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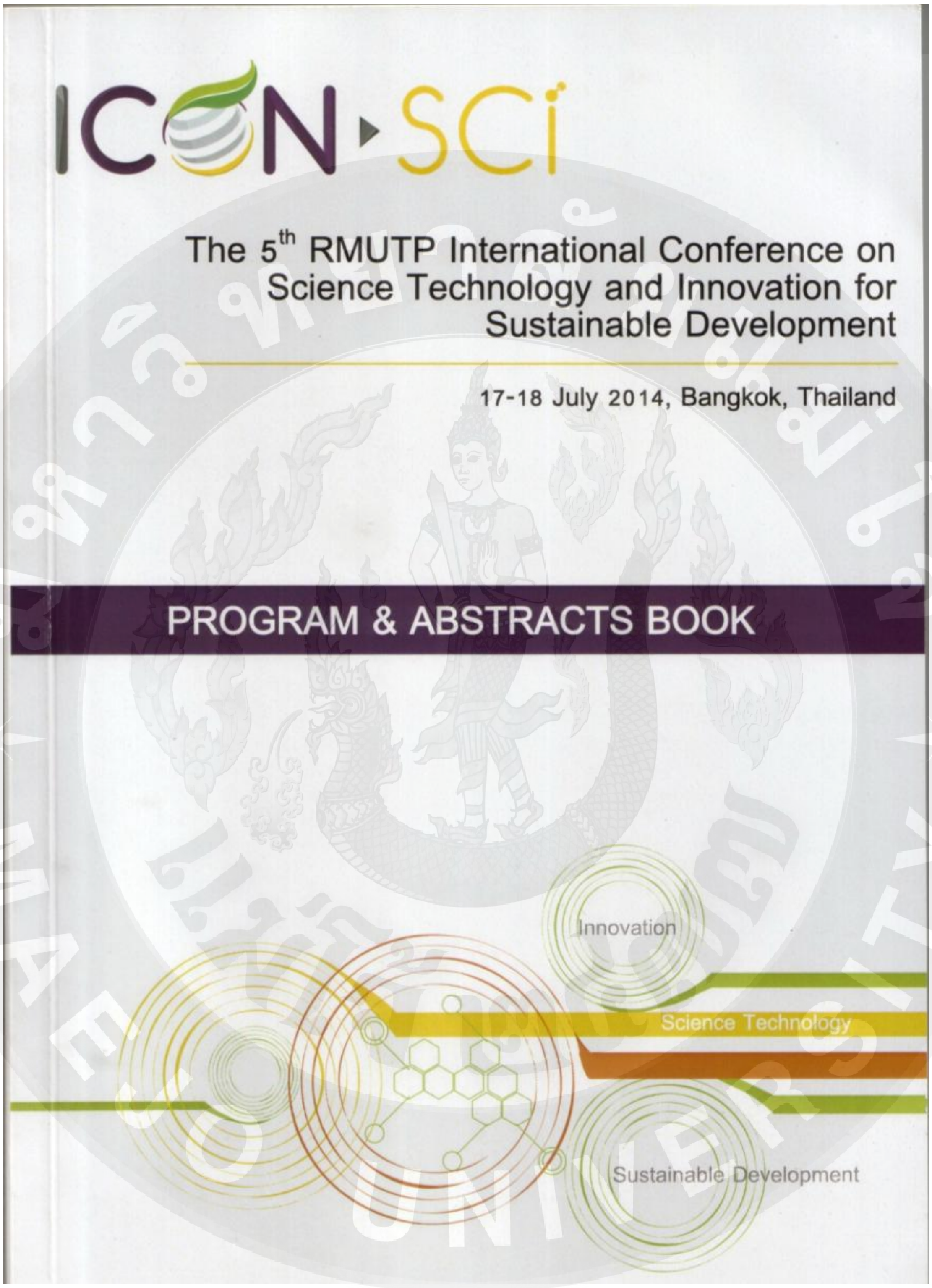
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MICROSTRUCTURE AND DIELECTRIC PROPERTIES OF CEMENT/RHA/PNZT CERAMIC COMPOSITE

