Local Raman spectroscopic study of BiFeO$_3$ strained states

YEN-CHIN HUANG$^1$, YI-CHUN CHEN$^1$, FENG-NAN CHU$^1$, WEN-I LIANG$^2$, HSIANG-JUNG CHEN$^2$, YING-HAO CHU$^2$

$^1$Department of Physics, National Cheng Kung University, Tainan, Taiwan

$^2$Department of Material Science and Engineering, National Chiao Tung University, Hsinchu, Taiwan

APS March Meeting 2012
Outline

- **Introduction**
- **Experimental methods**
  AFM + Raman scattering system
- **Results and discussion**
  Domain structure
  Phase transition in different thicknesses and temperature
  Electric controlled strained states in local area
- **Conclusions**
The significant change of physical properties are usually observed in the perovskite materials with mixed phase.

**BiFeO$_3$ Multiferroics**

$T_N \sim 643K$

$T_C \sim 1103K$


AFM + Raman system

Experiment methods

Sample rotated 45°

Virtual energy level

1st excited vibrational state

Ground state

Rayleigh Anti-stokes

hv₀

hvₘ
Results and discussion

In-plane polarization

[Images of various polarizations at angles 180°, 135°, 90°, 45°, 0°, -45°, -90°, -135°, -180°]

[Diagrams showing crystal orientations [110] and [100]]
Results and discussion

Phases in different thickness

![Graph showing Raman shift vs. intensity for different thicknesses with images of 20 nm, 70 nm, 110 nm, 160 nm, and R phases.](image)

![Phase transition diagrams for different thicknesses.](image)
Results and discussion

Phase transition with temperature

![Graph showing Raman shift (cm⁻¹) vs. Intensity (a.u.) at temperatures 25°C, 75°C, 125°C, 150°C, and 175°C. Diagram illustrating in-phase transitions at different temperatures.]

Intensity (a.u.)

Raman shift (cm⁻¹)

RT <100>

<010>

<010>

In-phase

In-phase
Results and discussion

In-situ Raman measurement

Intensity (a.u.)

Raman shift (cm\(^{-1}\))

Original state

12 μm x 12 μm

T phase
Results and discussion

![Graph showing Raman shift vs. intensity for Original state and T phase.](image)

Intensity (a.u.) vs. Raman shift (cm\(^{-1}\))

- Original state
- T phase

12 μm x 12 μm
Results and discussion
Results and discussion
Conclusion

• The spectrum changed obviously in the thickest sample meant the change of the crystal symmetry.
• The peak \( \sim 360 \text{ cm}^{-1} \) disappeared around 150 °C. The phase transition correlated to the in-plane polarization rotated from [100] to [110].
• In-situ measurement could easily distinguish the T-like and R-like phase.
• The c axis vibrated peak \( (230 \text{ cm}^{-1}) \) was shifted to lower frequency in stressed states.
• The peak near 360 cm\(^{-1}\) was related to the magnetoelectric coupling. It shifted to higher frequency in relaxed state.
Thank you for your attention.