Infrared Detector Using Pyroelectrics

Chang-Wu Hur

***Abstract*—** The thin film of PbTiO3 is fabricated at substrate temperature of 100-150 °C. The infrared spectrum of the ferroelectric thin film is measured as temperature of thermal treatment, 400 - 550°C .

According to infra-red spectrum analysis, there are absorption bands at a nearby wave number of 1000 ~ 400 cm-1 and the thin film treated by temperature of 550°C has absorption bands of wave number 500 cm-1 similar to infrared response property of PbTiO 3 powder. The pyroelectric infrared detector is fabric ated after deposition of Pt and PbTiO3 thin film on Si wafer by sputtering machine. The measured remn ant polarization are 11.5-12.5μC/cm2 , breakdown el ectric field Ec is 100-120KV/cm ,and voltage respon sivity and detectivity is -280V/W, -108cm Hz/W.

I. INTRODUCTION

Infrared detectors are used in many fields of applications today, both civilian and defense oriented. Many of these are based on passive detection of thermally emitted electromagnetic radiation as described by the wellknown Planck's law. In this way it is possible to image objects in darkness, or carry out contactless temperature measurement. Active systems, on the other hand, are based on illumination of the object by an infrared source, such as a thermal emitter or an infrared laser. the operation of thermal detectors depends on a two-step process. The absorption of infrared radiation in these detectors raises the temperature of the device, which in turn changes some temperature-dependent parameter such as electrical conductivity. Thermal detectors may be thermopile (Seebeck effect), bolometer, Golay cell detectors, or pyroelectric detectors. The major advantage of thermal detectors is that they can operate at room temperature. However, the sensitivity is lower and the response time longer than for photon detectors. In order to obtain high sensitivity it is of utmost importance that the detector material is developed. The material selected in this paper is pyroelectric thin film. This pyroelectric material is based on the fact that certain dielectric materials of low crystal symmetry exhibit spontaneous dielectric polarization. When the electric dipole moment depends on temperature the material becomes pyroelectric. Usually a capacitor is fabricated from the material and the variation of charge on it is sensed. Common pyroelectric materials used for infrared detectors are TGS (tri-glycine sulphate), $LiTaO_3$ (lithium tantalate), PZT (lead zinc titanate) and certain polymers. A dielectric bolometer makes use of pyroelectric materials operated in a way to detect the change of the dielectric constant with temperature. A suitable material for this application is $PbTiO_3$.

In this paper, pyroelectric $PbTiO_3$ thin film is deposited by rf sputter and is measured electric and infra-red spectral properties. Infrared detector is simulated and fabricated.

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II. INFRARED SPECTRAL RESPONSIVITY , DETECTIVITY AND POLARIZATION OF FERROELECTRIC PBTIO3 THIN FILM

Si wafer is used as substrate in this experimental condition. Lower electrode of infrared detector is used by Pt thin film. The $PbTiO_3$ thin film is deposited using rf sputtering machine. It can form high vacuum with 10^{-6} ~ 10^{-7} Torr by using low temperature pump. After deposition of $PbTiO_3$ thin film, it can be annealed at 400-550℃. Table 1 shows the deposition condition of $PbTiO_3$ thin film.

Table 1 RF sputtering condition of PbTiO3 thin film.

Gas pressure	Torr	1.2X10-2
Distance of target and substrate	mm	40
Target diameter	mm	80
Sputtering gas		Ar(90%)+O2(10%)
rf incidence power	W	85

Figure 1 shows infrared property of PbTiO3 at room temperature. Figure 2 shows infrared property of PbTiO3 at 500°C. Figure 3 shows infrared property of PbTiO3 at 550°C.

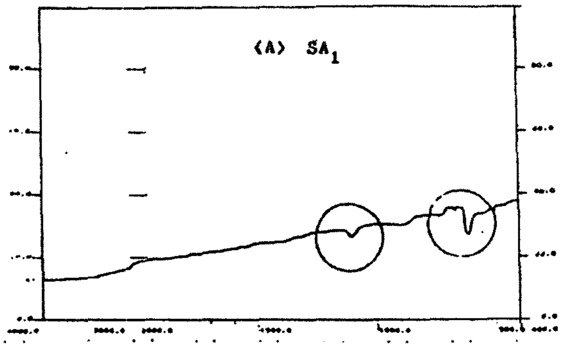

Fig. 1 Infrared property of PbTiO3 at roomtemperature.

