CHAPTER 5
CONCLUSIONS AND SUGGESTIONS

The effect of composition ratio and poling field strength on the hysteresis properties of (x)PMN-(1-x)PZT ceramics was study. Other characteristics such as phase formation, microstructure and density of the PMN-PZT ceramics were also investigated. The conclusions of this study, a few suggestions for further work are presented in this chapter.

5.1. Conclusions

1. The several compositions of $(x)Pb(Mg_{0.33}Nb_{0.67})O_3$-$(1-x)Pb(Zr_{0.44}Ti_{0.56})O_3$ (when x = 0.0, 0.1, 0.3, 0.5, 0.7, 0.9 and 1.0) ceramics were successfully prepared from PZT and PMN powders by a solid-state mixed-oxide technique. XRD studies indicate that PZT ceramic is identified as a single-phase material with a perovskite structure having tetragonal symmetry, while PMN ceramic is a perovskite material with a cubic symmetry. However, small amount of pyrochlore is also detected in PMN ceramic.

2. The microstructure of PMN-PZT ceramics show pores at grain boundaries and intragrains. The presence of pyrochlore phase was found on surface of PMN ceramics which associated to the presence of PbO volatilization. The grain size varies considerable from < 1 μm to 10 μm. However average grain size of ceramics does not vary significantly with composition.

3. The density of ceramic is composition-independent. The densities decrease with increasing PMN content until reach x = 0.5, then increase for higher x = 0.9. The apparent solid density which effect of the true volume of solid plus the volume of any closed pores which are present. It indicates the error of the Archimedes method. Therefore, it is not significant change with electrical properties.

4. The hysteresis parameters (P_r, P_s and E_c) were determined to be a function of the poling field strength. Generally, the poling field strength has a little effect on the hysteresis parameters of PMN-riched compositions (when $0.5 \leq x \leq 1$) but shows a marked effect on those of PZT-riched compositions (when $0 \leq x \leq 0.3$). The variation of the value of hysteresis parameters vary with poling field strength can be group into three. The polarizations (P_r and P_s) and coercive field (E_c) of PZT ceramic are largely increased with increasing of poling field strength, while the

values of polarization (P_r and P_s) of x = 0.1 and x = 0.3 (as a second group) are slightly increased but E_c remains constant. On the other hand, polarizations (P_r and P_s) of PMN-riched composition (as a third group) are increased until the poling field strength reaches 20 kV/cm, then become constant with further increasing of the poling field strength, while E_c still remains constant. The maximum values of hysteresis parameters observed at poling field strength of 30 kV/cm are in good agreement with previous research.[8]

5. The hysteresis parameters (P_r, P_s and E_c) were determined to be a function of the composition ratio. It is shown that the polarizations (P_r and P_s) reach peak values at x = 0.3, with the results of XRD analysis which show the significant change of XRD pattern at the composition between of x = 0.3 and x = 0.5, indicating that the MPB composition of PMN-PZT system should lie between these two compositions. Furthermore, the coercive field shows the maximum value for PZT and decreases with increment of PMN contents. It shows that the coercive field is nearly constant for the psudocubic composition (PMN), but increases with increasing PZT in the tetragonal region.

5.2. Suggestions

1. In the measurement of hysteresis loop, the recording method of the hysteresis loops should be done with the digital oscilloscope to enhance the display of the developed hysteresis loops under electric field. In addition, this software should be capable of the calculation of hysteresis loop area to determine the hysteresis loss.

2. Form the Sawyer-Tower circuit used in this experiment, it is usually assumed that the ceramic has a low loss and a high polarization, but the prepared ceramics are in most not perfect. The ceramics often have loss and small polarization. Thus, a circuit which provides cancellation for resistive losses and stray capacitance is needed, especially with lossy samples. The basic compensated circuits should be incorporated into the original Sawyer-Tower circuit in future work.

3. The hysteresis properties of other ceramics such as $BaTiO_3$ should also be determined for comparison. The tendency of the hysteresis parameter with poling field strength of other ceramics can also be used to confirm the accuracy and reliability of the results obtained from the sample.

4. Other poling conditions, such as soaking time and temperature, should be studies to obtain better results for each ceramic composition.