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Fabrication and Characteristics of Pyroelectric IR Sensor Using 1.6 ㎛ P(VDF/TrFE) thin film

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Abstract

A pyroelectric sensor using P(VDF/TrFE) film for sensing materials has been fabricated and evaluated with other commercial pyroelectric sensors that use ceramic materials for sensing. The device was mounted in a TO-5 housing to detect infrared light of 5.5 ~ 14 ㎛ wavelength. The NEP (noise equivalent power) and specific detectivity D^* of the device were 2.13 × 10^{-8} W and 9.37 × 10^6 ㎝/w respectively under emission energy of 13 ㎼/cm^2 respectively. These result shows a better characteristics than other commercial pyroelectric sensors NEP 8.08 × 10^{-7} W and D^* 2.47 × 10^5 ㎝/w.

1. Introduction

Nowadays, thermal pyroelectric infrared sensor materials include TGS single crystal, $LiTaO_3$, $PbTiO_3$, PZT, PLT and PVDF(polyvinylidene fluoride) as well as its copolymer.[1] Ferroelectric polymers offer several advantages over ceramic and single crystal materials. They are easily fabricated into large sheets and can be cut or bent into complex shapes without damage to the film. Therefore, since Kawai[3], in 1969, made the first observation of pyroelectricity in uniaxially-drawn and poled PVDF, ferroelectric polymers have been intensively investigated.

PVDF film can be used as a sensing element but a mechanical stretching technique is necessary obtain a pyroelectric effect.[1-3]

On the other hand, a poled VDF/TrFE (vinylidene fluoride trifluoroethylene) copolymer film is reported to be pyroelectric without stretching, thus making it a suitable candidate for pyroelectric sensors.[2-6]

For the realization pyroelectric infrared sensors use P(VDF/TrFE) films fabricated by the spin coating technique.[7] Aluminum electrodes are formed at both sides of the copolymer film to capacity type infrared sensor.[7] However the copolymer film thickness is less than ten micrometers, that the both electrode shorted. This difficulty is a major problem to make a pyroelectric infrared sensor using P(VDF/TrFE) thin film.[8] Moreover it is necessary to develop high quality pyroelectric sensors as industry demand is increasing.

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2. Experiments & measurements

The substrate, silicon, has a high thermal

expansion coefficient, and an FET of the preamplification portion can be integrated into it. A 3000 Å thickness SiO_2 layer was deposited on a silicon substrate as a insulating layer. Al bottom electrode was deposited on an SiO_2 layer by a thermal evaporator. The copolymer sample was formed by using 67 mol% Vinylidene Fluoride(VDF) and 33 mol% trifluoroethylene (TrFE), as supplied by Piezotech S. A. France, in powder form. A 9.0 ml 2-butanone (Methyl Ethyl Ketone) at 80 ℃ was used as a solvent. The VDF/TrFE copolymer (1.0±0.1 g) is dissolved in the hot 2-butanone solvent, resulting in a 10 %wt. concentrating VDF/TrFE copolymer. During the mixing process, the solution sample is heated up to 80 ℃. After the copolymer was completely dissolved, the solution cooled down to room temperature. Then the solution was spun on the Al bottom electrode. The spin coating was performed with two different combinations of spinning rates and times in succession: {(500 rpm, 2 sec.) and (5000 rpm, 30 sec.)}. The first combination was slow and short, thus allowing the solution to be spread over the whole substrate. The second combination is quicker and longer, thus allowing us to obtain the desired thickness. An advantage of this two-step spinning is the uniformity of the copolymer thickness. The resulting thickness is 1.6 μm. The thickness of the copolymer is measured by an alpha stepper. (Tencor Co.)

During the cooling of the deposited copolymer layer, local shrinking takes place and causes local stresses.[2] To evaporate the remaining 2-butanone solution, you must recover the local stresses, enhance its crystallization and improve the adhesion between the copolymer and the aluminum electrode. This annealing treatment is conducted in two steps. First, a sample is annealed at 25 ℃ for 24 hours. Second, a sample is annealed at 120 ℃ for two hours. The crystallization of the copolymer will increase. The local stresses are also recovered. All 2 - butanone is now evaporated from the copolymer. This annealing temperature is quite low than the other ceramic material processing. There are many advantages to fabricating devices as well.[1-6] A 3000 Å top aluminum electrode is deposited on the copolymer layer. Because VDF/TrFE film has a low melting point careful aluminum electrode deposition is essential. This aluminum electrode is used as a mask for etching the copolymer film also.

