Direct Visualization of General Ferroelasticity in Lead Halide Perovskites

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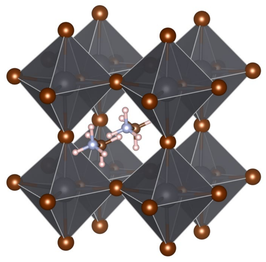
Introduction

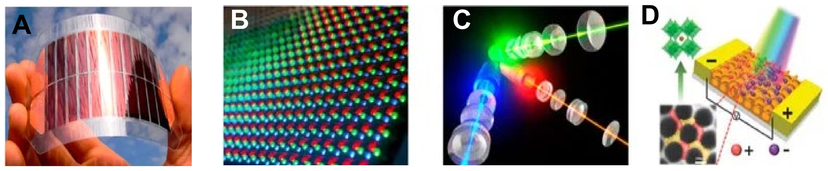
Structure of lead halide perovskites (LHPs)



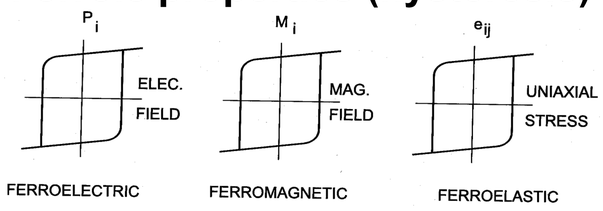
ABX_3

A ($CH_3NH_3^+$, Cs^+)
B (Pb^{2+})
X (I^-, Br^-, Cl^-)

Applications



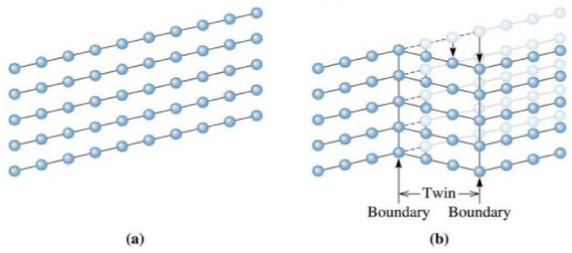
Ferroic properties (hysteresis)



Definition of ferroelasticity

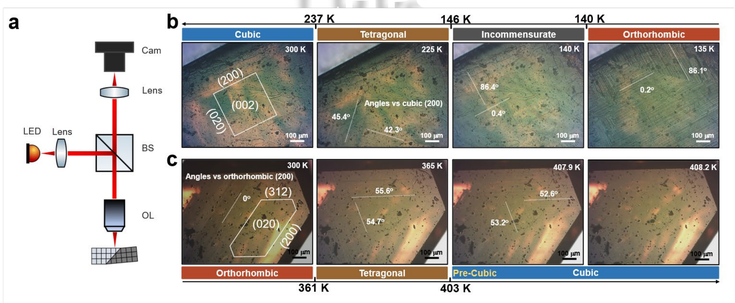
When **stresses** are applied to a ferroelastic material, one observes a highly non-Hookian **strain-stress** curve

Ferroelasticity at the microscopic level



- Applied stress induces **twinning**
- Coherent switching of twining
- Atomic or molecular rearrangement
- Lattice correspondence at the boundary

Ferroelastic phase transition in LHP

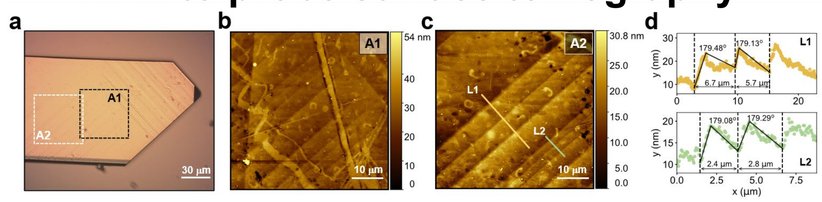


Imaging without polarizing optics!

Origin of domain walls' optical contrast

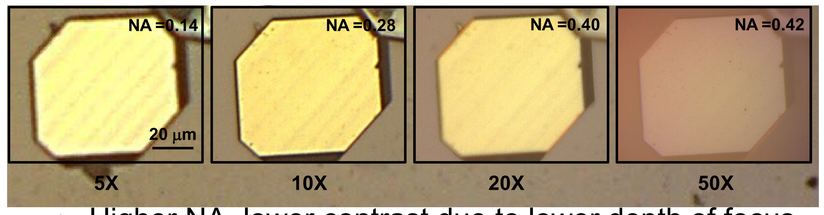
Surface or bulk feature?

