Ferroelectricity in $CsPb_2Nb_3O_{10}$ and Exfoliated 2D Nanosheets

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Introduction

Lead (Pb) is a pivotal element for ferroelectric materials. While Bi-based Aurivillius and Dion–Jacobson (DJ) phases have been widely explored as Pb-free alternatives, Pb-based layered perovskites remain underdeveloped. In particular, the DJ-type layered compound $CsPb_2Nb_3O_{10}$, first reported in 1988, has yet to be established as a ferroelectric material, despite its promising crystal structure [1]. Notably, $CsPb_2Nb_3O_{10}$ can be readily exfoliated into monolayer nanosheets of $Pb_2Nb_3O_{10}$ [2], offering opportunities for 2D ferroelectricity. In this work, we report for the first time the ferroelectric properties of the layered perovskite $CsPb_2Nb_3O_{10}$ and its exfoliated nanosheets [3,4]. This work expands the design landscape of layered ferroelectrics and underscores the impact of dimensional reduction on polarization stability in 2D systems.

Experimental Procedures

The layered perovskite $CsPb_2Nb_3O_{10}$ was synthesized by solid-state reaction. The structural and morphological characteristics were determined by XRD, SEM-EDS, and Raman measurements. Bulk ferroelectric behavior was confirmed by polarization–electric field (P–E) hysteresis loops and strain–electric field (S–E) curves. For ultrathin studies, the bulk system $CsPb_2Nb_3O_{10}$ was exfoliated into monolayer nanosheets by exchanging the interlayer cations Cs^+ with H^+, resulting in the extended interlayer distance, followed by intercalation with TBA^+ and mechanical shear from handshaking. The topography and height of the nanosheets were observed by AFM measurement, while the typical ferroelectric behavior was characterized by PFM measurements.

Results and Discussion

$CsPb_2Nb_3O_{10}$ crystallizes in a tetragonal system with a polar space group *P*4*mm*, as confirmed by both single-crystal and powder XRD analyses. SEM reveals a typical plate-like morphology. The spontaneous polarization was estimated as 7.93 μC cm^{-2}, with a Curie temperature of 260 °C. Exfoliated nanosheets exhibit a thickness of 1.8 nm, corresponding to a single perovskite layer. PFM measurements display a characteristic butterfly-shaped amplitude–voltage loop and a ~120° phase reversal, indicating robust ferroelectricity. Additionally, PFM lithography with a box-in-box bias reveals a distinct phase contrast reversal, further confirming reversible polarization switching. These results deepen our understanding of ferroelectricity in layered perovskites and highlight the potential of 2D ferroelectric materials.

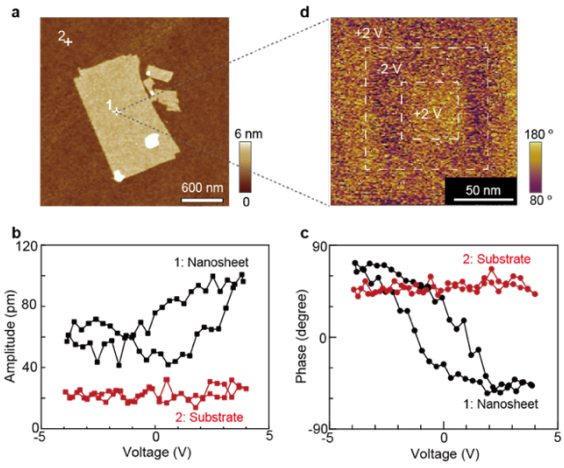

Figure 1. PFM measurements of $Pb_2Nb_3O_{10}$ nanosheet. (a) AFM image of a $Pb_2Nb_3O_{10}$ nanosheet on a Pt substrate. (b) PFM amplitudes and (c) phase signals from the nanosheet and the Pt substrate. (d) PFM lithography taken after writing a box-in-box pattern with reversed DC bias.

References

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