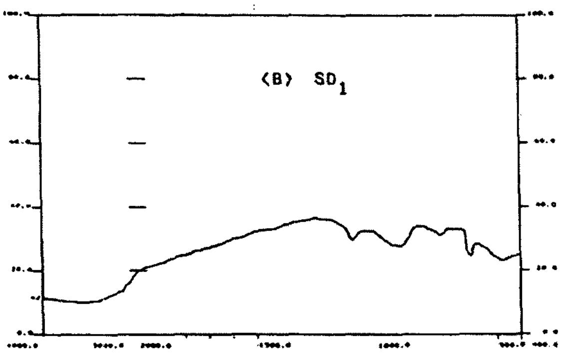

Fig. 2 Infrared property of PbTiO3 at 500°C.

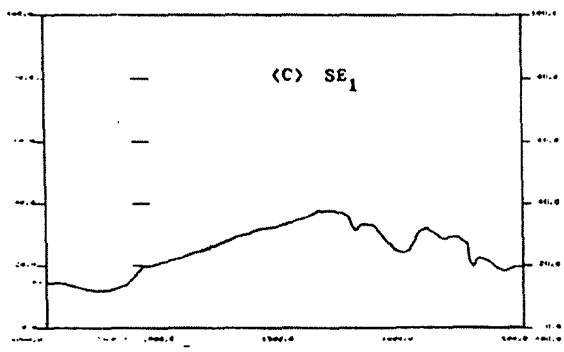

Fig. 3 Infrared property of PbTiO3 at 550°C.

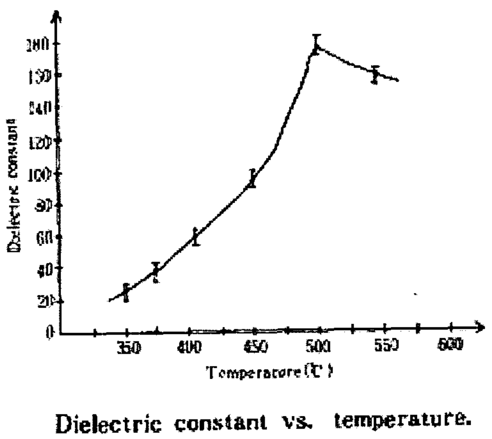

Fig. 4 Dielectric constant of PbTiO3.

Figure 4 shows dielectric constant of PbTiO3 as thermal treatment.

III. SIMULATION OF PYROELECTRIC INFRARED DETECTOR

Pyroelectric detectors of infrared radiation are fast-response thermal sensors operating at ambient temperature unlike semiconductor detectors, which require cooling. Their spectral response is uniform in a large range of wavelengths, including main band of IR transmission of the earth atmosphere. Further increase in pyroelectric response is possible by integrating pyroelectric sensors with silicon technology. Triglycine sulfate (TGS) based pyroelectric detectors are the most sensitive among available ferroelectric materials. The effective sensitivity and performance depend not only on the sensor element material characteristics, but also on electric, thermal and optical parameters of the complete structures components including associated electronics. Thus we have realized a simulation program. From which the performance of a detector structure be derived, we can predict and optimize pyroelectric detector. Using various single sensor configurations and pyroelectric parameters of modified TGS crystals grown in our laboratory, the calculated and predicted responsivity and other parameters will be presented for their use in thin film form. The results obtained can be encouraged for the development of $PbTiO_3$ thin film based detectors. The using language is the PASCAL which is TURBO PASCAL of BOLAND company.

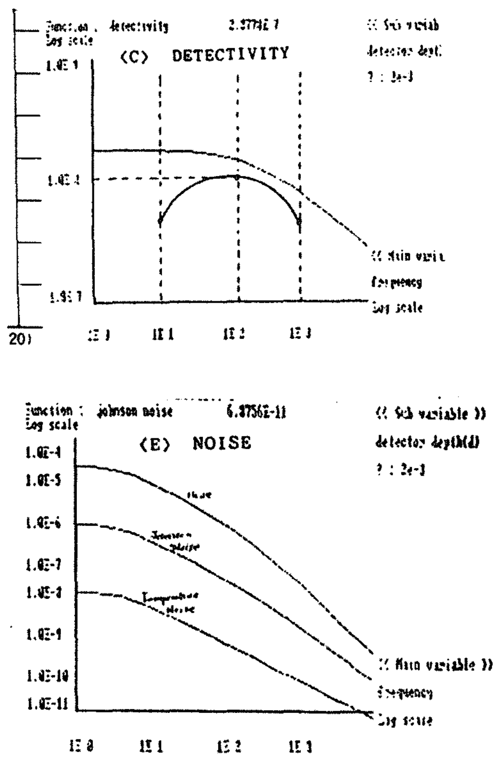

Fig. 5 The property of TGS using simulation.

