CHAPTER 1
INTRODUCTION

It is known that ferroelectric ceramics based on lead are most promising materials for the electronic device applications such as capacitors, actuators, transducers and sensors etc.[1,2,3] They offer many desirable characteristics, including large piezoelectric coefficients, large dielectric permittivity, wide operating temperature range and low cost. Therefore, the electrical properties of ferroelectric ceramics are extensively studied.

The perovskite PZT (lead zirconate titanate, $Pb(Zr_{1-x}Ti_x)O_3$), a solid solution of antiferroelectric PZ (lead zirconate, $PbZrO_3$) and ferroelectric PT (lead titanate, $PbTiO_3$) is a well-known material with of a normal ferroelectric characteristic. For the two end-members, PZ with an orthorhombic structure has a Curie temperature of ~ 230 °C,[4] while PT with a tetragonal perovskite structure has a Curie temperature of ~ 490 °C.[4] Therefore, the PZT system has Curie temperatures between 230 °C and 490 °C depending on Zr/Ti ratio. This system has a maximum dielectric constants and high electromechanical coupling coefficients near the morphotropic phase boundary (MPB) between rhombohedral and tetragonal phases,[5] e.g. $Pb(Zr_{0.52}Ti_{0.48})O_3$ near room temperature has the dielectric constant at about 730, and the electromechanical coupling coefficient at about 0.67 can be expected for this composition.[6] However, the large hysteresis loop arises in PZT when operating at high fields, resulting in high energy loss within the sample as heat.[8] The PMN (lead magnesium niobate, $Pb(Mg_{0.33}Nb_{0.67})O_3$) ceramic, on the other hand, has a narrow hysteresis loop (low loss) and higher dielectric constant compared to PZT. PMN ceramic has a dielectric constant of 12,600 at the temperature of the maximum dielectric constant (T_m) of -15 °C.[9] Moreover, little attention has been focused on its piezoelectric properties because of its low T_m.[9] Therefore, modification PZT with PMN is interesting because it is anticipated to reduce the energy dissipation in PZT system. In addition, the PMN-PZT system is expected to have a combination of desirable properties with high dielectric constant, high electromechanical coupling coefficient and low loss for use in efficiency devices.

All ferroelectric ceramics are a subset of the family of pyroelectric materials in which the direction of the spontaneous polarization can be changed between two or more orientations by applied field. The domains in ferroelectric ceramics can be reoriented by an electric field or by a mechanical stress loading of sufficient magnitude. The consequences of domain switching in ferroelectric materials are the occurrence of non-linear response.[10] Applying a large alternating electric field causes the polarization to reverse (switch), and this gives rise to the ferroelectric hysteresis loop, relating the polarization to the applied electric field. The hysteresis loop is the single most important measurement that can be made on a ferroelectric ceramic when characterizing its electrical behavior. Hysteresis loops come in all size, shape and similar to fingerprint identify the material in a very special way.[11] For this reason, hysteresis properties have to be considered when applying ferroelectric ceramics in any devices. The observation of hysteresis loops is carried out with a conventional Sawyer-Tower circuit.[12]

Ferroelectric ceramics usually consist of multiple domains. As a result, the ceramics may exhibit little or no net polarization.[11] Therefore, ferroelectric ceramics are need to be poled before used for applications. Poling is the process in which a DC electric field exceeding the coercive field (E_c) is applied to a multiple-domain ferroelectric to produce a net remanent polarization (P_r).[13]

Most of early studies[15,16] on PMN-PZT system have been focused on processing and dielectric properties, but there is still no work on its hysteresis properties. Therefore, this study is undertaken to better understand the hysteretic properties of the PMN-PZT system. The objectives are as follows:

1. To prepare ceramics in the PMN-PZT system by a mixed-oxide method.
2. To investigate effects of poling conditions on the hysteresis properties of the prepared PMN-PZT ceramics.
3. To investigate effects of composition ratio on the hysteresis properties of the prepared PMN-PZT ceramics.