DLATGS Pyroelectric Detectors: From Manual to Industrial Manufacturing

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ABSTRACT

Deuterated L-Alanine Doped Triglycine Sulfate (DLATGS) is a ferroelectric material typically used in applications of uncooled infrared (IR) detectors and imaging systems. DLATGS detectors provide linear response over a broad range of IR radiation and have high pyroelectric coefficient and low dielectric constant. The aim of this presentation is to provide a brief overveiw of DLATGS material and detector that includes history of DLATGS, crystal growth method, theory of pyroelectric materials, manufacturing and test processes, and useful electrical parameters of DLATGS.

INTRODUCTION

Deuterated L-Alanine Doped Triglycine Sulfate (DLATGS) is a ferroelectric material typically used in applications of uncooled infrared (IR) detectors and imaging systems [1]–[3]. The ferroelectric materials possess an electric polarization in the absence of an externally applied electric field such that the polarization can be reversed if the electric field is reversed. Since all ferroelectric materials exhibit a spontaneous polarization, all ferroelectric materials are also pyroelectric (the converse is not true). Pyroelectric materials exhibit electric polarization when their temperature is changed, leads to a temporary voltage across the crystal.

Triglycine Sulfate (TGS) is the basis of DLATGS material and exhibits spontaneous polarization under the Curie temperature of 49℃. The ferroelectricity of the first growth of TGS crystal was discovered in 1956 by Bernd T. Matthias[4]. The crystal structure of TGS is monoclinic with space group $P2_1$ in the ferroelectric phase below the Curie temperature and it transforms to centrosymmetric $P2_1/m$ at paraelectric phase above Curie temperature[5], [6]. One of the major drawbacks of pure TGS crystal is its tendency to depole near curie temperature leading to a decrease in the detector efficiency [7].

HISTORY OF DLATGS

To improve the performance of IR detectors at room temperature, pure TGS crystal is partially deuterated via deuteron transfer from D_2O, followed by slow evaporation or low temperature solution crystal growth method. The first preparation of deuterated triglycine sulfate (DTGS) crystals was in 1960 by Konstantinova[8]. The modified DTGS has a Curie temperature between 57 and 62 ℃ [9], this material however still needs an applied external electric field to be fully poled. By doping the DTGS with the amino acid L-Alanine, the crystal properties are improved by introducing an internal electric field to the crystal structure. This is because the L-Alanine carries a methyl group ($-CH_3$) side chain which inhibits DLATGS molecules from rotating within the lattice contributing to a permanently poled single domain crystal, namely, “locked-in” polarization [10], [11]. For the best of our knowledge, the first DLATGS crystal growth was developed in 1972 by Seymour Weiner and Henry P. Beerman at Barnes Engineering Company, Stamford, Connecticut, USA[12]. At the same time, it seems there were some attempts of DLATGS crystal growth in 1973 by Loiacono at ISOMET corporation in night vision Lab, Oakland, New Jersey, USA[13].

QUICK OVERVIEW OF IR RADIATIONS AND DETECTORS

The IR radiation is an electromagnetic (EM) waves with wavelength region longer than the visible light, lying from 0.75 μm to 1000 μm. In general, the IR spectrum is divided into three wavelength regions, the near IR (NIR) region from 0.75 μm to 3 μm, the mid-wavelength IR (MWIR) region from 3 μm to 5 μm, and the long-wavelength IR (LWIR) region from 5 μm to 14 μm[14]. IR EM waves are invisible to human eyes, they have a small energy, long wavelength, and they are emitted from all kinds of objects.

The two main types of IR detectors are thermal and photonic. The photodetector absorbs photons radiation in the p-n junction and converts it in the depletion region directly into an electrical current[15]. On the other hand, the thermal detector first converts the absorbed incident radiation into heat, which then produces an electrical current. However, there are benefits and challenges of using pyroelectric infrared (PIR) detectors over photon IR detectors. The main advantages of PIR detector over photon IR detector are that their sensitivity in a very large spectral bandwidth and temperature range, they do not require cooling and require low power, also, they have relatively fast response and generally low-cost materials[15].

From an applications perspective, DLATGS pyroelectric detectors are the most widespread in IR spectrometers, particularly in Fourier-transform infrared spectroscopy (FTIR) instruments. This is because DLATGS detectors provide linear response over a broad range of IR radiation extends from the edge of the near ultraviolet (NUV) light at 0.4 μm (~750 THz) to the far IR spectrum at 200 μm (~1.5 THz)[16]. Also, DLATGS material has high pyroelectric coefficient, and low dielectric constant and loss tangent. In general, the pyroelectric detector is considered as a capacitor and its spontaneous polarization is oriented normal to the plane of the electrodes.

CRYSTAL GROWTH METHOD

Crystal growth of DLATGS is done from solution by slow cooling methd which involves dissolving material in a liquid (or gel) medium and then recrystallize it under controlled conditions to produce crystals of a specific size, shape and perfection. Crystal growth of DLATGS from solution by slow cooling includes soluobility measurements, purification, filtiration and preperation of seed crystals, and crystal grwoth under slow cooling in a proper chamber under a specific conditions.

DICING, LAPPING AND POLISHING, AND METAL DEPOSITION

The DLATGS wafer fabrication is a procedure composed of many repeated sequential steps to produce complete DLATGS thin films for pyro detectors that includes dicing, lapping and polishing, and metal deposition.

MANUFACTURING AND TEST PROCESSES

In pyroelectric detector fabrication, the various processing steps fall into four general categories: crystal processing of DLATGS, header Assembly (preamplifiers w/o detector crystal), detector caps (Windows or Filters), welding and final Testing.

CONCLUSION

In conclusion, a summary of DLATGS material and detector that includes history of DLATGS, crystal growth method, theory of pyroelectric materials, manufacturing and test processes, and useful electrical parameters of DLATGS is mentioned in this short review.

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KEY WORDS

Deuterated L-Alanine Doped Triglycine Sulfate (DLATGS), Crystal Growth, Pyro IR Detector, Metal Deposition, Lapping and Polishing