

## FIRED 0-3 PIEZOELECTRIC COMPOSITE MATERIALS FOR BIOMEDICAL ULTRASONIC IMAGING APPLICATIONS\*

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### ABSTRACT

Piezoelectric composite materials have found wide applications in various transducer devices as they can easily be tailored to the specific needs of a device engineer. Recently developed fired 0-3 composites show encouraging properties as transducers for biomedical imaging applications. Fired 0-3 composites are prepared by pressing pellets of PZT powder, heat treating them at different temperatures from 700°C to 900°C, and back filling with different polymers. The piezoelectric properties of this material have been evaluated using a resonance technique. In this type of composite, thickness coupling factors are in the range of 0.20 to 0.35,  $d_{33}$  is 80-200 pC/N, acoustic impedance is 8-12  $10^6$  Rayl and the dielectric constant is 150-500, depending on the firing condition and the type of polymer used. These properties have been studied as a function of temperature from -50°C to 100°C. The pulse-echo response, the transmitting and receiving voltage response of these composites in water medium are recorded. From these data the optimum firing and poling condition and the type of polymer are determined.

### 1. INTRODUCTION

Lead Zirconate Titanate (PZT) ceramics are used extensively as a piezoelectric material despite their several shortcomings. Though PZT has a large  $d_{33}$  coefficient, it has various other disadvantages. In most electronic devices there are several practical involved and number of material parameters have to be optimized. An electromechanical transducer, for example, might require a combination of properties such as large piezoelectric coefficient ( $d$  or  $g$ ), low density and high mechanical flexibility. High density of PZT makes it difficult to obtain good impedance matching for medical ultrasonic applications. Also PZT is a very brittle material and to fabricate sensors with different shapes will be difficult.

To overcome these problems, two phase material will be better compared to a single phase material. A composite material combining the desirable properties of two different phases might be vastly superior. The main problem is to effect the combination of the two phases to maximize the figure of merit. The earlier work on ceramic-polymer

composites for piezoelectric devices can be found elsewhere.<sup>1,2</sup> Combining material means not only choosing component phase with the right properties but also coupling them in the best manner. A variety of composite with different connectivities are feasible.<sup>3</sup> The combination adopted by us is the 0-3 connectivity.

A composite with 0-3 connectivity consists of a three-dimensionally connected polymer matrix loaded with piezoelectrically active material connected in zero dimension. 0-3 composite material is easy to fabricate and one can make very thin sheets from them. The miniature ultrasonic transducer for biomedical applications require very thin piezoelectric sensors. This type of composite is easy to fabricate.

Earlier attempts were made to fabricate 0-3 flexible composites<sup>4</sup> with lead titanate as the active material. They used modified lead titanate since it gave greater piezoelectric anisotropy. The lead titanate was produced by water quenching the ceramic. The particle size used was 5  $\mu$ m. To make the composite, the piezoelectric powder and chloroprene rubber were mixed and rolled into 0.5 mm thick sheets at 40°C using a hot roller and then heated at 150°C for 20 minutes under a pressure of 13 kg/cm<sup>2</sup>. It was shown in this paper that loading in excess of 60 volume percent filler is required to achieve useful piezoelectric properties. By adopting such hot rolling processes it is difficult to get a higher loadings of the filler in the composite.

In the present paper, the method of preparing 0-3 composites with loadings of 55% - 70% filler is described. A piezoelectric response is obtained which depends on the firing condition of the composite. These properties were studied as a function of temperature from -50°C to 100°C. The receiving response of this material in water medium is determined and the same is reported. From these data the optimum firing and poling condition and the type of polymer has been determined.

### 2. COMPOSITE PREPARATION AND POLING

Piezoelectric material used in this study was PZT-5G1A powder obtained from Ultrasonic Powder Inc. To prepare composite 100 gms of filler material was mixed with 7 gms of 20 wt% PVA solution in water and pressed into pellets (thickness 0.15 to 0.20 cm and diameter = 1.6 cm) at  $1.4 \times 10^8$  dyne/cm<sup>2</sup> pressure. The pellets were placed on alumina plates and heat treated at different temperatures namely 700°C, 800°C and 900°C for 90 minutes and cooled to room temperature in 20 minutes. Thus the PVA

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