Nanoscale Analysis of Conductance Switching Dynamics and Current Hysteresis in $(GeTe)_2$-Sb_2Te_3 Superlattice Films Using Scanning Probe Methods

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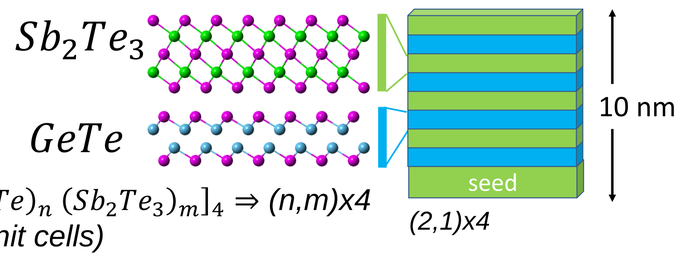
Motivation

Nanoscale evaluation of 2D phase change materials, i.e. chalcogenide superlattices made of *ferroelectric* $GeTe$ and *topological insulator* Sb_2Te_3 layers, **for use in phase-change memory, thermoelectric and magnetoelectric devices.**

[Adv. Mater. Interfaces ***1*** *(2014) 1300027]*

Superlattice (SL) structure

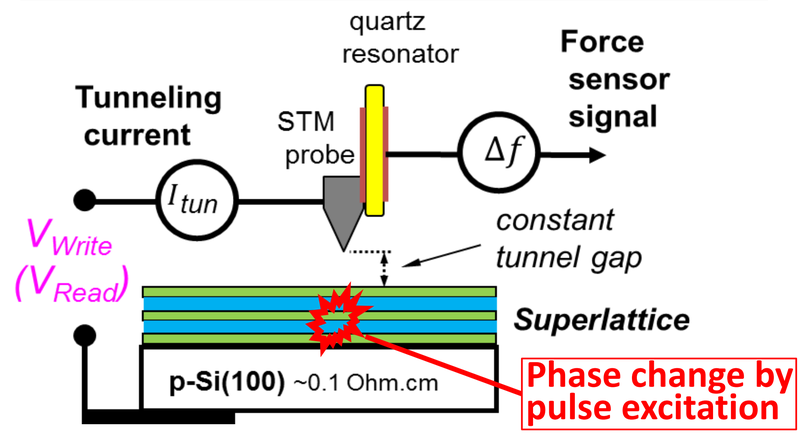


$[(GeTe)_n\,(Sb_2Te_3)_m]_4 \Rightarrow$ (n,m)x4 *(in unit cells)*

SL-A: seed layer and SL were deposited at 230°C.

SL-B: seed layer was grown at RT+annealing@230°C, and SL was deposited at 230°C.