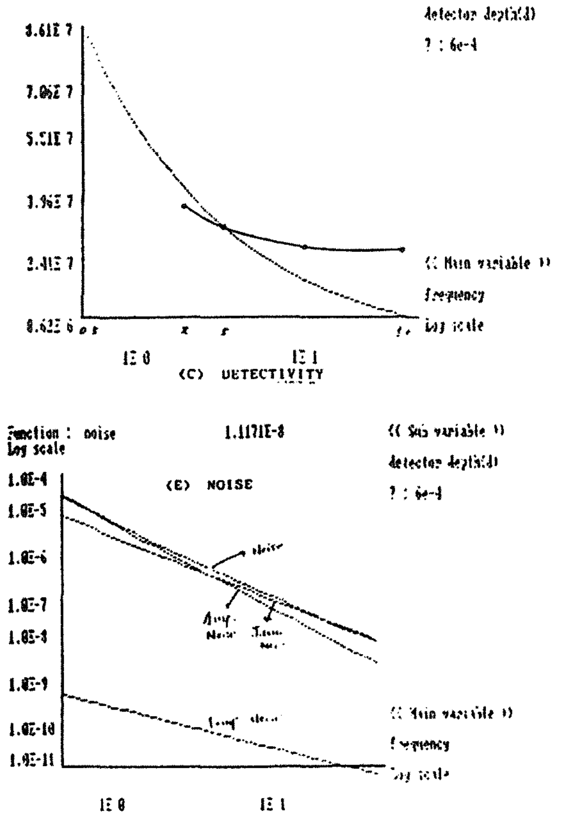

Fig. 6 The property of PVF2 using simulation.

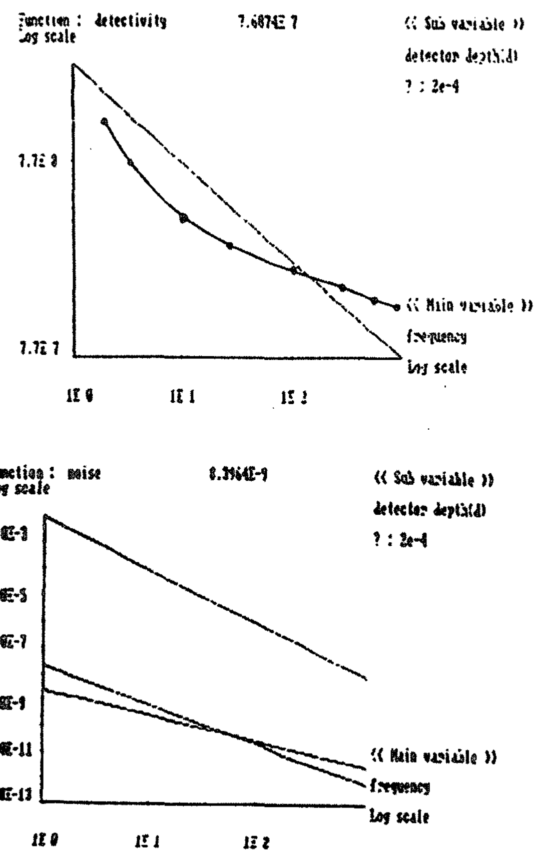

Fig. 7 The property of PbTiO3 using simulation.

Figure 5 shows properties of TGS(Tri Glycine Sulphate) using this simulation. Figure 6 shows properties of PVF_2 using this simulation. Figure 7 shows properties of $PbTiO_3$ using this simulation. Table 2 and 3 shows the physical data and synthesis of simulation results on TGS , PVF_2 and $PbTiO_3$ thin film respectively.

Table 2 The physical properties of pyroelectrics.

	TGS	$PbTiO_3$	PvF_2
Temperate(°C)	49	470	120
Pyroelectric coefficient($X10^{-8}$)	3.5	6	0.24
Dielectric constant	42	200	11
specific heat	2.5	3.2	2.5
conductivity($X10^{-2}$)	6.4	32	0.13
Thermal expansion coefficient($X10^{-3}$)	2.6	32	1.3

Table 3 The simulation results of pyroelectrics.