To be considered an infrared sensor array, a pyroelectric copolymer must be patterned.[1,2,4,6] Furthermore, by allowing aluminum wire bonding and IC housing, the bonding pad has to be freed. Therefore, some areas of the copolymer have to be etched. Wet etching is used to etch the copolymer. Methyl ethyl ketone (2-butanone) is used as an etching solvent in wet etching. Experiments have been carried out to evaluate the etching results. The etch-rate of the copolymer film is around 2 μm/min at 30 ℃ and increases as the temperature increases. A higher etch rate and etch temperature, result in a remnant copolymer film on a bottom electrode while a lack of adhesion results between the copolymer film and top electrode. After the wet etching process, a sample is annealed at 160 ℃ for 20 minutes again to enhance the adhesion between the copolymer and the aluminum electrode. Finally, a sample is annealed at 120 ℃ for 1 hour to evaporate humidity absorbed in a sample during the wet etching process. Figure 1 shows a SEM photograph after wet etching using the top electrode as a mask.

As mentioned above, a sample is annealed at 25 ℃ for 24 hours. Second, a sample is annealed at 120 ℃ for two hours. The crystallization of the copolymer will increase.[2,5] The local stresses are also recovered. All 2-butanone is now evaporated from the copolymer. But for the adhesion between the copolymer and the aluminum electrode, another annealing treatment needed. After top electrode deposition a sample

is annealed at around 160 ℃ for 10 minutes. The adhesion between the copolymer and the aluminum electrode will also be enhanced by this process. The lamellar becomes thicker, the improving the structure of the copolymer results to a high crystallinity level. Next the temperature is slowly decreased to 25 ℃. This process is illustrated at Figures 2 and 3.

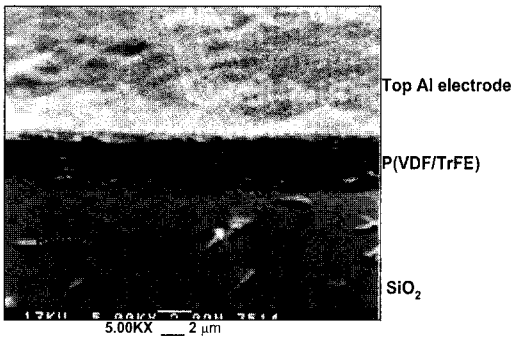

Fig. 1. SEM photograph of P(VDF/TrFE) film after etching.

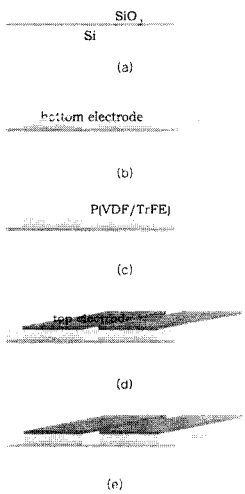

Fig. 2. A schematic diagram of fabrication procedure for a pyroelectric sensor.

Figure 4 shows a schematic diagram of housing sensor. The device was mounted in a TO-5 housing to shield it from surrounding noises and other interferences. Because there are FET and sheet resistance in a TO-5 package between the sensing area and FET detachment, the length is minimized. Figure 5 shows a schematic diagram of the output signal measurement system. It is also measured on the condition in Table 1. When measuring the signal, one electrode is covered and then measured. This is because when the two top electrodes are exposed to infrared simultaneously, there is no signal output from the compensated effect. Figure 6 shows a schematic diagram of a noise measurement system. Table 1 shows the signal and noise output measuring conditions.

