CHAPTER 5

Conclusions

In this research, Michelson interferometer has been developed to measure induced-strain of ferroic materials caused by electric field, which was affected by temperature and magnetic field. This includes the setup of modified Michelson interferometer with Sawyer-Tower circuit and modified the sample holder to observe aging phenomena, frequency dependence, temperature dependence and magnetic field effect in the PLZT, PMN-PZT and PMN-PT relaxor ferroelectric materials, which is the materials with highly ferroelectric property due to the phase transition temperatures T_c/T_m near room temperature.

5.1 Conclusions

First, the frequency dependence property in induced strain measurement for PMN-PZT relaxor ferroelectric materials was observed. In less spontaneous polarization case, PMN sample demonstrated slim loop of induced strain and polarization as a function of electric field accompanying demonstrated the decreased maximum induced strain and polarization when the frequency was decreased from 0.05 to 0.02 Hz due to the electrical charged at the layer inside and the depolarizing field caused the electric field was lower than the applied field. In high spontaneous polarization case, 0.7PMN-0.3PZT sample demonstrated butterfly loop of induced strain and hysteresis polarization as a function of electric field due to the switching of spontaneous polarization, and demonstrated the decrease of polarization and change from anti-clockwise to slim and clockwise direction of polarization when the frequency was decreased from 0.1 to 0.01 Hz due to the electrical charged at the layer inside generated the depolarizing field, but the maximum induced strain still increased as a function of decreased frequency due to the fact that it was mainly dominated by spontaneous polarization switching having more time when the frequency was decreased. 0.9PMN-0.1PZT, 0.5PMN-0.5PZT and

0.3PMN-0.7PZT samples showed the increase of polarization as a function of decreased frequency because high electrical loss was probably caused by fewer layers inside samples from fabrication. For all sample results, 0.2 Hz of frequency is suitable for induced strain measurement as it shows high induced strain and negligible electrical loss effect.

Second, the aging phenomena in induced strain of PLZT relaxor ferroelectric materials was observed when they were left as a function of time. In the case of relaxor ferroelectric far from MPB, PLZT (9/70/30) sample showed hysteresis polarization with pinched like anti ferroelectric behavior (180° domain dominate) after 19 days aged, according to the depolarizing field resulted from the reorientation of the defect dipole inside for reduced the energy as electric energy after sample fabrication. The higher sintering temperature showed greater decrease in square polarization than induced strain as shown in Q electrostriction coefficient, and 1275°C sample having fewer decrease in induced strain due to fewer pores in microstructure (dense materials). In the case of relaxor ferroelectric near MPB, PLZT (9/65/35) sample showed higher hysteresis polarization and butterfly shape curve of induced strain referring high spontaneous polarization sample. The polarization and the induced strain was decreased after 19 days aged, the asymmetric butterfly shape was demonstrated according to the reorientation of 90° domain to preferred direction inside for reduced the energy as elastic energy after sample fabrication. The higher sintering temperature showed greater decrease in induced strain than square polarization as shown in Q electrostriction coefficient, and 1275°C sample having higher decrease in induced strain due to high stress inside which was released after annealing process.

Third, the temperature dependence property in induced strain behavior of PLZT, PMN-PZT and PMN-PT relaxor ferroelectric materials was observed. The induced strain was demonstrated two types of shape change indicating relaxor ferroelectric phase transition. In the case of relaxor ferroelectric to paraelectric phase, 0.9PMN-0.1PZT, 0.7PMN-0.3PZT and 0.9PMN-0.1PT samples showed induced strain and polarization decrease when temperature was increased to a slimmer loop due to less spontaneous polarization. In the case of normal to relaxor ferroelectric and paraelectric phase, PLZT (9/65/35), 0.5PMN-0.5PZT, 0.8PMN-0.2PT and 0.7PMN-0.3PT samples showed butterfly shape curve induced strain and hysteresis polarization which increased to the maximum high spontaneous polarization with asymmetry butterfly shape at normal to relaxor ferroelectric phase transition, then decreased as slimmer loop with showed 180° microdomain in s-P loop when the temperature was increased to paraelectric phase. The int p-E and int s-E of all samples showed non linear decrease as a function of temperature increased in relaxor ferroelectric to paraelectric phase transition, to confirm Curie-Weiss law of relaxor ferroelectric behavior.

Finally, the magnetic field effect in induced strain behavior of PLZT, PMN-PZT and PMN-PT relaxor ferroelectric materials was observed as magnetoelectric effect. The magnetic field effect could be clearly seen in the sample composition near morphotopic phase boudary MPB, which has high spontaneous polarization with 90° and 180° domain exhibiting different behavior to frequency and biased magnetic field. In the case of 90° domain mainly dominated, 0.5PMN-0.5PZT, 0.8PMN-0.2PT and 0.7PMN-0.3PT samples showed the increase of induced strain response to 90° domain switching with suppressed magnetic effect when bias magnetic field was increased but showed no magnetic effect to the polarization according to less response to 180° domain. In the case of 180° domain mainly dominated (PLZT (9/65/35) sample), all the induced strain and polarization exhibited the decrease affected by an increase of bias magnetic field according to some 180° domains were magnetically suppressed, resulting in the change of response to domain switching.

5.2 Suggestions for further work

5.2.1 There should be further development of sample holder loaded at higher temperature range, possibly up to 100°C. A new heater should replace ceramic heater and high temperature resistant material for sample holder should be used. To observe temperature dependence in ferroic materials which are used in high temperature range application such as oil pump in the machine is highly recommended.

5.2.2 To develop the range of magnetic field (B), the supply as altered shape or bipolar magnetic field should be used. This would give new information of magnetoelectric effect in ferroic materials.

5.2.3 To develop the range of induced measurement by Michelson interferometer into smaller or higher size than quarter wavelength of He-Neon laser with amplifier and analyzer (proceed and electrical device) to interpret the interference intensity to give the accurate measurement.