Available online at www.sciencedirect.com
ScienceDirect
Ceramics International 34 (2008) 793–795
CERAMICS INTERNATIONAL
www.elsevier.com/locate/ceramint

Properties 0–3 PZT–Portland cement composites

N. Jaitanong, A. Chaipanich *, T. Tunkasiri

Department of Physics, Faculty of Science, Chiang Mai University, Chiang Mai, Thailand

Available online 4 October 2007

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. Cement-based piezoelectric composites have been developed as smart structural composites. The goal of this work is to produce cement-based piezoelectric composites using lead zirconate titanate (PZT) and Portland cement (PC) with xPZT–$(1-x)$PC (where $x = 0.3$, 0.6 and 0.9). The composites were pressed together and cured in 100% RH curing chamber for 3 days before measurements. Dielectric constant (ε_r) at room temperature and piezoelectric coefficient (d_{33}) of the 0–3 piezoelectric PZT–Portland cement composites with different PZT content were investigated. The results show these composites have ε_r and d_{33} values of up to 536 and 87 pC/N, respectively, and there is a good potential for the application of these cement-based piezoelectric composites in civil engineering.

Keywords: B. Composites; C. Dielectric properties; C. Piezoelectric properties

1. Introduction

In the recent years, the interest in cement-based piezoelectric composites has grown rapidly with the demands from new application such as structural vibration control which has always received considerable research attention by the civil engineering community [1]. In addition, the sensor suitable for application in the field of mechanical engineering but cannot be simply transplanted into the civil engineering application. Thus, a new kind of sensor should be developed for civil engineering application [2,3].

Lead zirconate titanate (PZT) is a solid solution of lead zirconate and lead titanate which has good piezoelectric properties and used in a variety of applications such as sensors, actuators and transducers [4,5]. In 2002, PZT–cement composites of 0–3 connectivity were fabricated using a normal mixing and spreading method by Li et al. [2] of Hong Kong University of Science and Technology. These PZT–cement composites can solve the mismatch problem and have a slightly higher piezoelectric strain factor than 0–3 PZT–polymer composite with a similar content of PZT particles. These new PZT–cement composites will play important role in all kinds of civil engineering structure in order to make it intelligent where the composites have potential to be used for sensor applications [2,6,7].

While Li et al. [2] investigated the paste method at 50 and 70 vol.%, a pressed method has also been reported by Huang et al. [8] in producing PZT–cement-based composites using PZT up to 85% by weight (≈70 vol.%) where the composites were dry pressed rather than mixing together as paste. Very recently, it was reported that the particle size of PZT has an effect on the dielectric and piezoelectric properties of the composite where a median particle size of 620 μm was found to give better dielectric and piezoelectric results compared to previous reported works [9]. In this study, a pressed method was adopted similar to the method used by Huang et al. [7], and PZT of 620 μm was used to produce 0–3 connectivity PZT–cement composites. Furthermore, these PZT–cement composites were made using PZT at various compositions (30, 60 and 90 vol.%) in order to determine the effect at low, medium and high percentage volume of PZT on the electrical properties such as dielectric and piezoelectric properties.

2. Experimental procedure

The cement-based piezoelectric composites used in this investigation were prepared by two raw materials, which are normal Portland cement (PC) and lead zirconate titanate

* Corresponding author. Fax: +66 53 357512.
E-mail address: arnon@chiangmai.ac.th (A. Chaipanich).

0272-8842/$34.00
doi:10.1016/j.ceramint.2007.09.027

ceramics ($Pb(Zr_{0.52}Ti_{0.48})O_3$, PZT). The PZT powders were prepared by calcining lead titanate ($PbTiO_3$, PT) and lead zirconate ($PbZrO_3$, PZ) at the temperature of 800 °C. Then, PZT solid solution were pressed with an applied pressure using uniaxial press and sintered at 1200 °C for 2 h.

PZT ceramic particles of median size of 620 μm were used in this investigation as shown in Fig. 1. Portland cement and PZT were mixed and axially pressed into disks of 15 mm in diameter and about 2 mm in thickness to form PZT–PC composites of 0–3 connectivity. PZT compositions used were 30, 60 and 90 vol.%. Afterwards, PZT–PC pellet composite were put in curing chamber with 100% RH at 60 °C for 3 days. Phase characterisations were carried out using a X-ray diffractometer (XRD; Philips PW 1792 diffractometer) using Ni-filtered CuK radiation.

Dielectric properties such as dielectric constant (ε_r) and dielectric loss (tan δ) were investigated at room temperature with frequency are 1 kHz using a LCZ meter (Hewlett Packard 4194A) and the piezoelectric strain factor value (d_{33}) was measured using a d_{33} meter (piezometer System Model PM25) after the pellet composite were coated with high purity silver paint and were subsequently poled in a silicone oil bath at 130 °C and a DC field applied of 2 kV/mm for 45 min.