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Abstract

The microstructure and dielectric properties of lead niobate zirconate titanate (PNZT), rice husk ash (RHA) and Ordinary Portland cement (OPC) composites were investigated. Ordinary Portland cement was partially replaced with rice husk ash at 20% by weight of binder. The rice husk ash was ground for 180 minutes before using. PNZT of mid particle sizes (450μm) were used at 30%, 50% and 70% by volume to produce the composites. The composites were mixed and pressed together and cured with 97%RH in chamber water bath for 3 days before measurements. The dielectric properties were measured under room temperature at different frequency. The results indicate that the dielectric constant of the PC-RHA-PNZT composites increased with increasing PNZT content.

Keywords: Cement, RHA, PNZT, composites

Microstructure and Dielectric Properties of Cement/RHA-PNZT Ceramic Composites

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Abstract. The microstructure and dielectric properties of lead niobate zirconate titanate (PNZT), rice husk ash (RHA) and Ordinary Portland cement (OPC) composites were investigated. Ordinary Portland cement was partially replaced with rice husk ash at 20% by weight of binder. The rice husk ash was ground for 180 minutes before using. PNZT of mid particle sizes (450μm) were used at 30%, 50% and 70% by volume to produce the composites. The composites were mixed and pressed together and cured with 97%RH in chamber water bath for 3 days before measurements. The dielectric properties were measured under room temperature at different frequency. The results indicate that the dielectric constant of the PC/RHA-PNZT composites increased with increasing PNZT content

Introduction

Cement, such as Portland cement, has long been used as structural materials. Cement-based piezoelectric composite has good compatibility with civil engineering's main structural material-concrete. Therefore, research and development of the cement based piezoelectric composite play an extremely important role in advancing all kinds of civil engineering structure to be intelligent [1]. In addition, the benefit form the use of such piezoelectric-cement based composites is that these composites possessed better matching to the host structure than the normal piezoelectric ceramic or other types of piezoelectric composites. One of the mostly used piezoelectric ceramic materials is lead zirconate titanate (PZT) as it has very high piezoelectric coefficient (d_{33}) and dielectric constant (ε_r) [2-3] and most of the piezoelectric-cement based composites were produced using PZT as the piezoelectric ceramic in the composite [4-6]. Moreover, it is well known that PZT ceramics could be modified with different additives to make them more attractive for specific applications [7–8]. Niobium (Nb) is one of the most used additives to evaluate the dielectric and piezoelectric properties of PZT [9–11]. Also furthermore, it is well known that rice husk ash (RHA), an agricultural waste material, can be a highly reactive pozzolanic material produced by controlled burning of rice husk and providing several advantages, such as improved strength and durability properties, reduced materials cost due to cement savings and environmental benefits [12]. Reactivity of RHA is attributed to its high content of non-crystalline silica, and to its very large surface area governed by the cellular structure of the particles [13-14]. Thus, it is interesting to study the fabrication process and properties of Cement/RHA-PNZT ceramic composites where the rice husk ash in 20% replacements of Portland cement by mass in cement, without optimization of the ash by controlled burning. In this work, composites consist of Portland cement (PC) together with rice husk ash (RHA) matrix and lead niobate zirconate titanate (PNZT) ceramics were prepared and investigated.

Experimental Procedure

The following materials were used in this work: Ordinary Portland cement (OPC), Type I, rice husk ash (RHA) and lead niobate zirconate titanate (PNZT) ceramics. Ordinary Portland cement was partially replaced with rice husk ash at 20%by weight of cement (the rice husk ash was ground for 180 minutes before using). Lead niobate zirconate titanate (PNZT) ceramic particles of composition $Pb_{(1-x)},Nb_{x})(Zr_{0.53},Ti_{0,47})O_3$ where x=0.04 were produced using PNZT powder sintered at 1250ºC for 2 hours. The variations of PNZT ceramic of mid particle sizes (450μm) were used at 30%, 50% and 70% by volume. Then, PC, RHA and PNZT ceramic were mixed together and axially pressed into disks of 15 mm in diameter and about 1.75 mm in thickness to form PC-RHA-PNZT composite. Thereafter, the composites were placed for curing at 60^{o}C and 98% relative humidity for 3 days before measurement. Dielectric properties such as dielectric constant (ε_r) and dielectric loss (tanδ) were investigated at room temperature after the pellet composite were coated with high purity silver paint. Scanning Electron Microscope was used to study the microstructure of the composites

