 4 × 4 PIR image sensor is shown in Figure 2.

3. Results and Discussion

Figure 3 shows a PT thin film surface morphology. The result showed a fine-grained crystalline microstructure of $PbTiO_3$ thin film. A cross section of $PbTiO_3$ thin film is shown in Figure 4, and it indicates that grains are columnar in nature.

A XRD pattern of a deposited PT thin film is shown in figure 5 [2]. The annealing temperature is 550 °C and the annealing time is 15 minutes. From Figure 5, (100), (101), (111), (200) and (211) peaks of perovskite structure is observed.

From the P-E measurement we can obtain the remanent polarization Pr = 20.8 $\mu c/cm^2$ and coercive electric field Ec = 79.365 kV/cm. The pyroelectric coefficient of 1.09×10^{-5} C/m^2 K at 50 °C is measured as a function of temperature [3].

Figure 6 shows the voltage response of the fabricated PIR sensor. It shows that the maximum response is 600 (VW^{-1}) while the chopper frequency is 0.3 Hz.

Figure 7 shows the specific detectivity of the cell of PIR array. The maximum specific detectivity D* for the single sensor is 7.3×10^5 cm $Hz^{1/2}$ W^{-1} for a modulation frequency of 0.5 Hz. At the lower modulation frequency, the sensor has better D* [4].

Thermal-imaging system is recently focused on the multielements un-cooled PIR detectors. In this paper, the infrared sensors are used to construct 4 ×4 array to make thermal image array. Fabricated 4 x 4 PIR sensor is used to investigate thermal image.

The whole thermal image measuring system including 4 x 4 array sensor, band-pass amplifier, ADC converter, analog SW, 8051 emulator, power supply, PC and 8051 assembler program. The gain and bandwidth of the image measuring system are 1250 and 0.1–10 Hz.

The array sensor is tested when a hand movement from left side of array to right side. We use signal PIR sensor for signal testing before image test. When a hand to approach a PIR sensor there are a signal approach on oscilloscope. We can see the signal of the single PIR sensor in Figure 8. Then a 4 ×4 PIR array is used for IR image test.

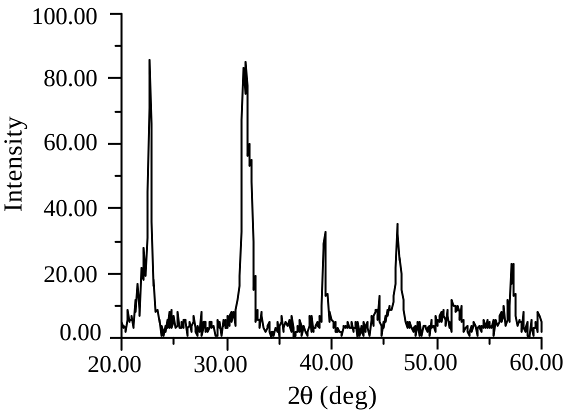

Figure 5. The XRD pattern of $PbTiO_3$ thin film on Pt/Ti/Si substrate.

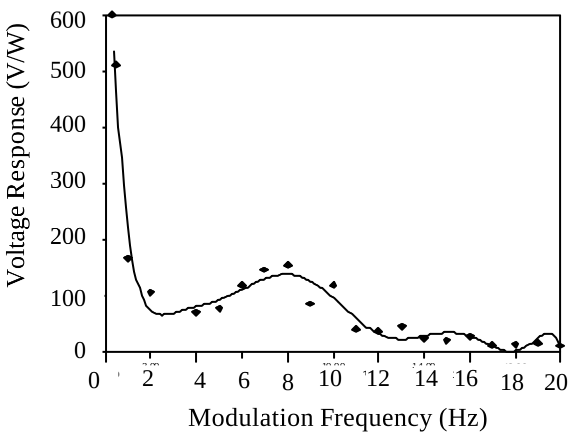

Figure 6. Voltage response of PIR sensor.

A hand approach the array from left-bottom of array to right-up side. Figure 9 shows every elements signal variation of 4 × 4 array. It appeares a signal variation from left to right [5].

4. Conclusion

In this experiment, an integrated pyroelectric infrared sensor have been successfully fabricated. The deposited $PbTiO_3$ thin film is a perovskite structure. From the XRD measurement. The FWHM of the (100) peak is 0.265 degree.

The pyroelectric coefficient of the obtained PT thin film is 2.25×10^{-4} C/m^2 K at 200 °C. The P-E measurement is shows that the remanent polarization is 20.8 C/cm^2 and the coercive electric field is 79.365 kV/cm.

In addition, the PIR properties are also measured. The maximum voltage response of the PIR sensor is 600 (VW^{-1}) with chopper frequency of 0.3 Hz. The maximum specific detectivity D* for a single sensor is 7.3 × 10^5 cm Hz$^{1/2}$ W^{-1} in a modulation frequency of 0.5 Hz.

Furthermore, we use 4 x 4 PIR sensor array

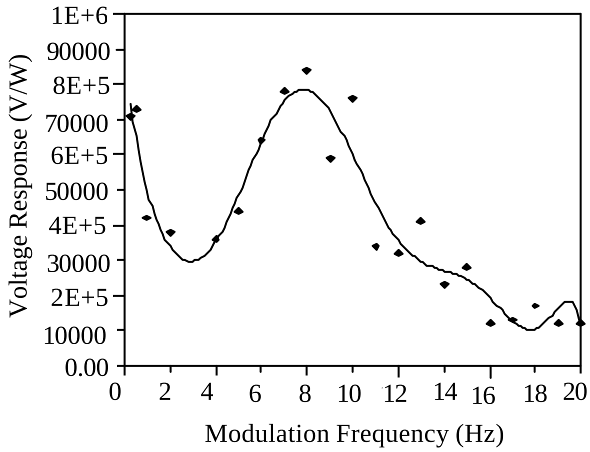

Figure 7. D* of PIR sensor.

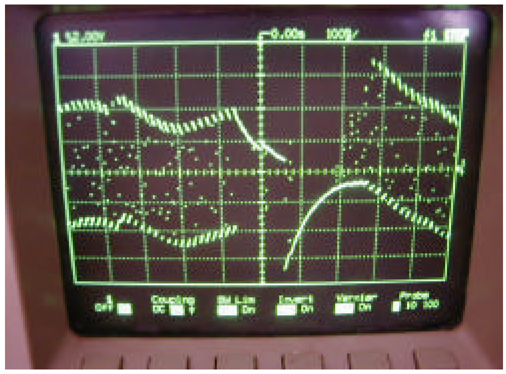

Figure 8. The signal of a PIR array cell (one hand to approach).

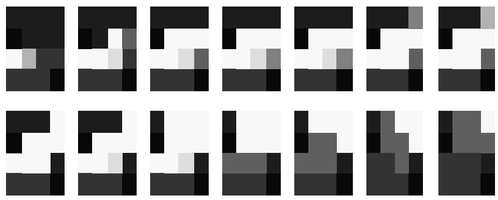

Figure 9. The thermal images variation of PIR a sensor, when a hand movement from left side of array to right side.

which is fabricated in this experiment to investigate thermal image. Combining with 8051 simulator, we can make thermal image to display in the monitor. In the future, we can choose the compensated type of pyroelectric sensor to be the best performance or chose the convenient fabrication to get the better performance.

References

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