3. Results and discussion

The XRD patterns of 0–3 lead zirconate titanate (PZT) and Portland cement composites are shown in Fig. 2. XRD patterns of PZT–PC composites are mainly attributed to PZT perovskite phase ($2\theta = 22.023°$, $31.387°$, $38.283°$, $44.917°$ and $55.524°$) and the intensities of the peaks increased with increasing PZT content in composite. Furthermore, the amorphous characteristics of the composites can also be observed from the broad peak presented in the XRD patterns.

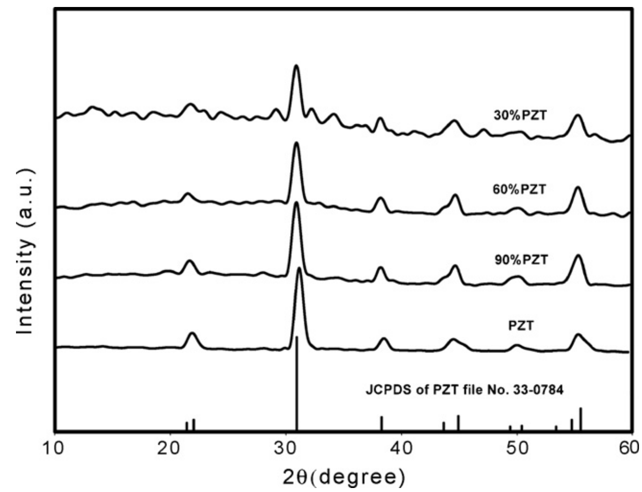

Fig. 2. XRD pattern of PZT–PC composites.

The dielectric constant (ε_r) results of the composites are shown in Fig. 3 and the dielectric loss (tan δ) results are given in Table 1. The results show that with increasing volume of PZT content, an increase in the dielectric constant was observed where ε_r values of the composites at 30 and 90 vol.% are 108 and 536, respectively. The dielectric loss results were found to decrease with increasing PZT content agreeing with the dielectric constant results due to the direct influence of PZT ceramic. A reasonably low tan δ value was obtained for composite with PZT at 90% (tan $\delta = 0.47$).

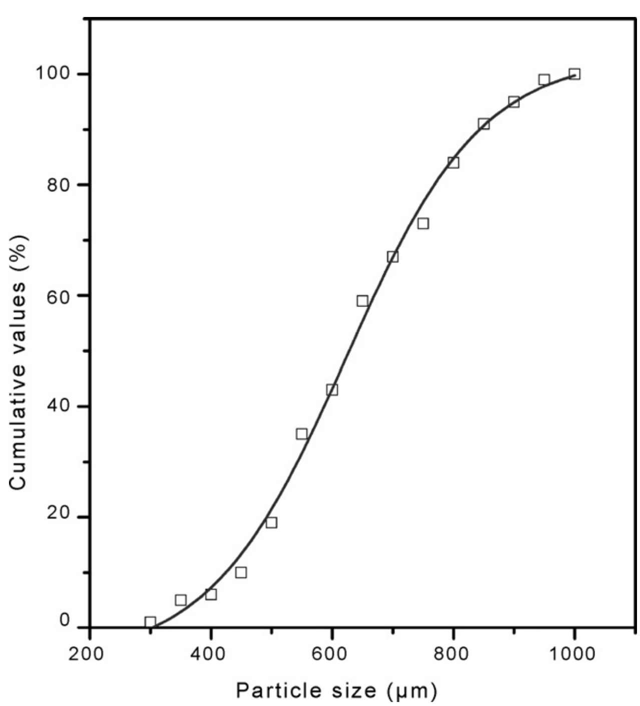

Fig. 1. Particle size distribution of PZT used in this study.

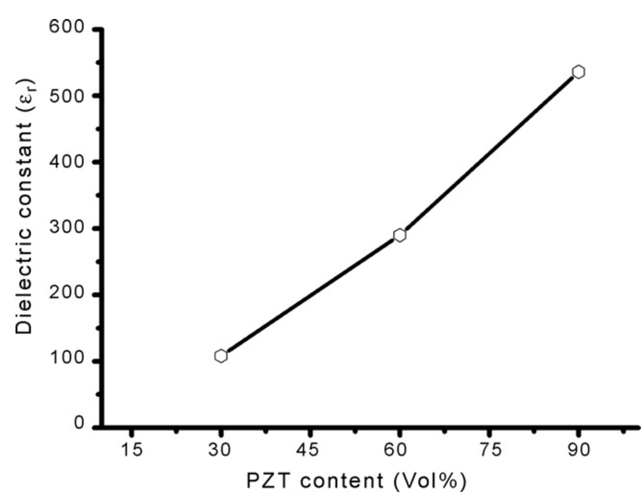

Fig. 3. Dielectric constant (ε_r) results of PZT–PC composites.

