Bistable switching behavior of anodic porous Alumina on Si substrate

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Outline

- Introduction
- Experimental Result
  - Porous alumina on bulk Al
  - Porous alumina on Si substrate
- Summary

Introduction

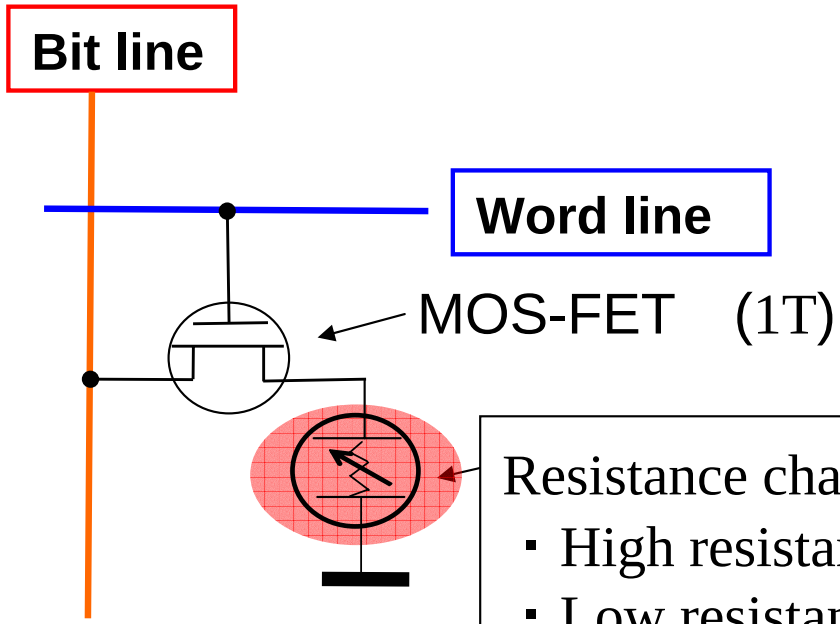
	SRAM	DRAM	Flash	Next generation memory			
				FeRAM	MRAM	PRAM	ReRAM
Cell size	140 F^2	4 ~ 8 F^2	4 F^2	12～25 F^2	20 F^2	4 F^2	4～6 F^2
Speed	H	-	-	H	H	-	H
Non-volatile	-	-	Y	Y	Y	Y	Y
W&R times	$>10^{15}$	$>10^{15}$	10^6	10^9 ～ 10^{12}	$>10^{15}$	?	?
Operating Principle	Interlock circuit with transistor	Electric charge in a capacitance	Electric charge at the floating gate	Ferroelectric ity with DRAM	Magneto resistance	Phase change between crystal and amorphous	Voltage induced resistance change?

Performance ① SRAM: high-speed and durability quality ② DRAM: high-accumulation and durability quality ③ Flash Memory: Nonvolatile and high-accumulation

Next generation memory is required all advantages of ① ② and ③.

Resistance RAM (ReRAM)

- Rresistivity can be electrically switched between high and low resistance states.
- ReRAM is seen as a potential candidate to replace conventional Flash memory and hence to push NVM technology towards the (sub-)22nm technology node.

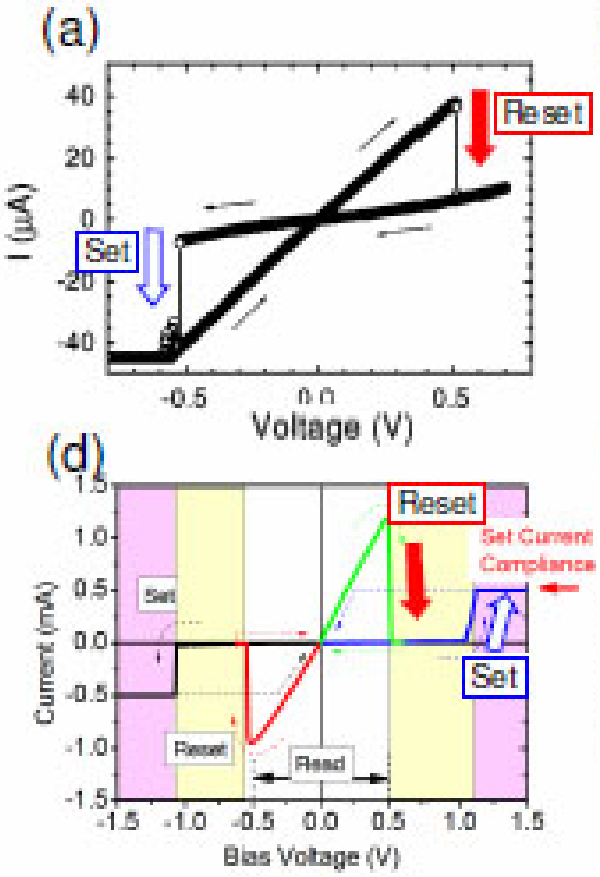


Resistance change resistance (1R)
- High resistance state：「1」
- Low resistance state：「0」

Attributes
–Non-volatile
–High density
–Non-destructive read
–Low voltage and low power

I-V character of ReRAM candidates

From CERC report (Inoue 2004, AIST)



(a) Au/Ti/$SrZr_{0.998}Cr_{0.002}O_3$/$SrRuO_3$

(b) Ag/CeO_2/$La_{0.67}Ca_{0.33}MnO_3$

(c) Ag/$Bi_2Sr_2CaCu_2O_{8+y}$

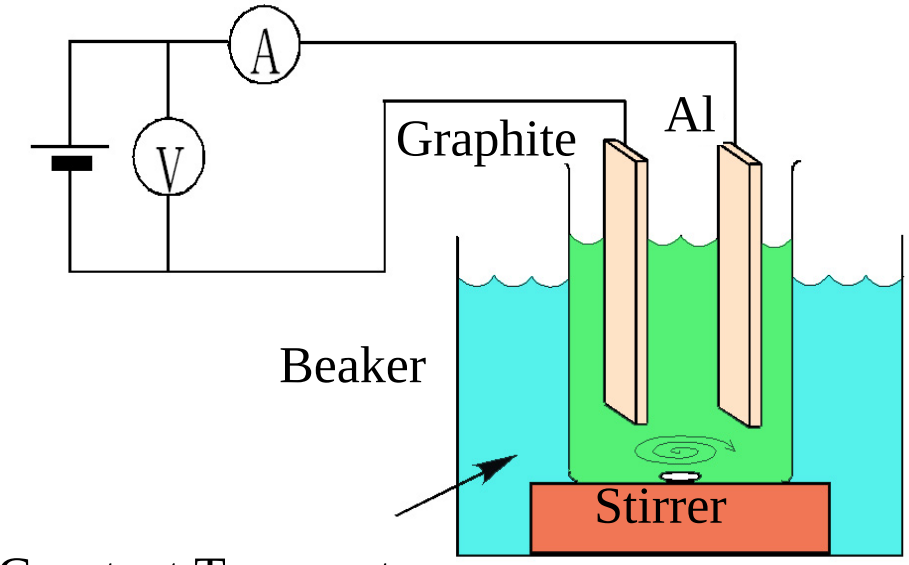
(d) Pt/NiO/Pt

Red: Rare metals

We have developed an anodic porous alumina for ReRAM

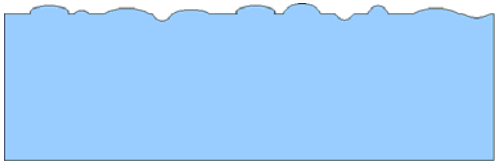
Fabrication of Anodic Porous Alumina

Mediaeval **B**eaker **E**lectrochemistry



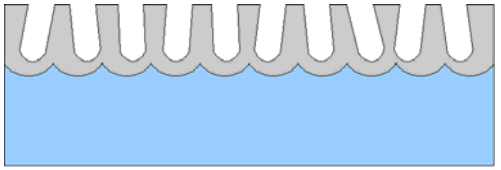
Constant Temperature

Al sheet (99.999%, *t*=0.5mm)