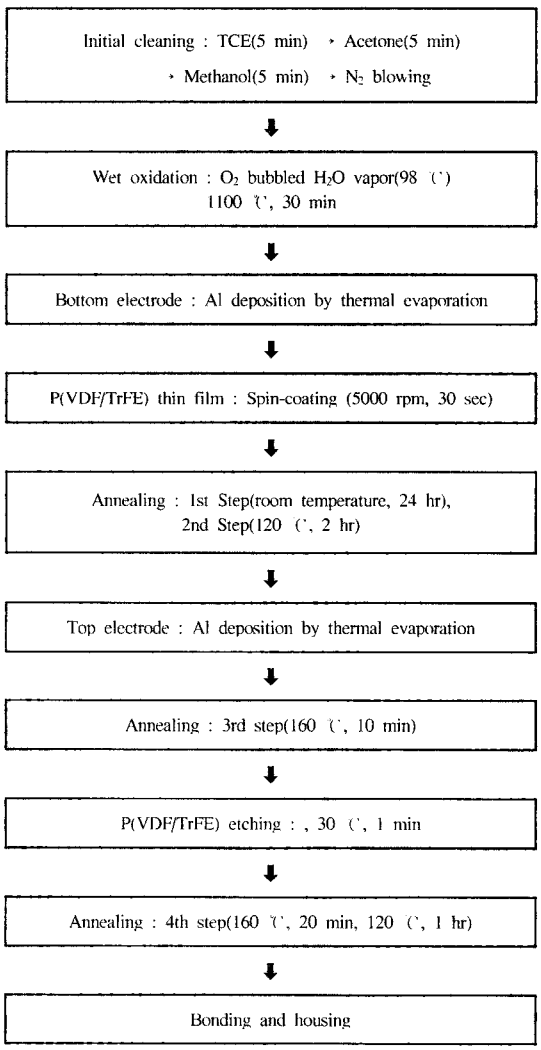

Fig. 3. A flow chart for a pyroelectric sensor.

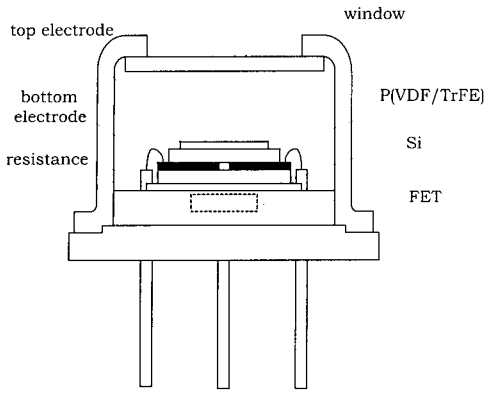

Fig. 4. A schematic diagram of a housing sensor.

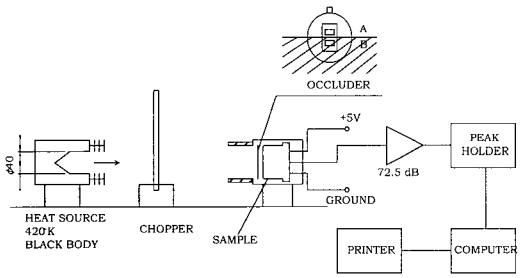

Fig. 5. A schematic diagram of an output signal measurement system.

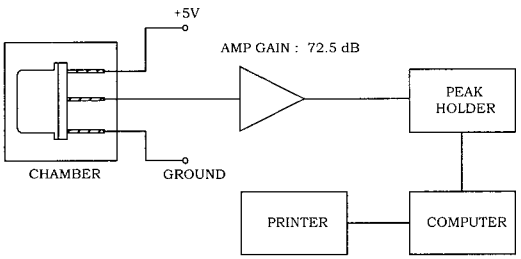

Fig. 6. A schematic diagram of a noise measurement system.

3. Results and discussion

Table 1 shows fabricated sensors' signal and noise output measuring conditions. The sensors' signal voltage output was 1.315 V and their noise voltage output was 215.7 ㎷. The NEP (noise equivalent power) and specific detectivity D^* of the device were 2.13 × 10^{-8} W and 9.37 × 10^6 ㎝/W respectively under emission energy of 13 μW/cm^2. Figures 7 and 8 compare data with other pyroelectric infrared sensors using ceramic materials. (NEP, D^*).