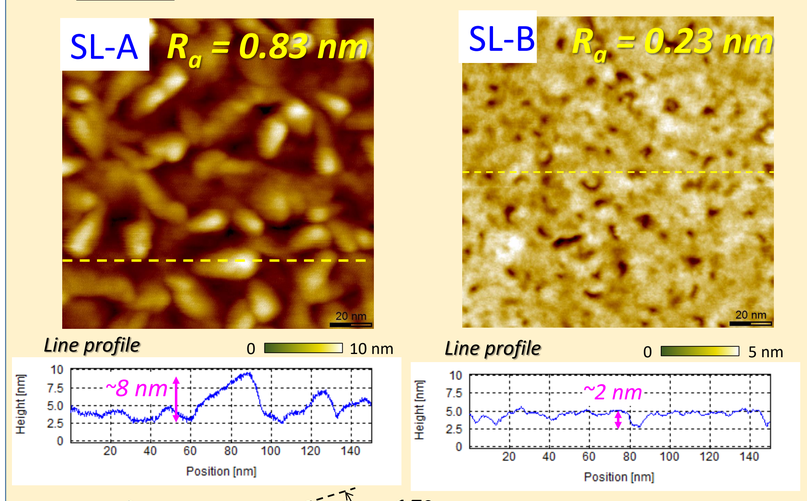
Integrated STM/AFM system



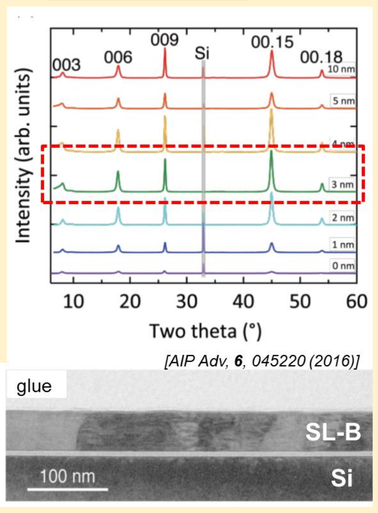
SL Film Structure

[Jpn.JAP ***54****, 04EK02 (2016)]*

AFM



XRD/TEM

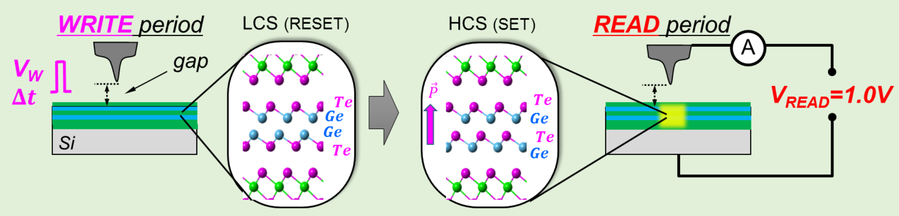


[AIP Adv, ***6****, 045220 (2016)]*

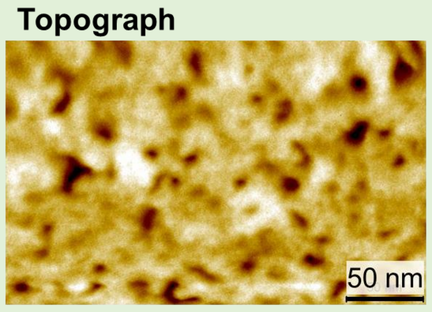
- **Large grains size** ~30 …100 nm
- **Uniform** crystal grain **orientation**

Initial transverse $R_\perp \sim 4.8\ k\Omega/cm^2$ (SL-A) and $\sim 4.2\ k\Omega/cm^2$ (SL-B)

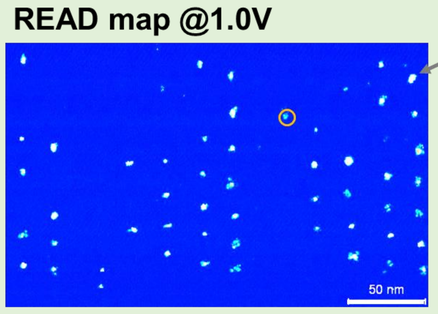
Conductance Switching by Pulse Voltage



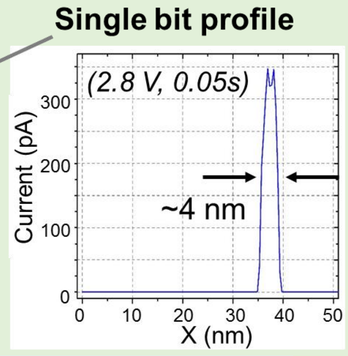
Topograph



READ map @1.0V



Single bit profile



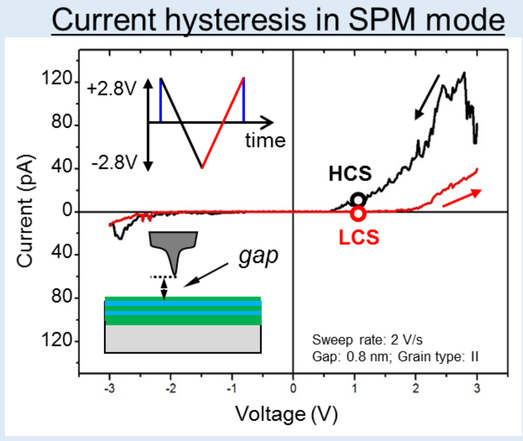
Morphology change **< 0.5 nm**; **OFF-ON** current **> 300**.