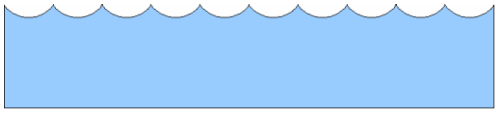


Electrical polishing

Anodizing (Oxalic acid, 0.3M/*l*)



Remove the anodic oxide layer
(Phosphoric acid + Chromic oxide)



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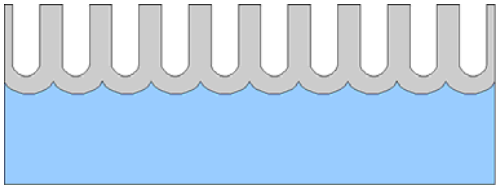
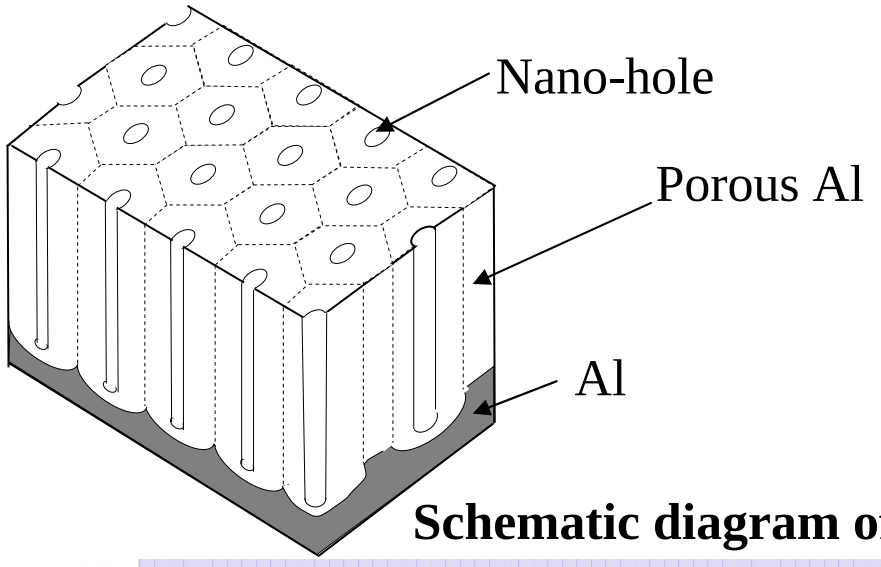
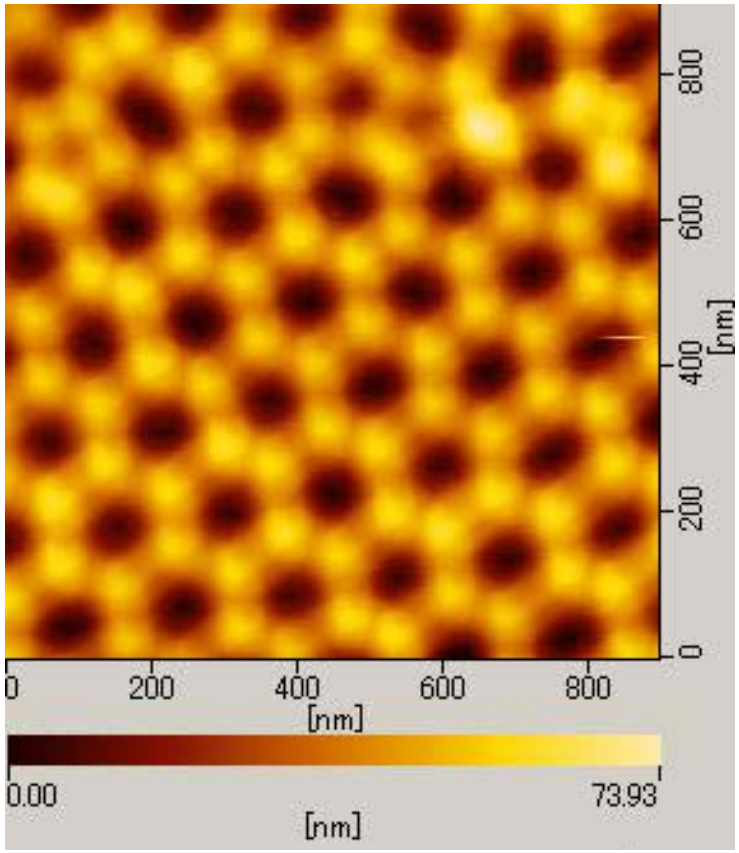
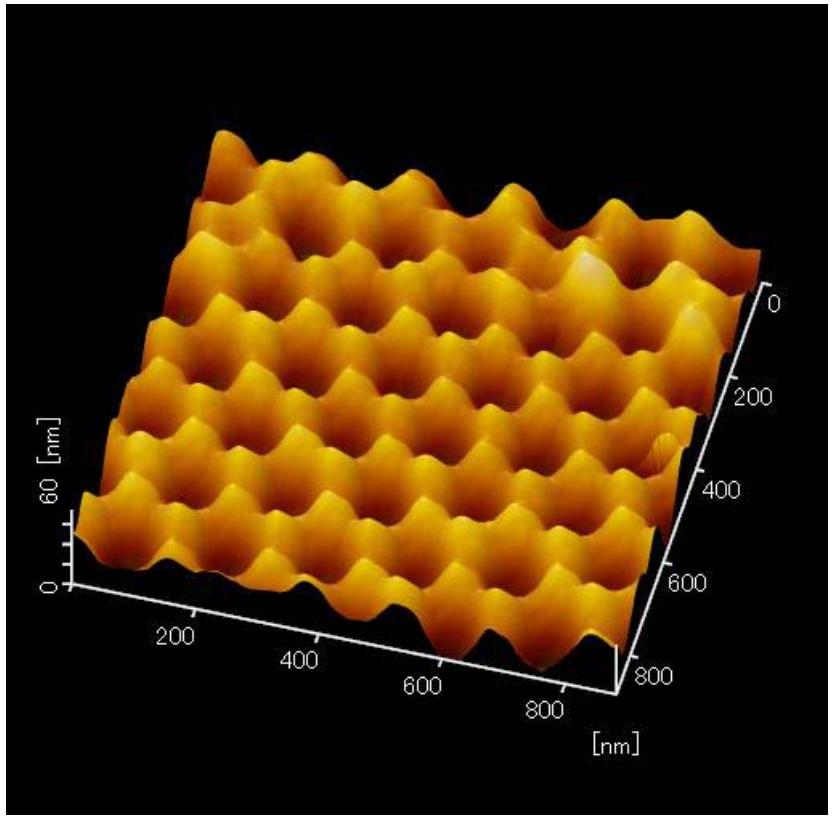




