Smart 1-3 Composites for Ultrasonic Transducer Applications

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Abstract

1-3 piezoelectric ceramic/polymer composites, consisting of parallel ceramic rods embedded in a polymer matrix, can convert mechanical energy into electrical energy and vice versa. Thus they are regarded as smart (or intelligent) materials because they can sense changes in the environment and actuate a desired response. In order to design devices based on 1-3 composites, a good understanding of the piezoelectric properties and resonance characteristics is required. The present paper reports the fabrication and piezoelectric properties of lead zirconate titanate (PZT)/epoxy and samarium and manganese doped lead titanate (PsmT) fibre/epoxy 1-3 composites. Selected studies of the applications of these 1-3 composites in the Centre for Smart Materials (CSM) at the Hong Kong Polytechnic University are also reported.

1. PZT/epoxy ultrasonic wire bonding transducers (138 kHz):

High frequency (≥ 100 kHz) ultrasonic wire bonding is an urgently needed technology as the IC packages in microelectronics industry are diminishing in size at a very rapid rate. As the size of bond pad decreases, the bonding frequency needs to go up in order to produce sufficiently small wire bonds. To ensure stable and high-yield operations, thickness-driven axial mode transducers operating at a few hundred kHz are required. Piezoelectric ceramics (e.g. PZT rings) used in state-of-the-art transducers have many non-axial modes in the kHz range. These non-axial modes will couple with the desired axial mode and thus give rise to degradation of the transducer performance. Moreover, PZT has high a mechanical quality factor Q_m, and thus has sharp resonances with limited bandwidths. PZT bonding transducers are very sensitive to load changes and may also suffer from frequency tuning and locking problems which result in bonding instability and low yield. When PZT/epoxy 1-3 composite rings are used instead of PZT rings, Q_m of the transducer is reduced thereby widening the operating bandwidth and improving the stability. Due to the decrease in mode coupling, the number of unwanted modes are reduced thereby giving a more efficient transducer. In CSM, composite transducers were fabricated and were found to have better performance than PZT transducers.

2. High-frequency (> 20 MHz) PSmT/epoxy transducers for medical ultrasound:

Recent trends in high-resolution ultrasonic imaging, e.g. in the imaging of arteries, in dermatology, ophthalmology and in monitoring wound healing, have called for the development of high performance transducers with frequencies above 15 MHz. Piezoelectric ceramic/polymer composites have good acoustic matching to human tissues and are thus good materials for fabricating high-frequency transducers. In CSM, PSmT fibres of 50 μm diameter were prepared by the sol gel method. After proper annealing and sintering, PSmT fibres with good piezoelectric properties were produced. By placing the fibres in a plastic tube with the fibres aligned parallel to the tube axis and then filling the tube with epoxy, a composite tube was fabricated. 1-3 composite disks were produced by slicing the tube perpendicular to the tube axis. These composite disks were used to fabricate ultrasonic transducers with operating frequency >20 MHz. Performance of the transducers are discussed.

Acknowledgements

The author would like to acknowledge financial support from the Center for Smart Materials of the Hong Kong Polytechnic University, the Innovation and Technology Fund (ITF AF 147/98) and the Research Grants Council of the Hong Kong Special Administrative Region (Project No. PolyU5190/99P).