	TGS	$PbTiO_3$	PvF_2
Responsivity(R_V)	0.5-10^3	1.6-$2.1X10^3$	1.8-180
Detectivity($X10^7$)	4-30	1.4-500	0.86-8.6
NEP(Noise Equivalent Power)($X10^{-8}$)	4-30	0.0042-0.713	1.16-11.6

IV. PROPERTIES OF INFRARED DETECTOR

The pyroelectric infrared detector of this experimental is fabricated as deposition of Pt and $PbTiO_3$ thin film on Si wafer by sputtering machine. Figure 8 shows the measuring system of the pyroelectric infrared detector. From the measuring results, we can estimate that the measured remnant polarization are 11.5-12.5$\mu C/cm^2$, breakdown electric field E_c is 100-120KV/cm ,and voltage responsivity and detectivity is -280V/W, -10^8cm Hz/W.

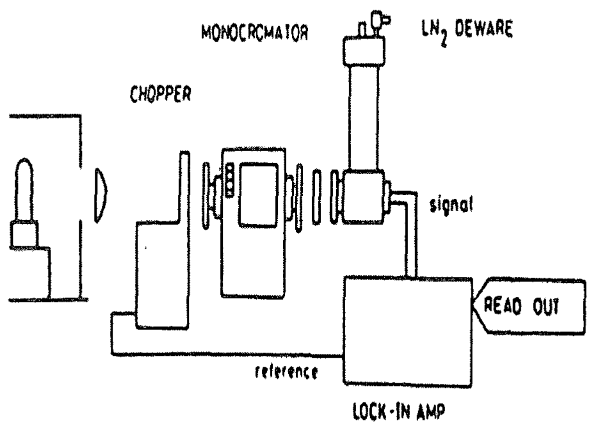

Fig. 8 The measuring system of the pyroelectric infrared detector.

Figure 9 shows sensing properties of pyroelectric $PbTiO_3$ thin film.

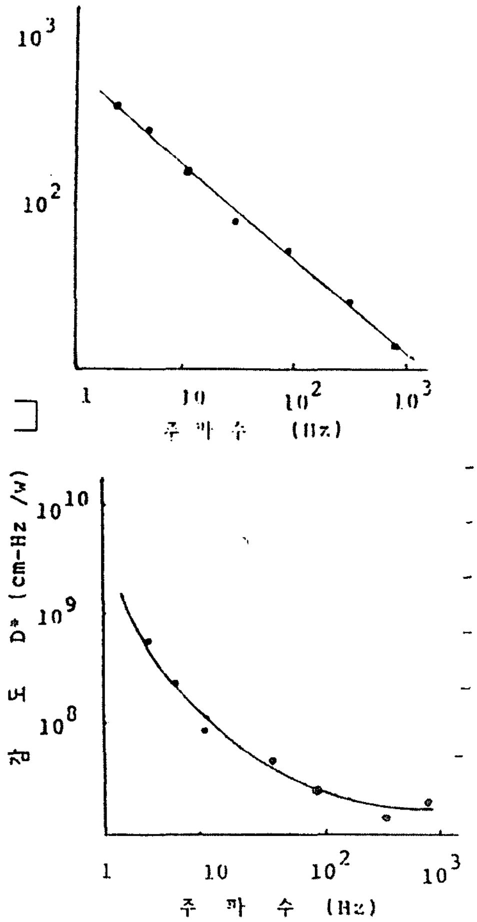

Fig. 9 The sensing properties of pyroelectric PbTiO3 thin film.

V. CONCLUSIONS

Pyroelectric infrared detectors using PbTiO3 thin film were fabricated. It was found that specific detectivity D* of the detector is a strong function of the modulation frequency of the incident radiation. Noise plays an important role at low frequencies (<20 Hz). When the modulation frequency is low (<10 Hz), the noise is dominated by 1/f noise. This characteristics can be clearly seen from the noise–frequency spectrum. A theoretical model was used to simulate the dynamic responses of the pyroelectric IR detector. The simulated results fitted quite well with the experimental results. The voltage responsivity and detectivity was 280V/W, 108cm Hz/W at the chopping frequency of 20Hz. The voltage responsivity RV was in linearly inverse proportion to frequency and the detectivity D* was in exponentially inverse proportion to frequency. These phenomena give good results for infrared detector.

From the experimental and measuring results, infrared detectors can be used in many fields of applications. Pyroroelectric thin film can be applicable to civilian and defense etc.

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