Schematic diagram of porous Al

AFM image of Porous Alumina





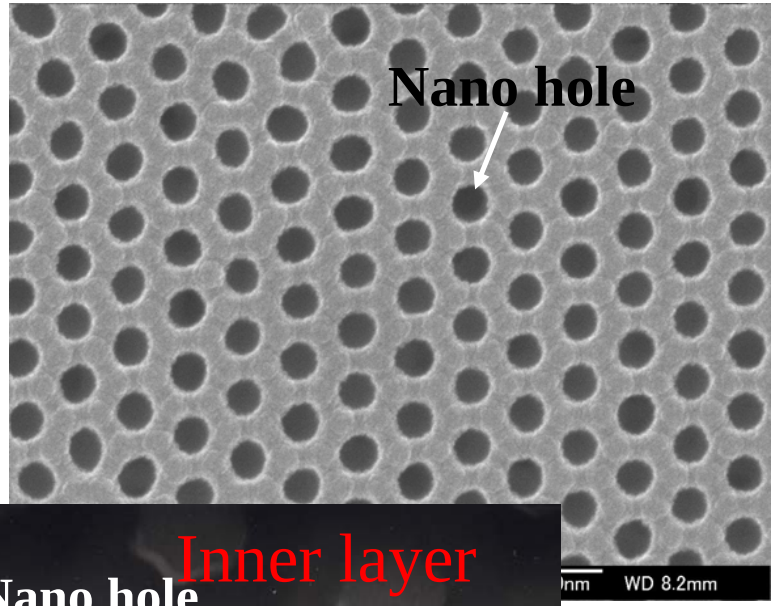
AFM tapping mode images

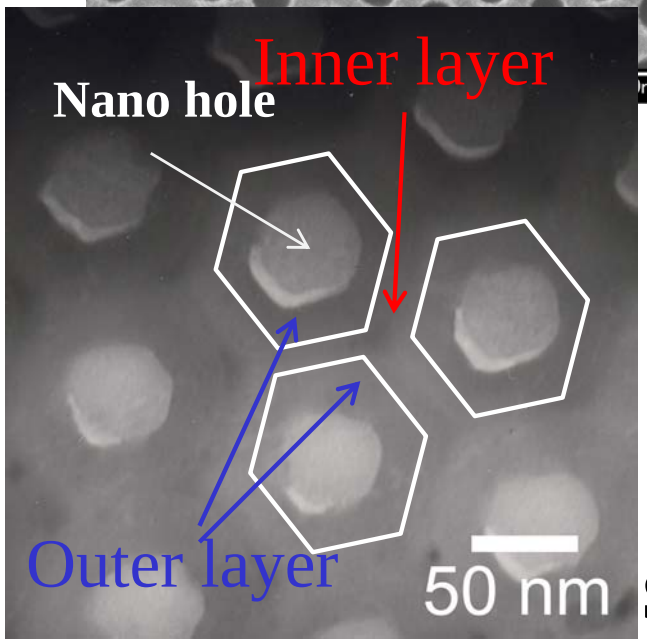
0.3M/l Oxalic acid
40V

Pore diameter : 50nm
pitch : 100nm

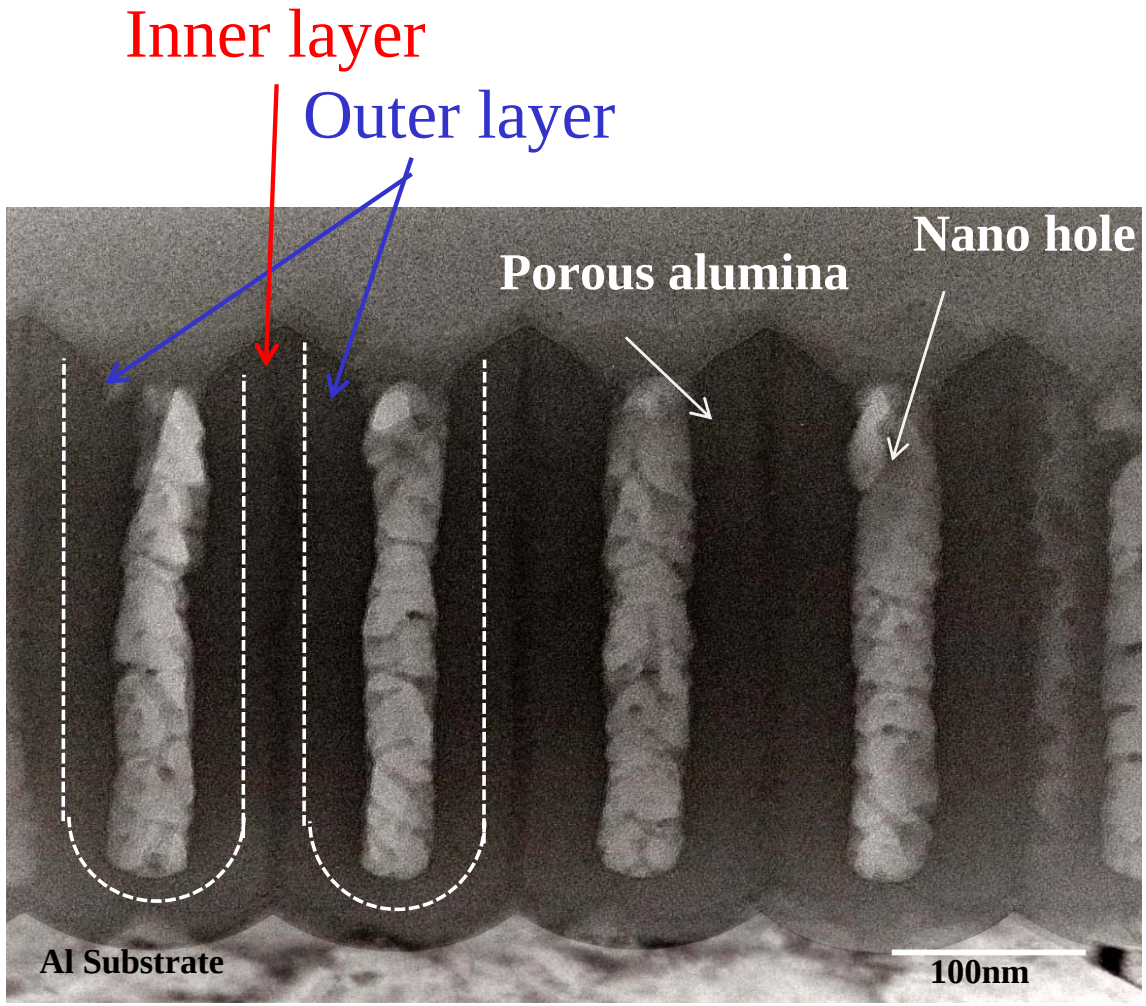
SEM and TEM image of Porous Alumina

Surface SEM image





Surface TEM image

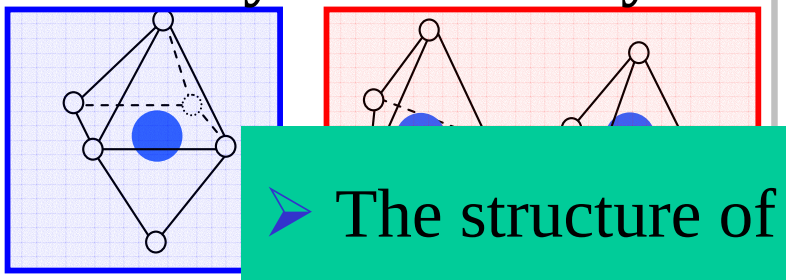


Cross-sectional TEM image

Structural Analysis with NMR

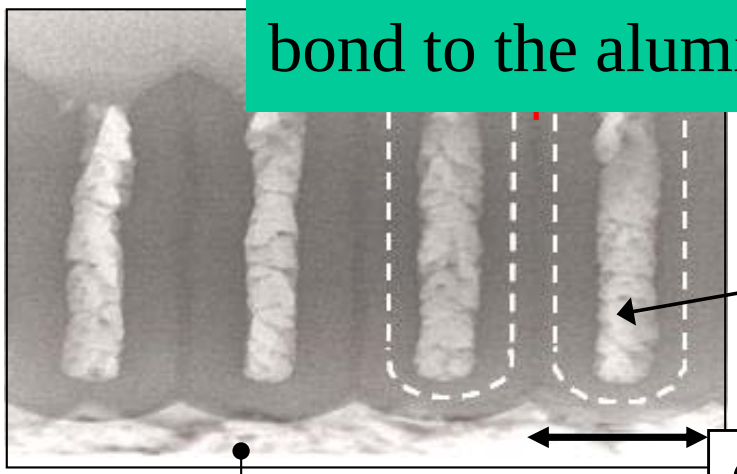
Duplex AlOx

Outer layer **Inner layer**



T.Iijima,...,G.Kido, T.Shimizu,
Chem.Lett. 34, 9 (2005)

- The structure of both layers are amorphous.
- The outer layer contacts the electrolysis solution during the synthesis and water molecules can easily bond to the aluminum atoms.