Results and Discussion

Fig. 1 showed the dielectric properties of PC-RHA-PNZT composites were investigated. The dielectric properties of the both composites are measured as a function of content of PNZT ceramic has been studied at frequency for 1 kHz at room temperatures. It can be seen that there is a roughly nonlinear increase of the dielectric constant values of the composites as a function of the PNZT content. It can also be explained that with increasing the PNZT volume fraction, the dielectric value of the composite increased gradually.

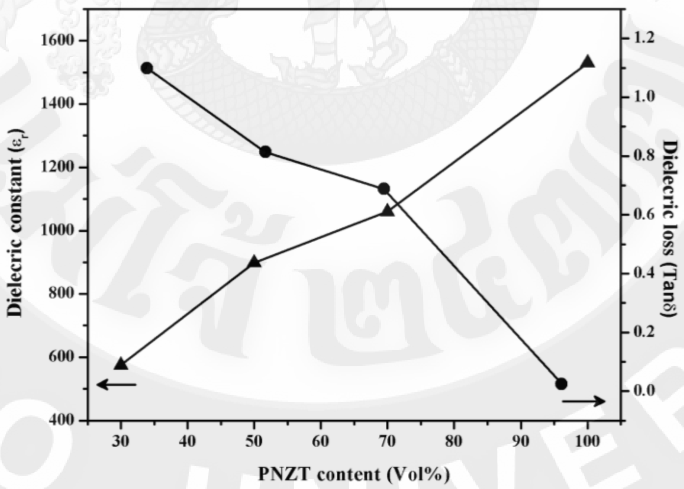

Fig. 1 Effect of PNZT content on dielectric constant and dielectric loss of PC/RHA-PNZT composites.

The reason is probably that the larger the volume fraction of PNZT ceramic, the larger the contribution of the interface polarization on the total polarization of the composite, which leads to an increase of the dielectric value of the composite. This means that the change of the dielectric constants of the composites is mainly caused by interface polarization of the composites and various polarization of the cement/RHA matrix. Moreover, the enhancement in ε_r value can be attributed to the introducing of PNZT content which with high dielectric constant of cement/RHA-based composite. PNZT ceramic exists in the composites as tiny grains, just as introduces a lot of tiny capacitors. The more PNZT content, the more tiny capacitors introduced. Therefore, the higher dielectric constant appears in the composites with higher content of the PNZT ceramic [15]. On the other hand, the dielectric loss results were found to decrease with increasing PNZT ceramic content due to loss cement/RHA being used. Conduction ion in the cement/RHA matrix would contribute to the loss in the dielectric. A reasonably low tan δ value was obtained for composite with high ceramic disperse phase content [4, 6].

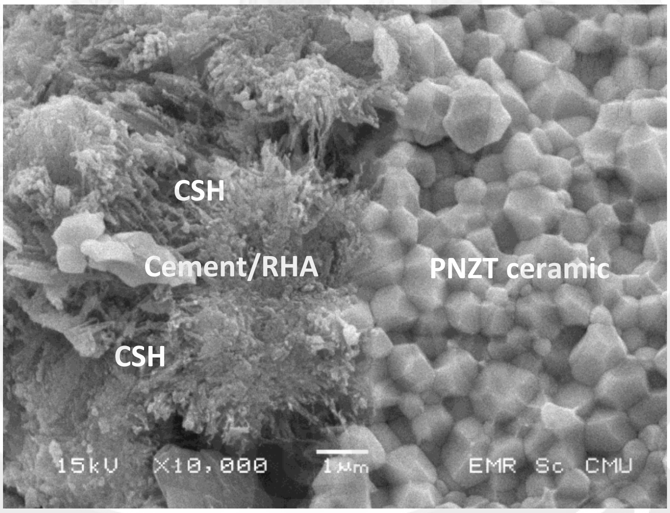

Fig. 2 SEM micrographs at interfacial zone of PC/RHA-PNZT composites

The SEM images of the PC/RHA-PNZT composites are shown in Fig. 2. The SEM micrograph reveal that a typical microstructure of the composites at the interfacial zone between the PNZT ceramic particle and the cement/RHA matrix where PNZT ceramic grains can be seen next to cement hydration products such as calcium silicate hydrates (CSH), Calcium hydroxide $Ca(OH)_2$

