CHAPTER 1

INTRODUCTION

1.1 Overview

Functional composite materials have found use in a number of applications such as sensors, actuators and transducers. An important approach for making functional composites is to bring together two or more different materials [1]. The emphasis of many-phase system in materials science and technology is still growing due to a vast area of applicability of the composites by combining superior properties of individual constituent phases since their properties can be adjusted to the requirements of various devices [2].

Civil engineering infrastructure are exposed to dynamic loading from distinct sources which can be due to traffic loads, strong wind, earthquakes ground motion and reciprocating machinery. For some important modern constructions, such as high-rise buildings and large-span bridges, dams, and so on, severe vibration and significant internal damage may be caused by these dynamic loads. They not only pose a great threat to the safety of the constructions however also cause important inconvenience to the users. Smart or intelligent constructions including effective health monitoring and active vibration control of constructions has been developed to solve these problems [3-6] and in a smart structure, sensors and actuators are essential components for sensing and controlling purposes.

Cement-based piezoelectric composite has good compatibility with civil engineering main structural material-concrete because it not only has sensing function but also actuating property which is greatly appropriate for applications in civil engineering fields, e.g. modern structures, including high-rise building, dams, and bridge decks whose failure would cause disasters. Moreover, cement-based piezoelectric composite using cement as a matrix forpiezoelectric composite can solve the mismatch problem [7]. Therefore, research and development play an extremely considerable role in advancing all kinds of civil engineering structure to be smart or intelligent of the cement-based piezoelectric composite [8]. The use of such composites would provide an advantage in the matching of structural concrete. Li et al. [7] reported that 0–3 Portland cement–lead zirconate-titanate (PZT) piezoelectric composites can overcome the matching problem for ≈40–50% PZT by volume, the acoustic impedance is close to that of concrete, i.e. 8.95 x 10^6 kg·m^{-2}·s^{-1} as compared to PZT (≈ 21.2 x 10^6 kg·m^{-2}·s^{-1}).

Most important piezoelectric ceramic is lead zirconate titanate (PZT) due to its advantageous properties and well-characterized behaviors [9]. This is because PZT ceramics (1) possess high electromechanical coupling coefficients (2) have high T_C values, which permit high temperatures of operation or high temperatures of processing during the fabrication of devices, (3) can be easily poled, (4) possess a wide range of dielectric constants, (5) are relatively easy to sinter at low temperatures and (6) form solid-solution compositions with many different constituents [10]. Therefore, because of these unique characters of PZT, it is very interesting to investigate composites produced from these two piezoelectric material with the main civil engineering material, cement. Moreover, the connectivity of composite is a key feature in property development in multiphase solids since physical properties can change by many orders of magnitude depending on the manner in which connection are made. Each phase in a composite may be self-connected in zero, one, two, or three dimensions. In the case of diphase composites, there are 10 connectivities, designated as 0-0, 1-0, 2-0, 3-0, 1-1,2-1,3-1,2-2,3-2, and 3-3 [11]. In this study, a 0-3 cement-based piezoelectric ceramic composite has been developed since it is the easiest form of composites to be fabricated, where the ceramic phase is zero dimensions (0) and the cement phase is three dimensions (3). For 0–3 connectivity composites, it is however, difficult to obtain good piezoelectric properties due to the difficulty in poling ceramic particles in such composites. One way to effectively improve poling of piezoelectric ceramic is to create a continuous electric flux between piezoelectric particles by the introduction of a small volume fraction of a third phase, such as graphite (C) and germanium (Ge) [12-14]. However, another way to decrease the leakage current caused by the interfacial pores and the cement matrix pores can be implemented by adding admixture to fill these pores, such as polymer or antifoaming [15]. Polyvinylidene fluoride (PVDF) is semicrystalline polymer with pyroelectric and piezoelectric properties. Its high permittivity and relatively low dissipation factor make it a potential candidate and useful in many applications [16, 17]. Therefore, the third phase such as carbon and PVDF can be introduced into the piezoelectric-cement composites and their effects on the dielectric, piezoelectric and ferroelectric properties are investigated.

1.2 Objectives of this work

In this study, the fabrication, microstructure and electrical properties of 0-3 cement based piezoelectric composites consisting of one selected piezoelectric material e.g., PZT and two selected third phase e.g., carbon and PVDF were investigated.

Therefore, the investigation was divided into two main parts:

- The first part investigates the microstructure and electrical properties of piezoelectric ceramic-Portland cement composites made using PZT as piezoelectric ceramic.
- The second part investigates effects of carbon and PVDF addition on microstructure and electrical properties of piezoelectric ceramic-Portland cement composites.