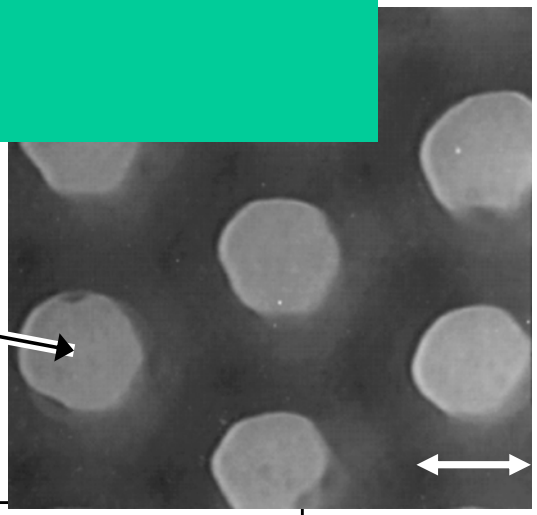


Al

100nm

Cross section TEM

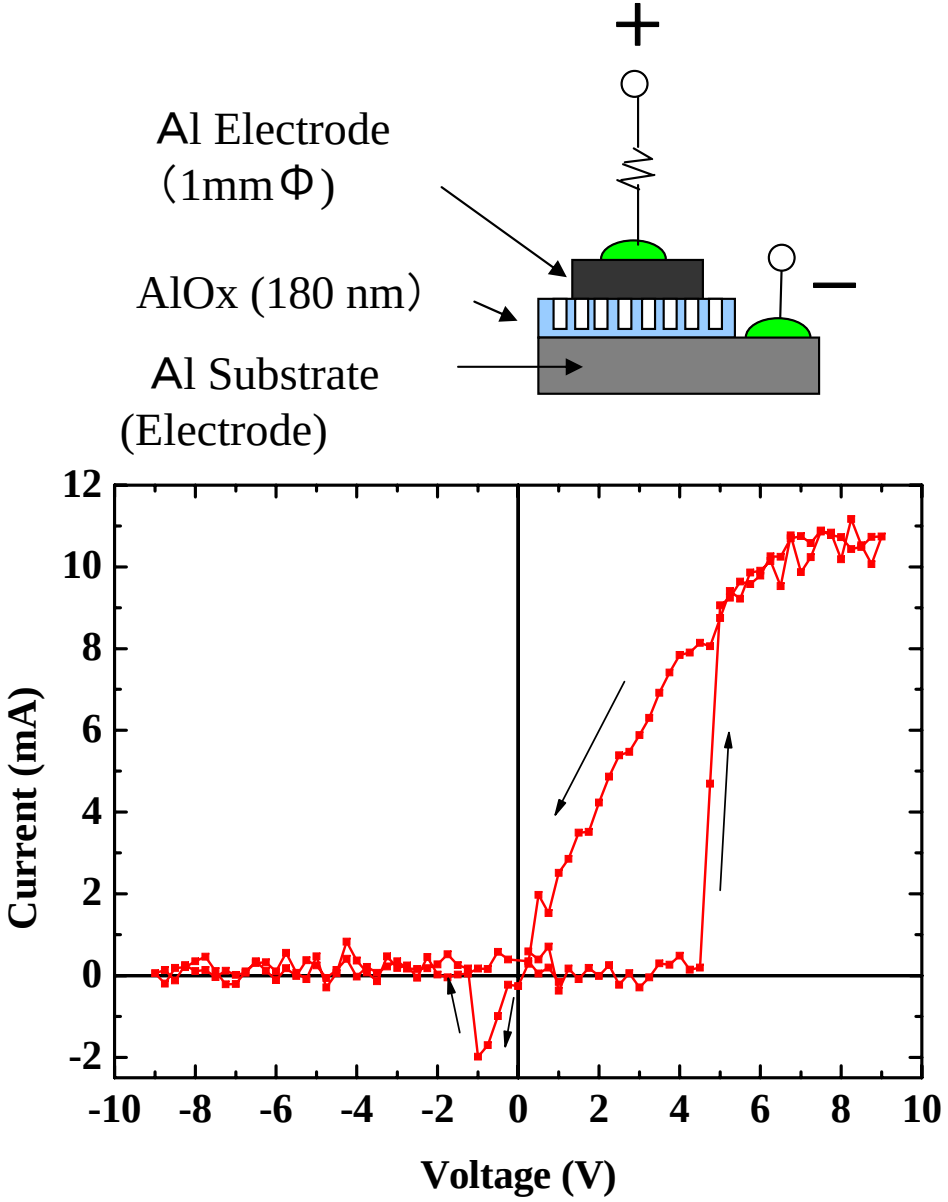
Nano-hole



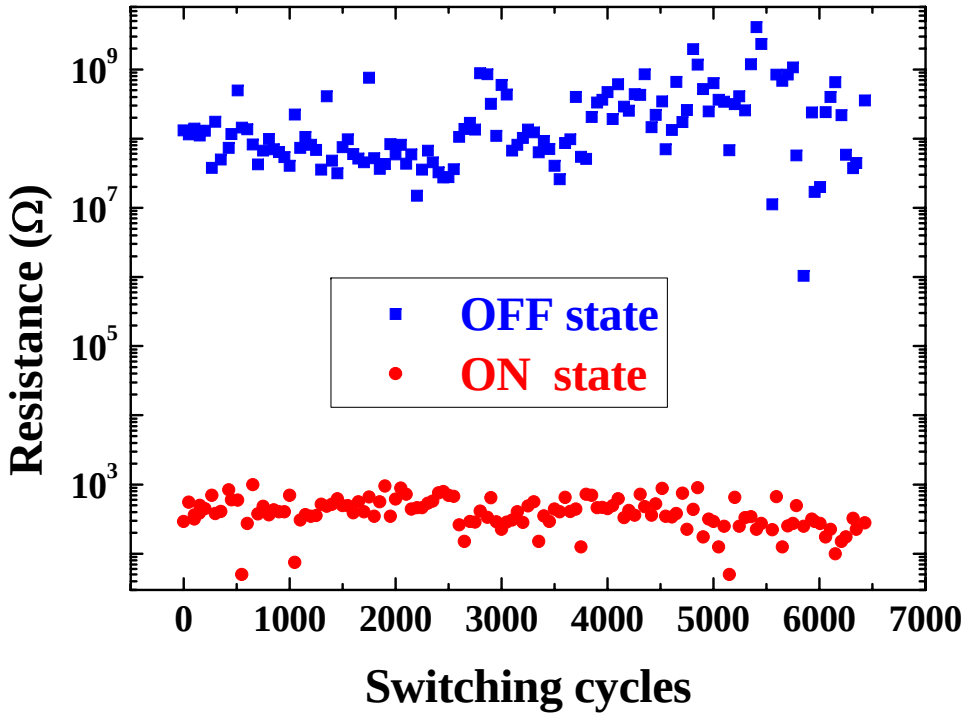
Surface TEM

50nm

Switching Properties of AlOx-ReRAM



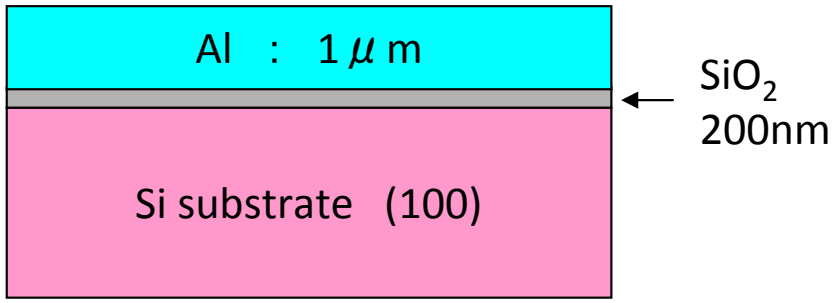
I-V property of AlOx-ReRAM

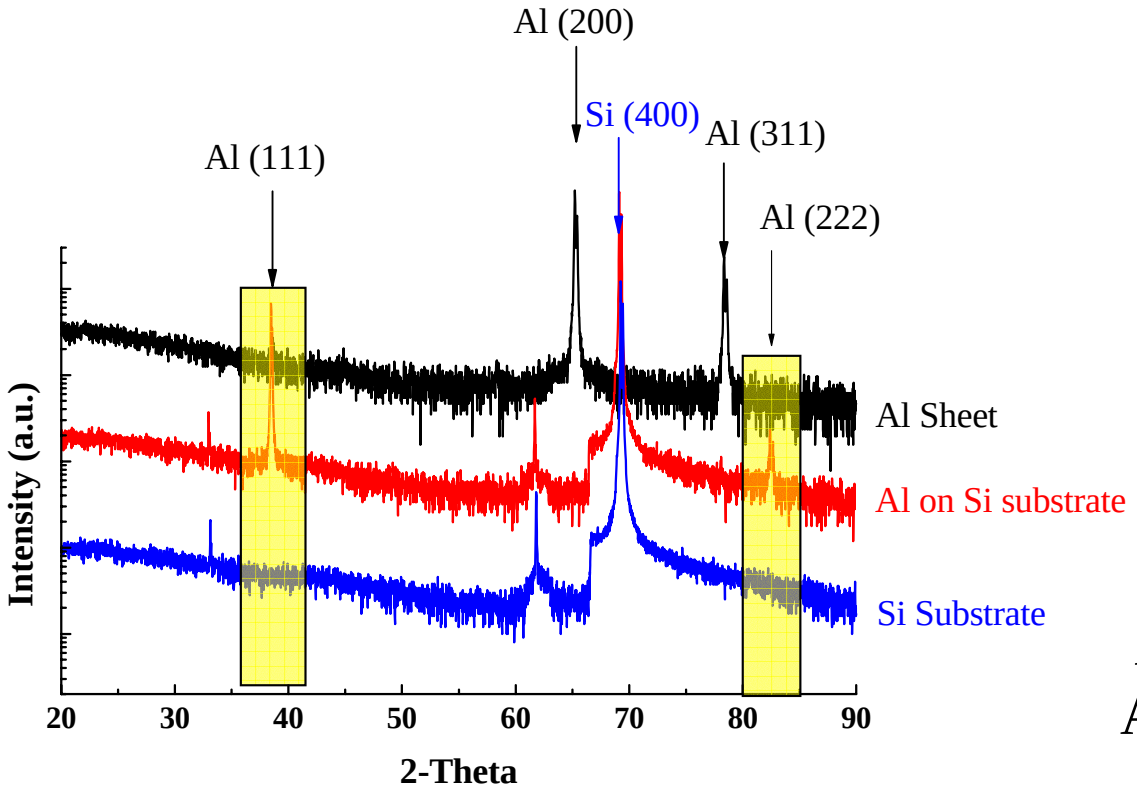


