CHAPTER 7

CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

7.1 Conclusions

Based on experimental results, it has been demonstrated that the choice of the processing methods plays an important role in phase formation, microstructure and electrical properties of perovskite PMN-PT systems. The main trends outlined in this work are as follows:

(1) The single-phase perovskite PMN powders and ceramics can be successfully formed by employing either columbite or corundum *B*-site precursor method via a rapid vibro-milling. Amongst the two *B*-site precursor methods, lower optimized calcination temperature for the production of pure PMN powders can be obtained by using the columbite-route, whereas the smallest obtainable particle size was found in the corundum-route PMN powders. The presence of MgO in the microstructures of PMN ceramics may lead to the pyrochlore elimination and results in enhancement of the dielectric properties.

(2) A simple process has been developed for the preparation of PT nanopowders with 100% perovskite phase by employing a combination of mixed oxide synthetic route and a rapid virbro-milling technique. It was also possible to obtain rather dense PT ceramics with homogeneous microstructure and better dielectric properties by the two-stage sintering technique.

(3) The ceramic-nanocomposites in the perovskite PMN-PT systems were successfully achieved by employing the bimodal particle size packing concept. Their electrical properties are strongly influenced by the presence of secondary phases and

densification mechanism which in turn depend on the processing parameters, i.e., purity, homogeneity and firing conditions. The observed characteristics of electrical and thermal properties may ultimately be governed by the factors that affect chemical compositions, microstructural evolution and the preparation processes.

7.2 Suggestions for Further Work

A number of interesting issues remain unanswered concerning the relationship between microstructural evolution and electric properties of the ceramic-nanocomposites in the PMN-PT system. Thus, it is anticipated that this could be partly filled by the following suggestions for the further work.

(1) Further work on the microstructural characterization (e.g. via high-resolution TEM) especially the domain and grain boundary characteristics of the PMN-PT materials would facilitate a better understanding of complex perovskite ferroelectric in general.

(2) Some improvement may be achieved by increasing the density of the PMN-PT ceramic-nanocomposites by using techniques such as spark plasma sintering, hot-pressure sintering or isostatic pressing.

(3) Further work arising directly from this study would focus attention on the compositions within the MPB region of the (1-x)PMN-xPT system where $0.3 < x < 0.4$. Careful investigations of the effects of sintering condition on the phase formation, densification, microstructure, electrical and thermal properties would provide knowledge and baseline for further academic work.

(4) The ceramic-nanocomposites approach developed in this work could be applied to other perovskite ferroelectrics such as PNN-PZT or PZN-PZT systems.

(5) Further work on the mechanical properties (e.g. strength and fracture toughness) of the PMN-PT ceramic-nanocomposites would determine for applications.