Thesis Title Electrical Properties of Piezoelectric Ceramic-Portland Cement Composites

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ABSTRACT

Smart structural composites are multifunctional structural materials which can perform functions such as sensing strain, vibration reduction and are essential because of their relevance to mitigation and structural vibration control. Recent advances in sensor development have resulted in significant interest in developing in diagnostic technique for damage detection of both existing and new structures. The objectives of this thesis are to fabricate and investigate new smart composites for the sensing and actuation applications in civil engineering. The fabrication and properties of 0-3 cement-based piezoelectric ceramic composites are emphasized. In this study, lead zirconate titanate ceramic (PZT) was used as a ceramic-phase mixed with Portland cement to produce new composites. However, the 0–3 connectivity cement-based piezoelectric composites is still difficult to obtain great piezoelectric properties due to the difficulty in poling ceramic particles in such composites because of the evidence

of some pores in the composites. Therefore, a novel approach to effectively improve poling of piezoelectric ceramic is to add an insulator and semiconductor phases between piezoelectric particles by the introduction of a small volume fraction of a third phase. In this study, polyvinylidene fluoride (PVDF) and carbon graphite were chosen as a third-phase with PZT and Portland cement to produce new composites of ceramic-cement-third phase combination. Microstructure of the new composites was investigated using Scanning electron microscope (SEM) and Piezoresponse force microscope (PFM). The piezoelectric properties (d_{33} and g_{33}), ferroelectric properties and dielectric permittivity (ε_{33}) were then investigated.

The dielectric results present that with increasing volume fraction of ceramic content, an increase in the dielectric constant was observed. For the ferroelectric properties at combination between ceramic and cement of 50:50 by volume%, it can be seen that there is an increase in both the *instantaneous* remnant polarization (P_{ir}) and the *instantaneous* coercive field (E_{ic}) when the external electrical field (E_0) increases. In addition, the piezoelectric values of the 0–3 ceramic-cement composites show a roughly nonlinear increase as a function of the ceramic content and the piezoelectric properties of the cement-based piezoelectric composite are improved with increasing cement hydration age. Moreover, the dielectric constant of ceramic-cement composite with the third phase addition was found to increase with increasing the third phase as carbon graphite whereas with PVDF addition the dielectric values showed significant decreases. However, the dissipation energy in ferroelectric hysteresis loops and the dielectric loss of the composite added with carbon graphite were found to increase due to the increase in conducting material while the insulative PVDF addition can reduce these dissipation loss. Also, the PVDF addition in the composite can solve the problem relating to the poling process and show good connectivity by filling the pores at the interface region between the piezoelectric ceramic phase and the cement phase. Thus, the use of PVDF as a third phase and as an insulator can be seen to evidently reduce the loss and the poling time in poling process and noticeably improve the piezoelectric properties of the composites. Therefore, this novel composite is deemed suitable for sensor application.