Resistance switching of AlOx-ReRAM

More than **6000** cycles have been demonstrated

Fabrication of Porous Alimina on Si substrate





Electron Beam Deposition

Substrate :

SiO_2 (200nm) / Si (100)

Substrate temperature :

Room temperature

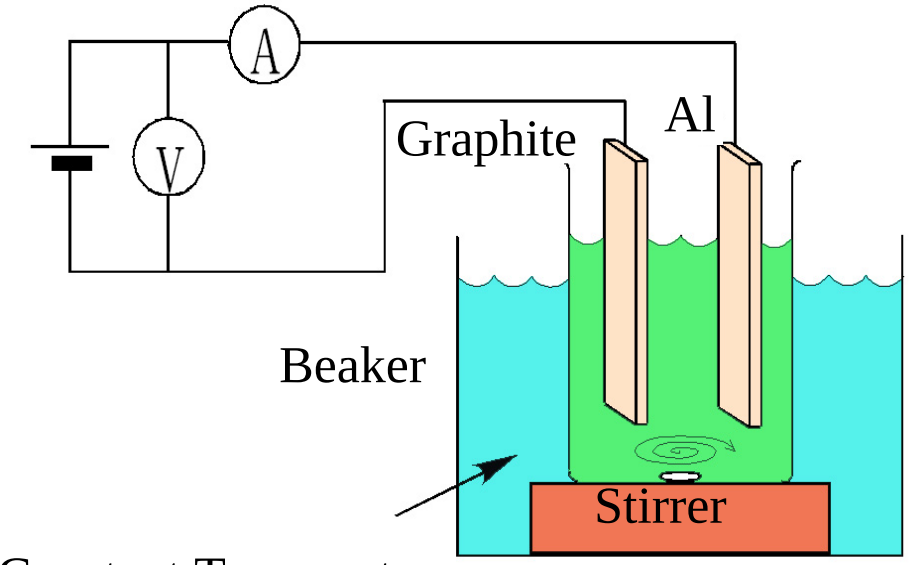
Growth rate :

