Temperature-modulated pyroelectricity measuring system for single crystals of molecular ferroelectrics and analysis of modulation frequency dependence of the pyro-current using a 1D heat transfer model

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Pyroelectricity is a response of polar material subjected to temperature change. The electric current is thus usually recorded by sweeping temperature of the sample. However, rate of the temperature sweep is experimentally limited, and it is difficult to obtain sufficient signal strength from a small sample such as an organic single crystal. In the present study, we developed a light-irradiation temperature-modulated pyroelectricity measuring system to investigate electric polarization in single crystals of molecular ferroelectrics, especially conductive materials that have been newly confirmed their ferroelectric polarization [1-3].

To investigate the phase transition mechanism in terms of pyroelectricity, it is necessary to perform the measurements over a wide temperature range. However, such a soft and fragile material as organic crystals changes its properties due to lattice distortion caused by difference in the thermal expansion coefficient between the sample and the heat bath, if it is cooled or heated by a normal heat conduction method.

In order to prevent the occurrence of lattice distortion, the sample temperature is controlled by a heat exchange gas cryostat, and the dynamically modulation of the temperature is applied in a non-contact manner with a use of a modulated laser in the present system. Whereas the modulation measurement is advantageous in signal sensitivity and temperature accuracy, the magnitude of the temperature modulation is difficult to measure, making it difficult to evaluate the pyroelectric coefficient from the experimental results. In the present study, we performed a thermal diffusion analysis of the irradiation heat in a specimen surrounded by heat exchange gas to calculate the temperature oscillation during the modulation experiments, and applied the analysis to explain the pyroelectricity measured for a single crystal of $LiNbO_3$. Features of the modulation frequency dependence of pyroelectricity are discussed based on the results of the thermal model calculation for the standard sample measurement.

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