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Integrated pyroelectric array based on PCLT/P(VDF-TrFE) composite

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Abstract

Calcium and lanthanum modified lead titanate (PCLT) powder was prepared by a sol–gel process followed by annealing at 850°C. The PCLT powder was dispersed in vinylidene fluoride-trifluoroethylene copolymer [P(VDF-TrFE)] to form a composite containing 12 vol.% of ceramic powder. A film of thickness 12 μm was prepared by spin-coating four layers of the composite on a glass substrate. The film was poled and then removed from the substrate. It was then bonded to a silicon chip with readout electronic circuitry to form an 8×1 integrated linear pyroelectric array. The voltage responsivity, voltage noise, and specific detectivity of the sensors in the array were measured as functions of frequency and found to agree well with the values calculated from a one-dimensional heat diffusion model.

Keywords: Pyroelectric array; Composite; Calcium and lanthanum modified lead titanate; Vinylidene fluoride-trifluoroethylene

1. Introduction

There have been extensive studies of pyroelectric sensors and arrays using vinylidene fluoride-trifluoroethylene copolymer [P(VDF-TrFE)] films as sensor materials [1–4]. These sensors and arrays are usually fabricated by spin-coating the films on silicon wafers containing readout electronic circuitry. Ceramic/copolymer 0–3 composite films, consisting of ferroelectric ceramic particles embedded in a [P(VDF-TrFE)] matrix, have also shown good potential as pyroelectric sensors [5,6]. One advantage of the composite sensor is that it has enhanced pyroelectric activity compared to the P(VDF-TrFE) sensor because of the high pyroelectric coefficient of the ceramic. Moreover, the piezoelectric activity of the composite sensor is weaker than that of the P(VDF-TrFE) sensor since the pyroelectric coefficients of the ceramic and P(VDF-TrFE) have opposite signs. This weakened piezoelectric activity leads to reduced electrical noise due to vibration [5–7].

In this work, a ferroelectric ceramic with high pyroelectric coefficient, calcium and lathanum modified lead titanate (PCLT), is chosen as the particulate filler. An 8×1 integrated linear array with PCLT/P(VDF-TrFE) composite film as the sensing material has been fabricated, and its performance has been measured and compared with a model calculation.

2. Fabrication of PCLT/P(VDF-TrFE) composites

The procedure for preparing PCLT powder by a sol–gel process has been described in our previous report [8]. The powder used in this study was annealed at 850°C. It has an average crystallite diameter of 50 nm as determined by X-ray diffraction and an average particle diameter of 200 nm as determined by gravitational sedimentation. The P(VDF-TrFE) copolymer with 70 mol% of VDF (supplied by Piezotech) used in the present study has a Curie temperature T_c of 105°C upon heating and a melting temperature of 150°C as determined by differential scanning calorimetry (DSC). Copolymer pellets (1 g) were dissolved in a 10 ml mixture of methyl–ethyl–ketone (MEK) and ethanol (66/34 vol.%) [9]. A suitable amount of PCLT powder was added to the copolymer solution and the suspension was dispersed in an ultrasonic bath. Fig. 1 shows a SEM micrograph of a PCLT/P(VDF-TrFE) 0–3 composite with

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