and ettringite (the SEM micrographs of $Ca(OH)_2$ and ettringite do not show any specific crystalline form). Moreover, the angular shape PNZT particle is believed to contribute to better mechanical interlocking with the cement/RHA phase due to the angular aggregate having rough surface appearing to provide better mechanical interlocking with the cement/RHA phase [16].

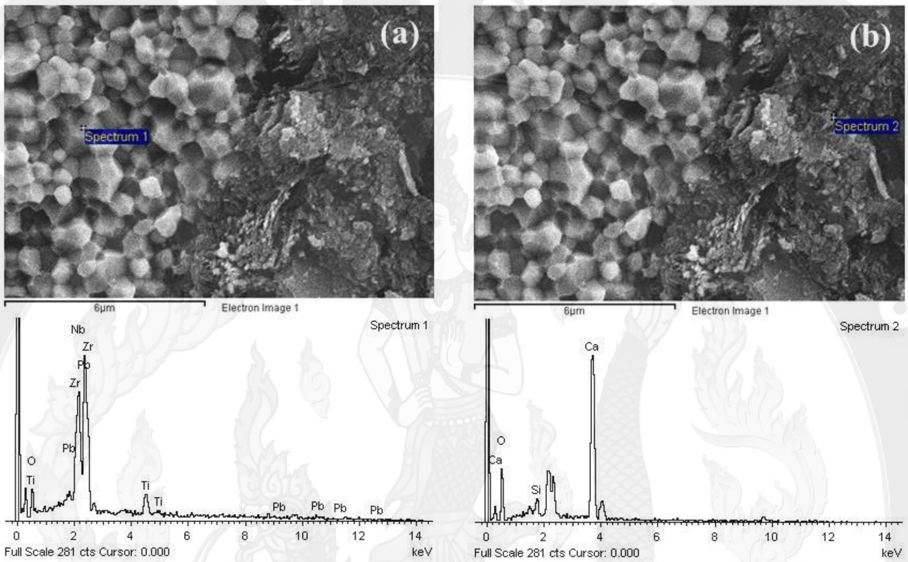

Fig. 3 EDS spectrum of PC/RHA-PNZT composites at interfacial zone : (a) spectrum of PNZT ceramic phse, (b) spectrum of Cement/RHA phase.

However, the properties of cement based products are largely dictated by CSH. Hydrated phases, mostly CSH, form slowly and the material consolidates as space is filled with CSH and crystals of Calcium hydroxide and Ettringite phase. Furthermore, RHA which contains high amount of silica, as in cement, is important as a minor cement substitute. When water is added to cement, the hydration starts topically and showed product of cement hydration which were calcium silicates hydrate, CSH and calcium hydroxide, $Ca(OH)_2$. The SiO_2 will combine with the released $Ca(OH)_2$ which contains more CSH [17].The energy dispersive x-ray diffraction of PC/RHA-PNZT composites can be seen in fig. 3. The elements of PNZT ceramic (fig. 3(a)) such as Pb, Nb, Zr, Ti and O were detected for confirmation also the elements of cement hydrates (fig. 3 (b)).

Conclusions

The composites consist of Portland cement (PC) together with rice husk ash (RHA) matrix and lead niobate zirconate titanate (PNZT) ceramics were prepared. The results found that the dielectric constant of PC/RHA-PNZT composite increased when volume percentage of PNZT was increased while the dielectric loss result was found to decrease with increasing PNZT content. Moreover, SEM micrographs show angular PNZT ceramic particle bond well with the cement/RHA matrix with the percentages of cement replaced by 20% RHA.

Acknowledgements

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