1.3 Methodology and Analyses

The experimental part of the work consists of the initial preparation of piezoelectric lead zirconate titanate (PZT) powders and ceramics. Then, PZT-PC composites of 0-3 connectivity and PZT-third phase-PC composites were fabricated. Dielectric properties (using LCR-meter) and piezoelectric properties (using d_{33} meter), ferroelectric hysteresis properties (using Sawyer-Tower circuit) were investigated. The microstructure of the composites was investigated using Scanning electron microscopy (SEM). Piezoelectric force microscopy (PFM) was also used to investigate sub-micron domain property of the composites. The summary of overall work can be seen as follows;

- Literature review
- Powder synthesis by a solid-state mixed oxide technique
- Ceramic processing by pressing and sintering
- Composites fabrication by normal mixing, pressing and curing
- Poling process with optimum a degree of poling
- Measurements: dielectric properties, piezoelectric properties, ferroelectric properties and microstructure
- Measuring instrument: LCR-meter, d_{33} meter, Sawyer-Tower circuit, SEM and PFM

Flow chart of preparation and characterization of cement-based PZT composites is illustrated in Fig. 1.1.

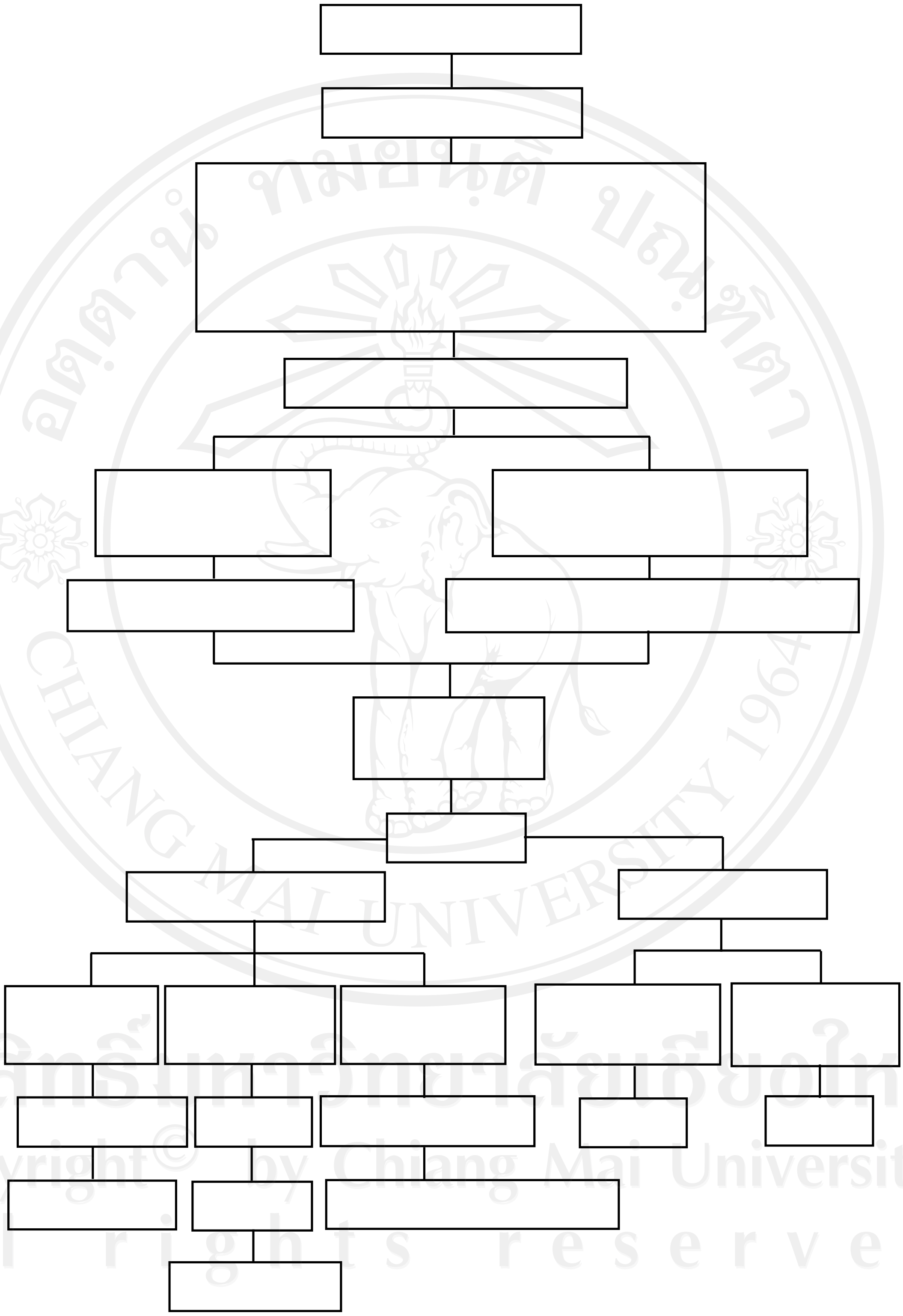

Fig 1.1 Flow chart of preparation and characterization of cement-based PZT composites