Key advantages :

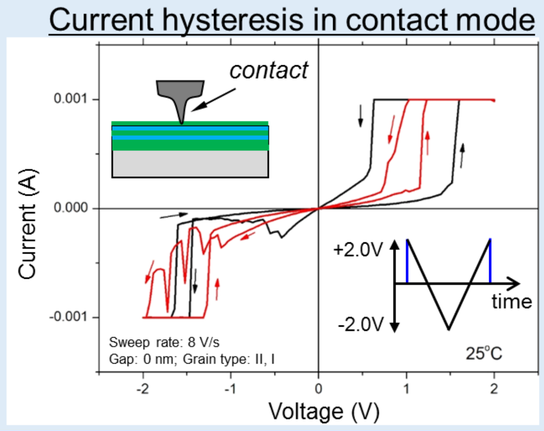
- *Stress-free* measurements in the non-contact mode,
- Easy *tuning* of electric field strength and injection current,
- Observe *temporal change* during the phase transition at nanoscale.

Current Hysteresis

Current hysteresis in SPM mode

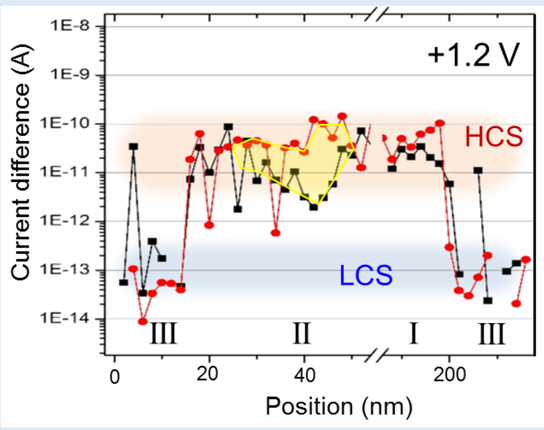


Current hysteresis in contact mode



Bipolar switching of the SL

Position-Dependence of the Hysteresis



Kinds of grain responses

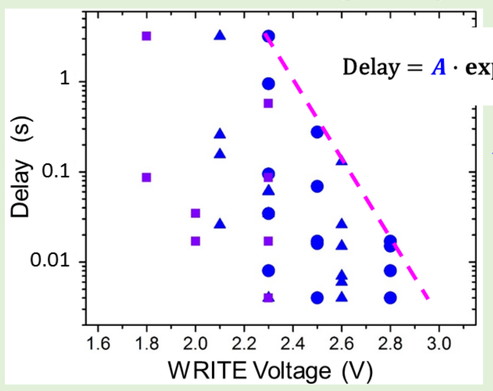
Type (%)	Switching (< 2.5V)	Switch Delay(s)	*Hysteresis loop*
I 52%	Yes	< 10^{-3} *	Yes
II 40%	Yes	0.05...3	Yes
III 8%	No	-- --	-- --