Table 1. Signal and noise output measuring conditions.

Ambient temperature		25 ℃
Black body temperature		420 °K
Aperture of black body		ø40
Emission of infrared energy		13 μW/㎠
Chopping frequency		1.0 ㎐
Amp. gain	signal	72.5 dB(1㎐)
	noise	72.5 dB
3 dB bandwidth		0.4~4.5 ㎐
Stabilization time(noise)		3 min
Measuring time(noise)		20 s

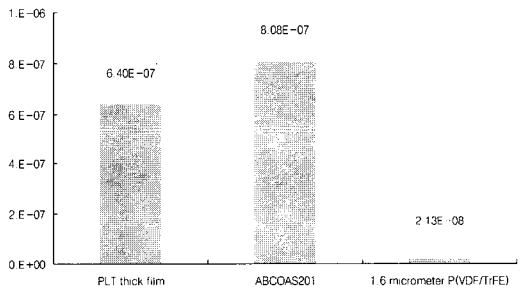

Fig. 7. Data compared with other pyroelectric infrared sensor using ceramic materials. (NEP)

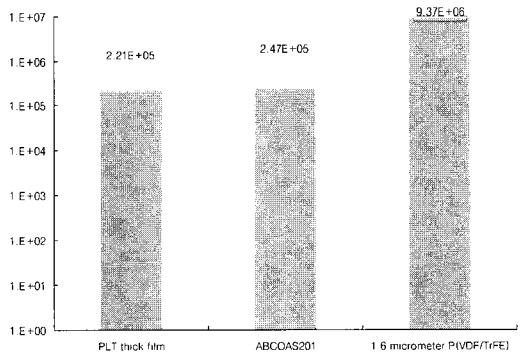

Fig. 8. Data compared with other pyroelectric infrared sensor using ceramic materials. (D^*)

4. Conclusion

A pyroelectric sensor using 1.6 ㎛. P(VDF /TrFE) thin film for sensing materials has been fabricated and evaluated with other commercial pyroelectric sensors that use ceramic materials for sensing. The device was mounted in a TO-5 housing to detect infrared light of 5.5 ~ 14 ㎛ wavelength. The NEP (noise equivalent power) and specific detectivity D^* of the device were 2.13×10^{-8} W and 9.37×10^{6} ㎝/ Wrespectively under emission energy of 13 $\mu W/cm^2$.

5. Acknowledgements.

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6. References

[1] S. B. Lang, Source book of pyroelectricity, Gordon & Breach, London, 1974.

[2] R. W. Whatmore, "Pyroelectric devices and materials,," Rep. Prog. Phys., Vol. 49, pp. 1335~1386, 1986.

[3] H. Kawai, "The piezoelectricity of polyvinylidene fluoride," Japan. J. Appl. Phys., Vol. 8, pp. 975-976, 1969.

[4] R. J. Phelan Jr., R. J. Mahler, and A. R. Cook, "High D* pyroelectric polyvinylidene fluoride detectors," Appl. Phys. Lett., Vol. 19, pp. 337-338, 1971.

[5] G. T. Davis, J. E. Mckinney, M. G. Broadhurst, and S. C. Roth, "Electric -field-induced phase changes in poly (vinylidene fluoride)," J. Appl. Phys. Vol. 49, pp. 4988-5002, 1978.

[6] W. Bohmeyer, W. Kabel, H. Volkmann, R. Danz, B. Elling and W. Strak, "Pyroelectric detectors based on PVDF," Exp. Tech. Phys., Vol. 30, pp. 65-74, 1982.

[7] Sung Yeol Kwon, Ki Wan Kim, "Fabrication and characteristics of pyroelectric infrared sensors using P (VDF/TrFE) film", Journal of the Korean Sensors Society,. Vol. 8, pp. 226-231,1999.

[8] Sung Yeol Kwon, Young Woo Kim, Seung Choon Bae, Sung Kun Park, and Ki Wan Kim, "Dielectric characteristics of with poling pf P(VDF/TrFE) films for pyro -electric infrared sensor," Journal of the Korean Sensors Society,. Vol. 9, pp. 9-14, 2000.

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