Evaluation of the piezoelectricity of Preyssler-type polyoxometalates by converse piezoelectric measurements

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Piezoelectric materials have been actively researched because they exhibit unique physical properties such as direct and converse piezoelectric effects. The emergence of piezoelectricity requires the breaking of inversion symmetry. Therefore, about 70% of all materials don't exhibit piezoelectric effects. To break through this theory, we focused on single-molecule electret (SME).[1,2] This molecule, a Preyssler-type polyoxometalate $[M^{n+}\subset P_5W_{30}O_{110}]^{(15-n)-}$, encapsulate a metal ion within its cage-shaped molecular structure (Fig. 1). Since the metal ion can move between two equivalent stable sites in the molecule, each with an occupancy of 0.5, this molecule is centrosymmetric. However, when an external electric field is applied to this material, ion migration between the ion sites is induced, resulting in polarization hysteresis like that of ferroelectrics. Generally, ferroelectric materials exhibit piezoelectricity; therefore, SME would also exhibit the piezoelectric effect, even though it is a centrosymmetric material.

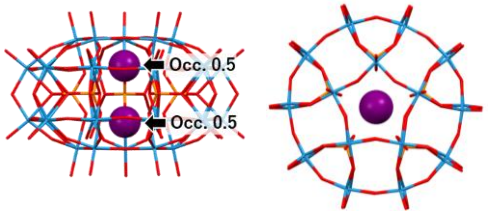

Fig. 1. Side and top view of a Preyssler-type polyoxometalate structure.

In this research, the converse piezoelectric effect of SME was measured. The pellet sample of $K_{12}[Tb\subset P_5W_{30}O_{110}]$ was prepared by applying pressure to the powdered sample. The strain of this pellet was measured using a laser Doppler vibrometer while applying sinusoidal voltage to the pellet's longitudinal axis. The component derived from the converse piezoelectric effect was extracted by Fast Fourier transform (FFT). From the amplitude and phase difference of the strain obtained by FFT, the piezoelectric coefficient of the SME was estimated to be -8.47×10^2 pm/V (Fig. 2). From this result, SME is a novel material that exhibits the piezoelectric effect, despite being a centrosymmetric material.

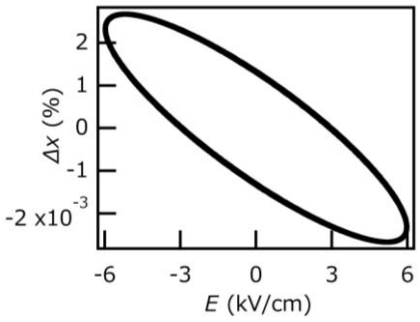

Fig. 2 Strain due to the converse piezoelectric effect extracted by FFT.

1) C. Kato, S. Nishihara, *et al*., *Angew. Chem. Int. Ed*., 57,13429-13432, **2018**.
2) S. Nishihara, *Nat. Nanotechnol*., 15, 966-967, **2020**.