Table 1
Dielectric properties of PZT–PC composites

Dielectric properties	PZT content (vol.%)		
	30	60	90
Dielectric constant, ε_r (at 1 kHz)	108	290	536
Dielectric loss, tan δ	1.08	0.75	0.48

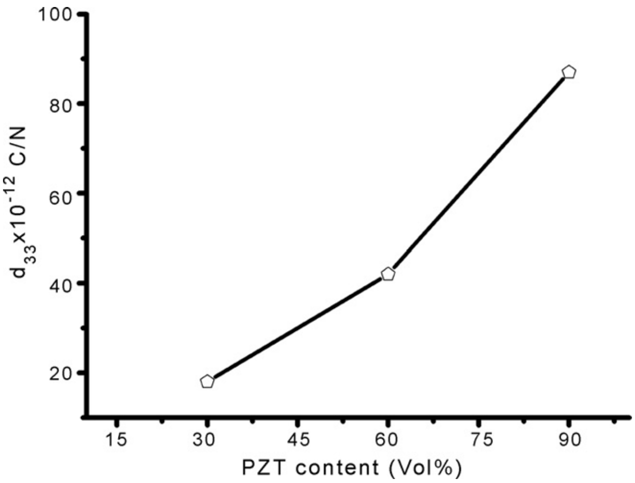

Fig. 4. Piezoelectric strain factor (d_{33}) results of PZT–PC composites.

Piezoelectric strain factor (d_{33}) results of the composites are shown in Fig. 4. The results show that higher piezoelectric strain factor value increased with PZT content and that a relatively high d_{33} for the composite with 60% and 90% was recorded where $d_{33} = 42$ and 87 pC/N, respectively.

4. Conclusions

- Generally, the XRD peaks of PZT–PC composites were found to be attributed to the perovskite PZT peaks. However, amorphous peaks can also be observed due to the presence of the cement matrix.
- The dielectric properties of PZT–PC composite increased when volume percentage of PZT was increased where ε_r values of the composites at 30 and 90 vol.% are 108 and 536, respectively.
- The dielectric loss results were found to decrease with increasing PZT content and a reasonably low tan δ value of 0.47 was obtained for composite with PZT at 90%.
- The piezoelectric strain factor increased with increasing volume percentage of PZT content and relatively high d_{33} values for the composite with 60 and 90% were found at 42 and 87 pC/N, respectively.

Acknowledgements

The authors are grateful to members of staff at the Electroceramics Research Laboratory, Faculty of science, Chiang Mai University for the research facilities made possible for this research work. The authors would like to express their gratitude for financial support from the Thailand Research Fund (TRF), the Commission on Higher Education (Thailand) and the graduate school of Chiang Mai University.

References

[1] G.W. Housner, A.L. Bergman, T.K. Caughey, A.G. Chassiakos, R.O. Claus, S.F. Masri, Structural control: past, present and future, J. Eng. Mech. 123 (9) (1997) 897–978.

[2] Z. Li, D. Zhang, K. Wu, Cement-based 0–3 piezoelectric composites, J. Am. Ceram. Soc. 85 (2002) 305–313.

[3] Z. Li, B. Dong, D. Zhang, Influence of polarization on properties of 0–3 cement-based PZT composites, Cem. Concr. Compos. 27 (2005) 27–32.

[4] Z. Zheng, Y. Qu, W. Ma, F. Hou, Electrical propertiesvand applications of ceramic–polymer composites, Acta Mater. Compos. Sinica 15 (4) (1998) 14–19.

[5] T. Furukawa, K. Ishida, E. Fukada, Piezoelectric properties in thee composites systems of polymer and PZT ceramics, J. Appl. Phys. 50 (7) (1979) 4904–4912.

[6] B. Dong, Z. Li, Cement-based piezoelectric ceramic smart composites, Compos. Sci. Technol. 65 (2005) 1363–1371.

[7] S. Huang, J. Chang, L. Lu, F. Liu, Z. Ye, X. Cheng, Preparation and polarization of 0–3 cement based piezoelectric composites, Mater. Res. Bull. 41 (2006) 291–297.

[8] S. Huang, J. Chang, R. Xu, F. Liu, L. Lu, Z. Ye, X. Cheng, Piezoelectric properties of 0–3 PZT/sulfoaluminate cement composites, Smart Mater. Struct. 13 (2004) 270–274.

[9] A. Chaipanich, Effect of PZT particle size on dielectric and piezoelectric properties of PZT-cement composites, Curr. Appl. Phys. 7 (2007) 574–577.