200nm / sec

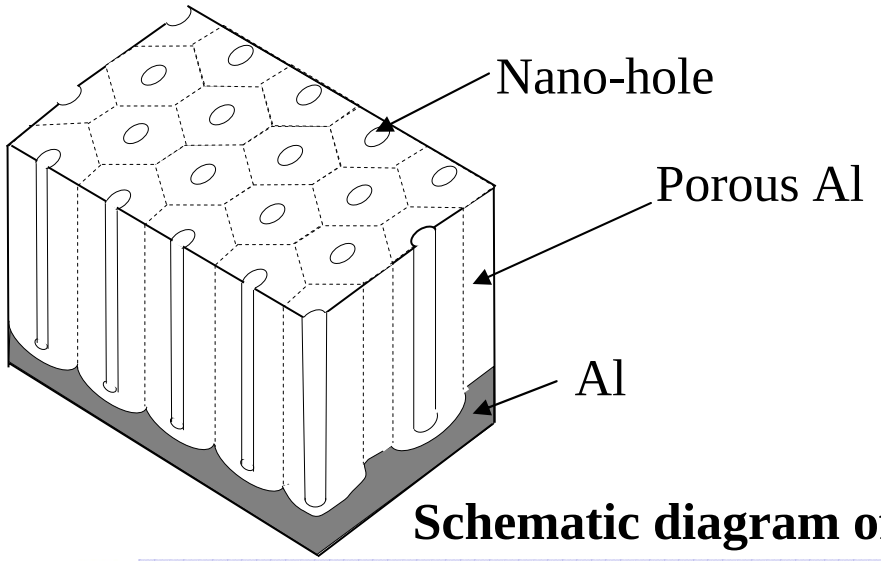
Al thin films are strongly oriented in an Al (111) direction

Fabrication of Anodic Porous Alumina

Mediaeval **B**eaker **E**lectrochemistry



Constant Temperature



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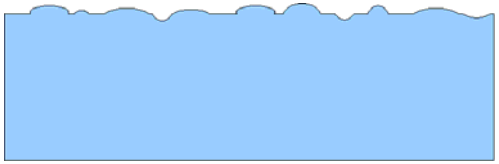

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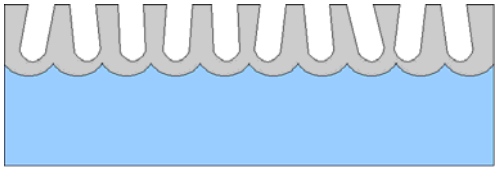

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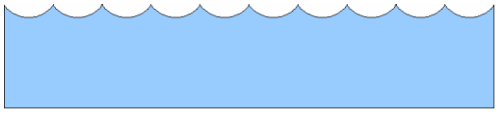

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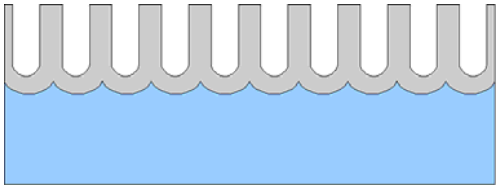
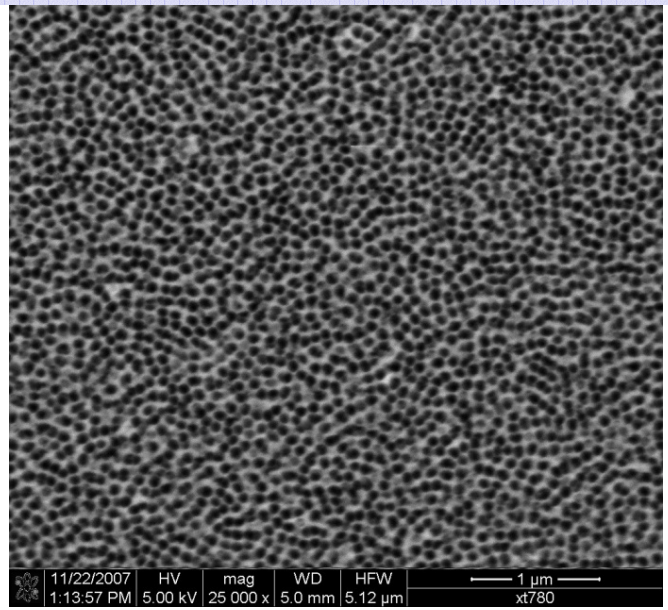
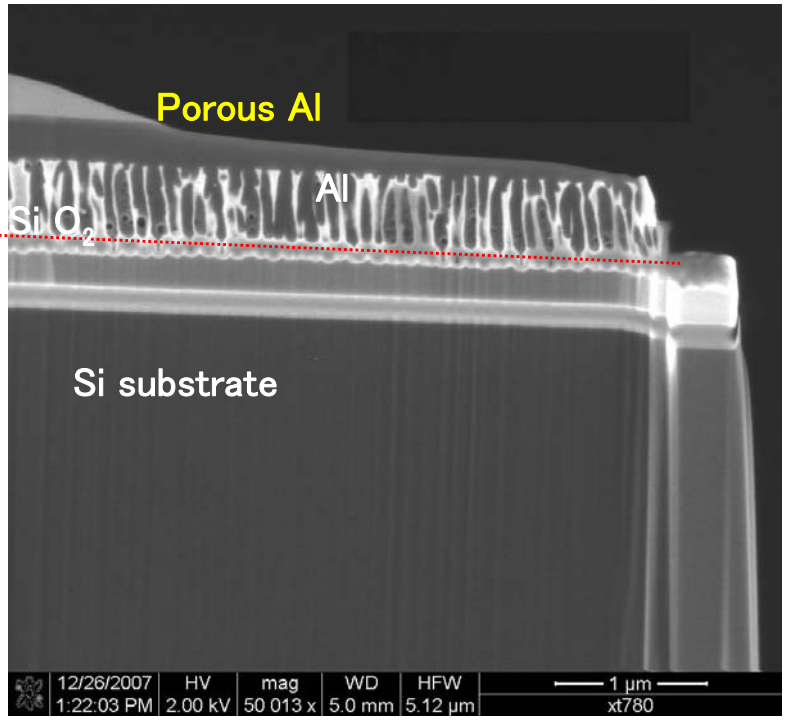