AFM to probe surface tomography



- Correlated well with optical contrast
- 10 nm height difference
- Not able to generate sufficient contrast

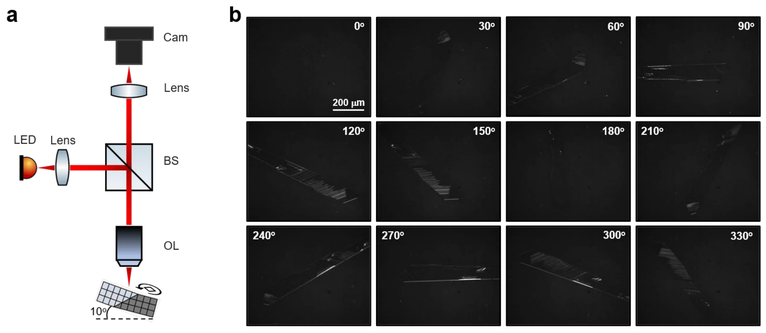
Numerical aperture (NA) dependent imaging



- Higher NA, lower contrast due to lower depth of focus

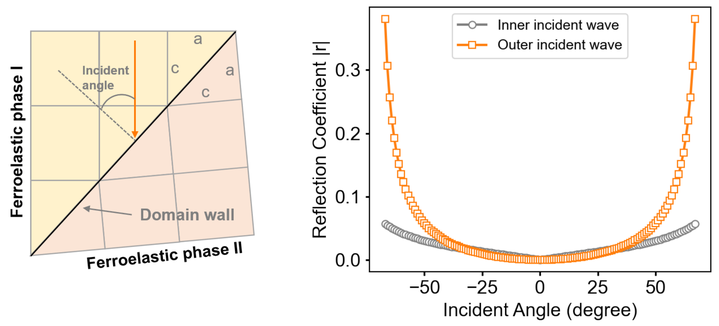
$$d_{\text{tot}} = \frac{\lambda \cdot n}{\text{NA}^2} + \frac{n}{\text{M} \cdot \text{NA}} e$$

Dark field imaging to probe crystal bulk



- Surface reflected light: directed out
- Clearly observed domain walls
- Reflection comes from domain walls within crystal bulk

Reflection coefficients at the domain wall

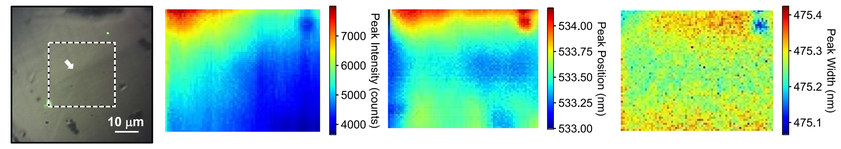


Origin of domain walls' optical contrast

Reflection at the domain walls within crystal bulk

Impact on emission

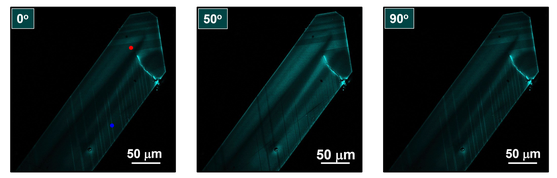
One-photon photoluminescence (1PPL)



- **532 nm** excitation:

  Near bandgap, shallow penetration, surface property
- **Optically benign**
- Match with previous report

Two-photon photoluminescence (2PPL)

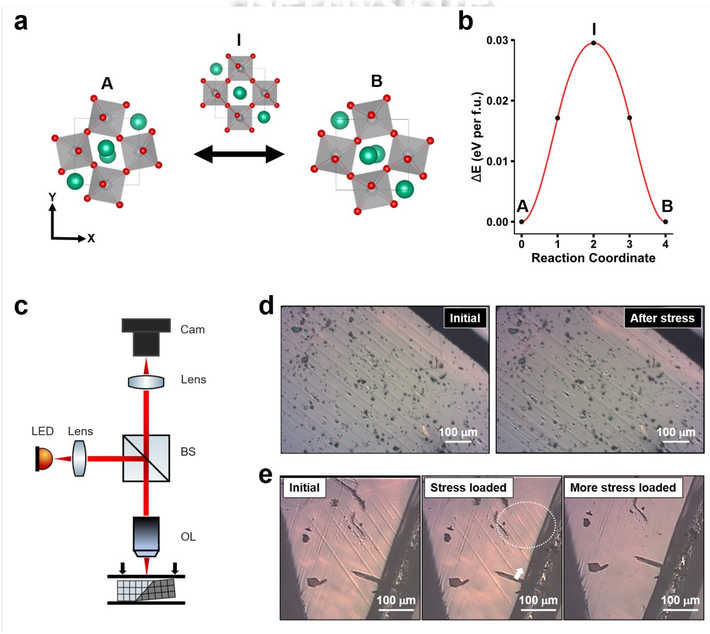


- **800 nm** excitation:

  Far below bandgap, deep penetration, bulk property
- **Difference observed in emission!**
- Photocycling effect & waveguide effect

Domain wall impacts emission!

General ferroelasticity in halide perovskites



General ferroelasticity confirmed

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References

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2. *J Opt Soc Am* **1995**, *12* (9), 2048.
3. *Annu Rev Mater Res* **2012**, *42* (1), 265–283.