** - time resolution limit*

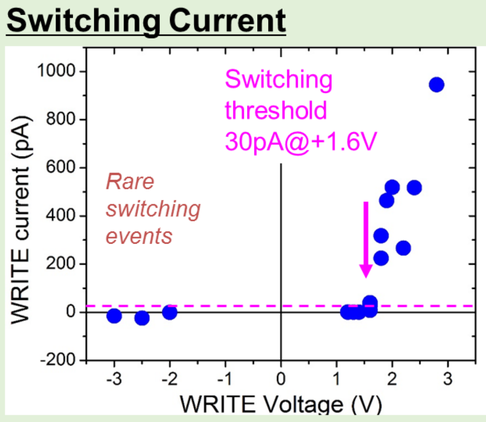
HCS/LCS ratio ~ **10^2 - 10^3**

Statistics

Statistics of Switching Delay



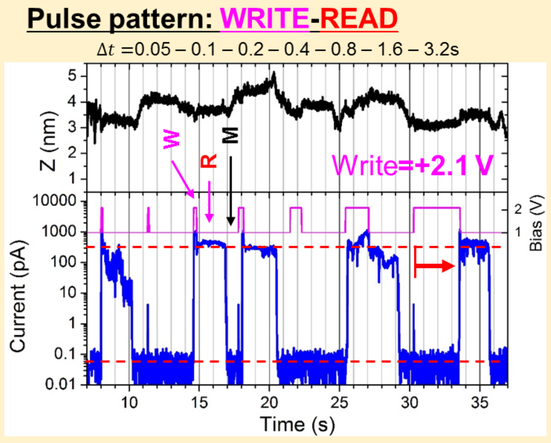
Switching Current



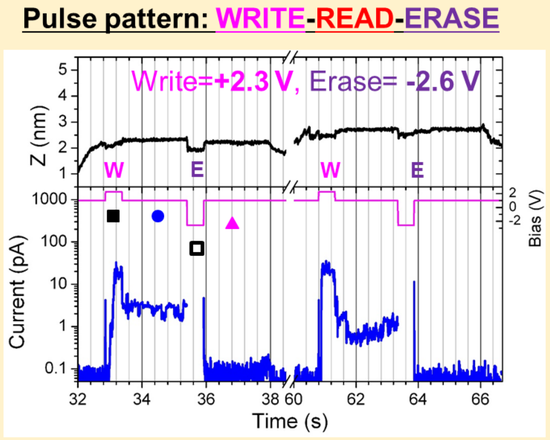
Switching time **>1.2 ps** @2MV/cm; WRITE current **>30 pA**

Conductance Switching Dynamics

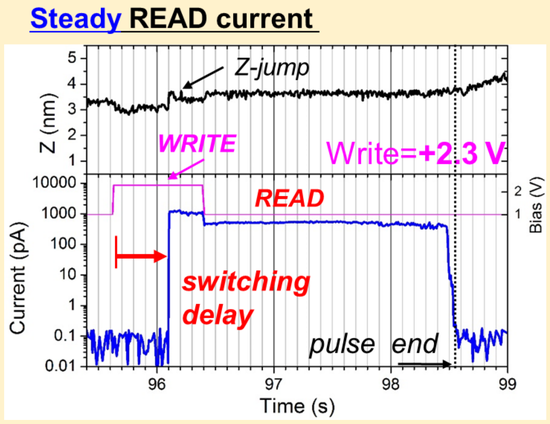
Pulse pattern: WRITE-READ



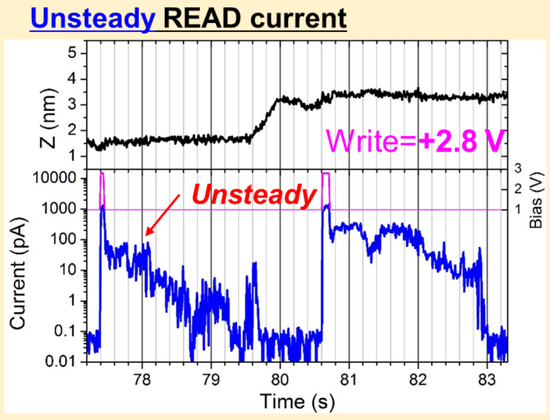
Pulse pattern: WRITE-READ-ERASE



Steady READ current



Unsteady READ current



Summary

- We develop **SPM-based analysis methods** for evaluation of voltage-induced transformation in 2D systems at nanoscale.
- We applied them to examine the conductance switching in **$(GeTe)_2$-Sb_2Te_3** superlattice films.

[Sci. Reports ***6****, 33223 (2016)]*