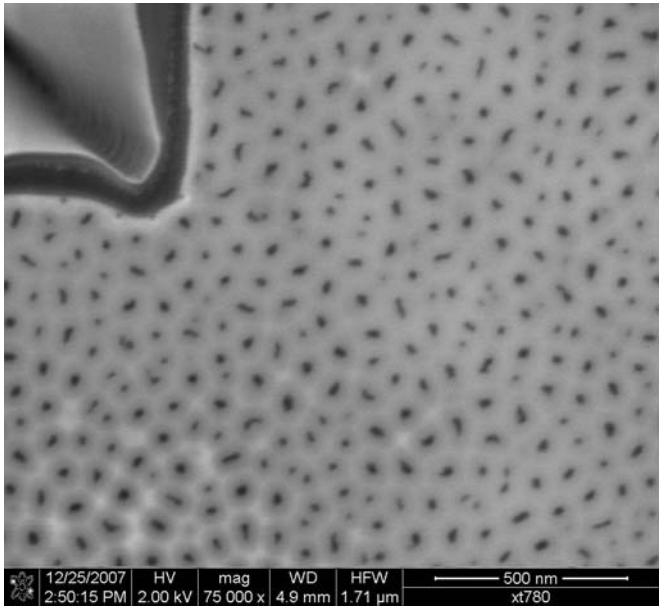
SEM image of the sample



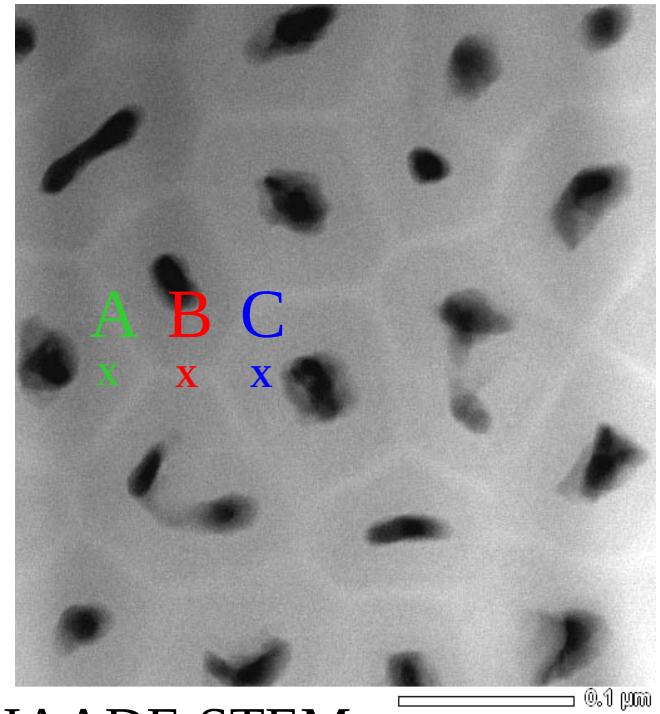
Surface SEM image

Cut with FIB

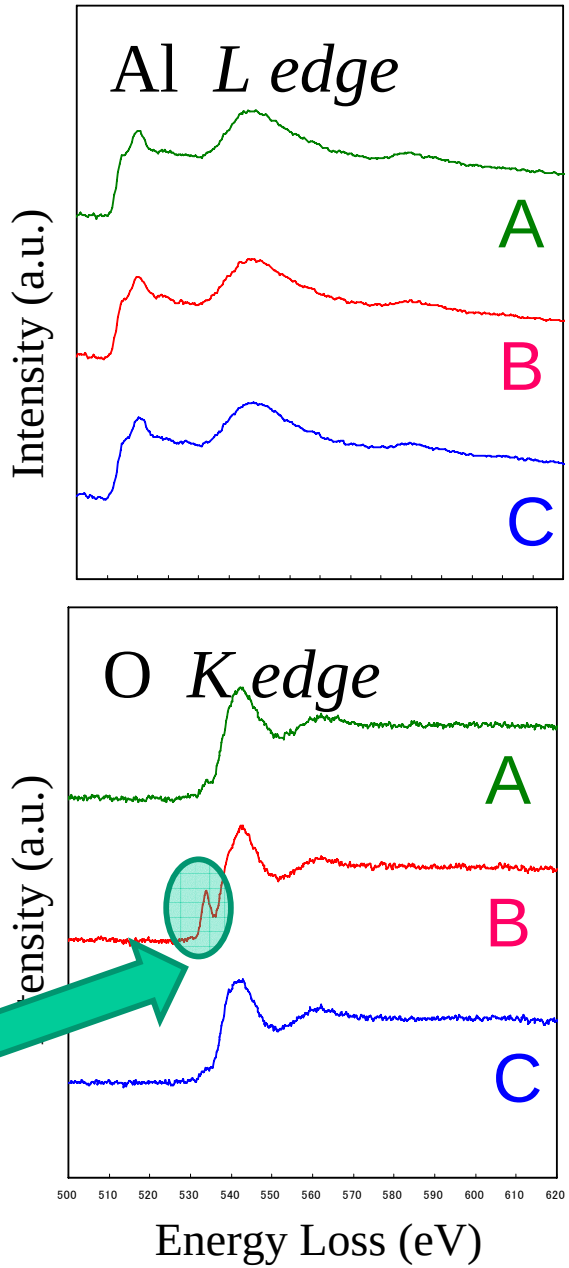




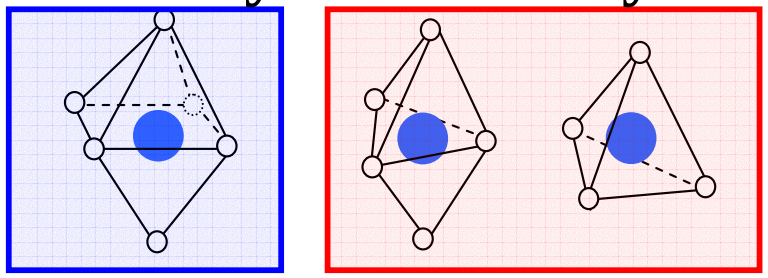
Electron Energy Loss Spectroscopy (**EELS**)



HAADF-STEM



Outer layer **Inner layer**

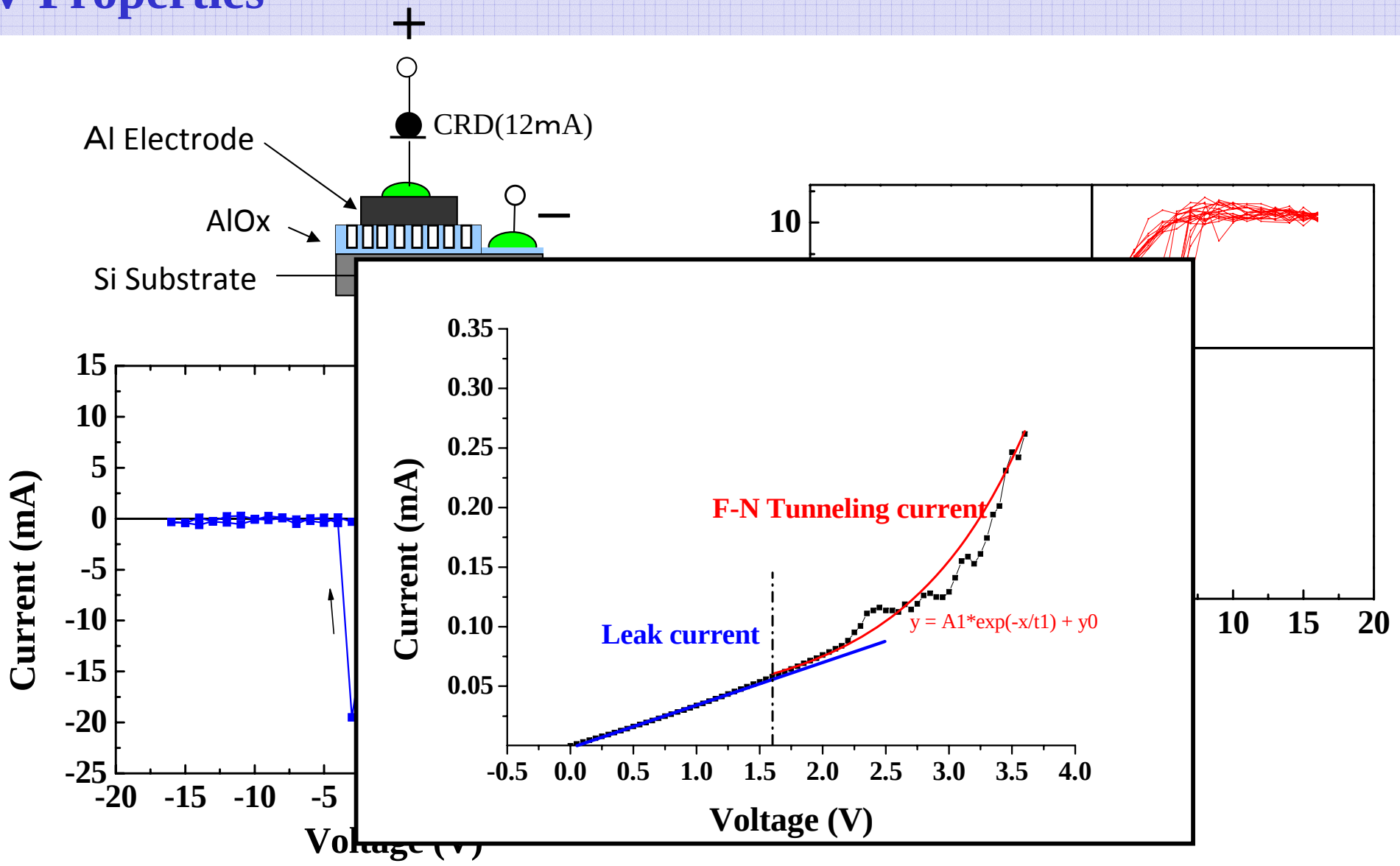


AlO_6 AlO_5 AlO_4

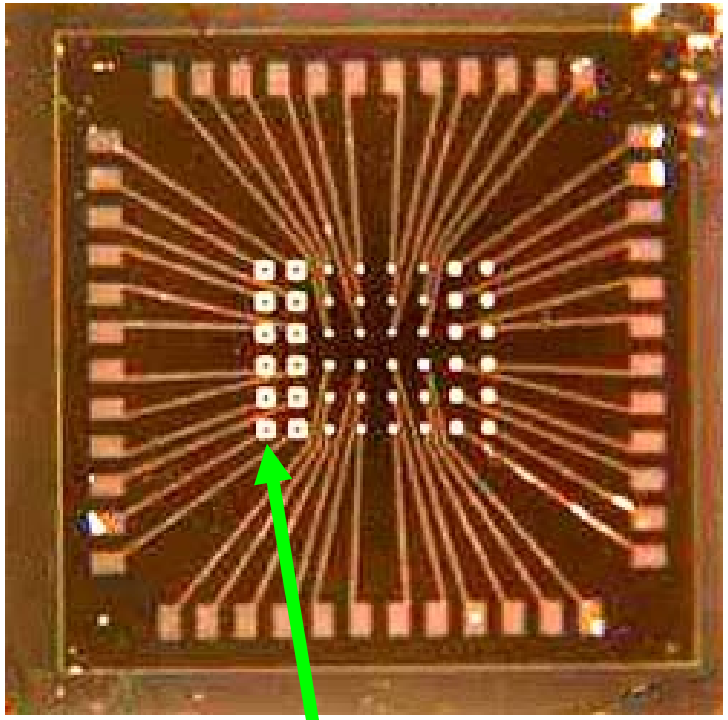
It is considered that it originates in the oxygen defect.

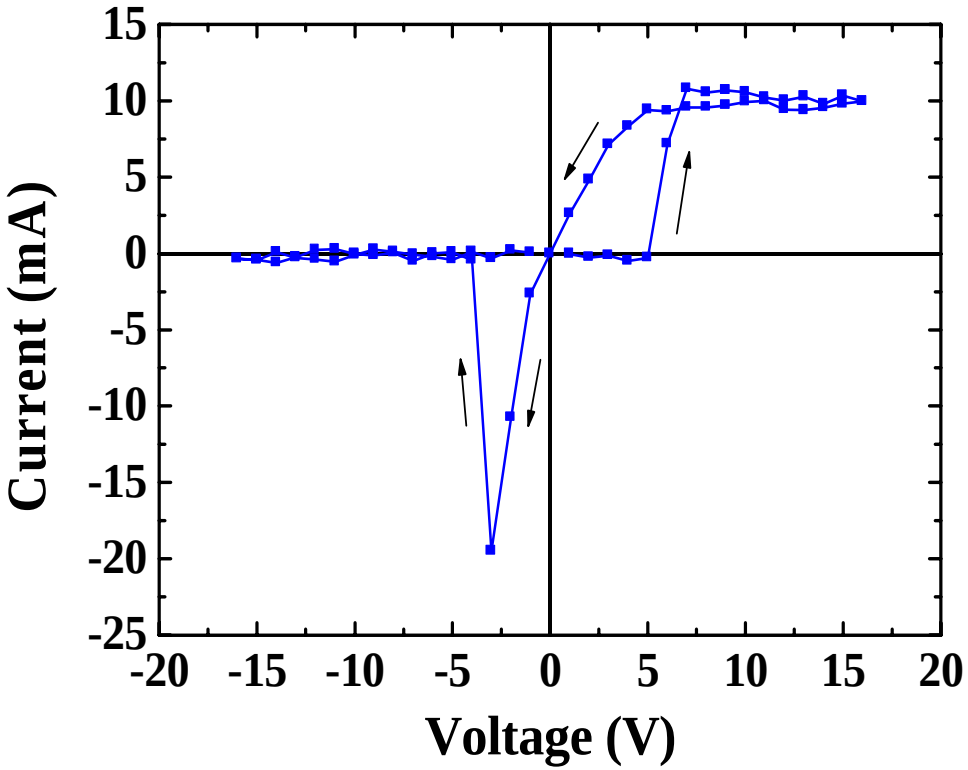
A and C B

I-V Properties



I-V curve of fabricated on Si substrate





AAO on SiO_2/Si

The sizes of the square are 200, 100, 50 and 25 micrometer. The upper electrode is made by Al deposition. The electric current is limited at plus 12 mA by a current limiting diode.

Summary

- We have found a bistable switching effect in anodic porous alumina thin film.
- The set/read/reset/read cycles were repeated more than 6000 cycles.
- We also succeed in fabricating ReRAM cell using anodic porous alumina on Si substrate.
- The current of OFF state is consisted of leak current and Fowler-Nordheim tunneling in low electric field region.

We believe anodic porous alumina is a promising material for a next-generation nonvolatile memory