Observation of Current Paths of Anodic Porous Alumina for Resistive Random Access Memory by Conducting AFM

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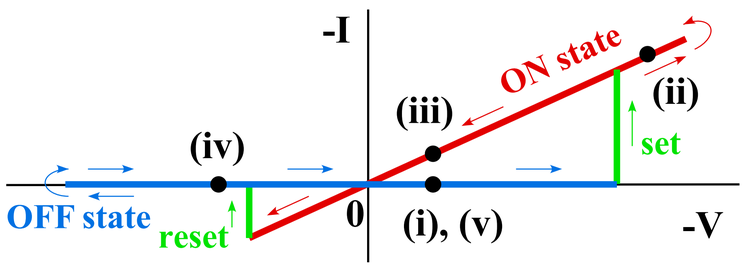
BACKGROUND: Resistive random access memory (ReRAM) using various kinds of oxide materials has been developed recent years. However, mechanisms of their voltage-induced switching effect depend on the materials and they are still not perfectly understood. In addition, knowledge of the mechanism is also important to optimize the ReRAM devices from a viewpoint of application. On the other hand, anodic porous alumina films have a complex structure, and the switching mechanism and current paths are not clear.

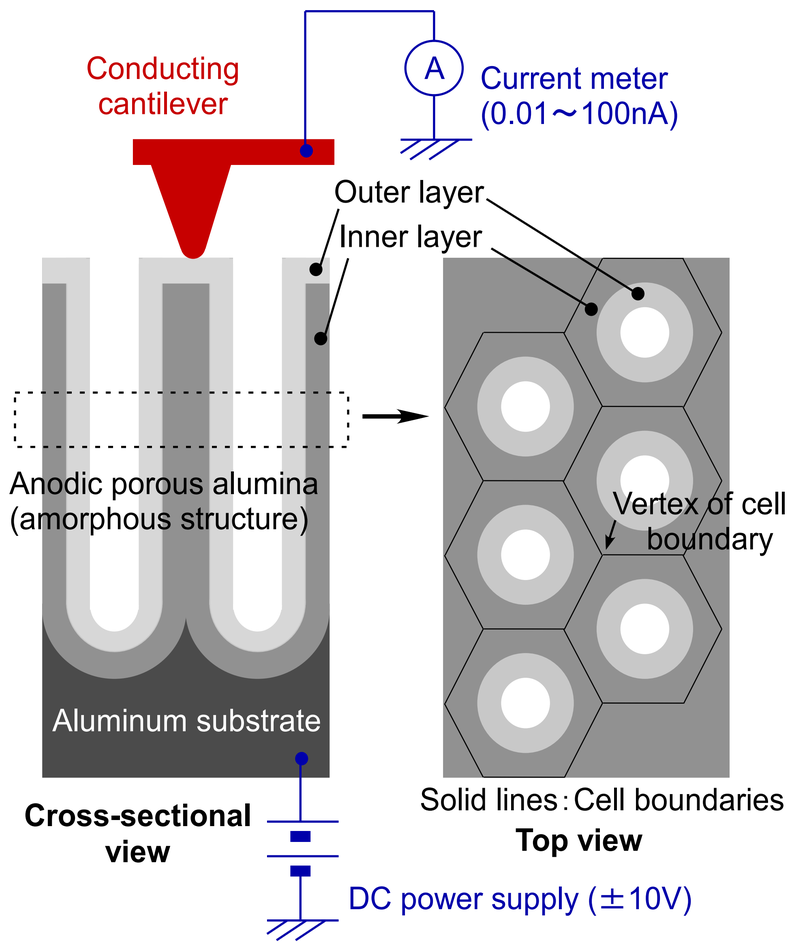
OBJECTIVE: Conducting atomic force microscopy (CAFM) is a powerful technique to observe surface structures and local currents simultaneously. Thus, we would like to confirm the switching effect and to observe terminals of the current paths by CAFM. Information of the conducting path is important to discuss the switching mechanism as a first step.

SAMPLE PREPARATION:
The films were formed by a two-step replication method. 99.99% Al substrate was anodized in an oxalic acid (0.3M/l) solution with a cathode plate (Pt) at 293K for 3h with a constant applied voltage of 40V. Then the anodic oxide layer was removed in a mixture of phosphoric acid (6wt%) and chromic acid (1.8wt%) at 333K. Then the Al specimen was anodized again for 16s. Thickness of the film is about 50nm.

MEASUREMENT PROCEDURE:
(i) a small negative voltage (typically -0.4V) is applied to confirm that there are no current paths initially,
(ii) a negative voltage (typically from -2 to -10V) is applied to change the electrical state from OFF to ON (set),
(iii) the small negative voltage is applied again to observe current paths on the alumina surface,
(iv) a positive voltage (more than +0.4 V) is applied to change the state from ON to OFF (reset),
(v) the small negative voltage is applied again to confirm disappearance of the current paths,
(vi) repeating the procedure from (ii) to (v).



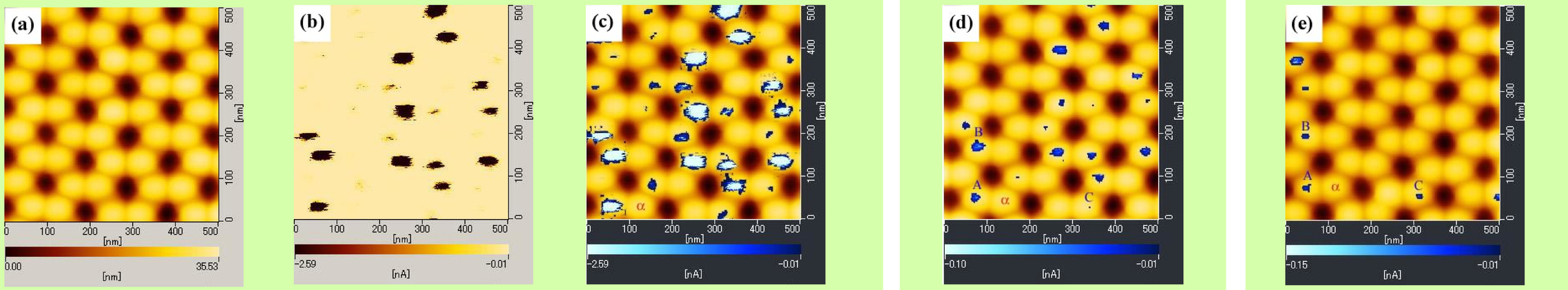
The relationship between the memory effect in an ideal I-V characteristic and measurement points of CAFM for the procedures from (i) to (v).



A schematic diagram of anodic porous alumina film structure and the setup of CAFM measurements.

SEIKO SPI3800N/SPA300HV, Rh or Au coated cantilever, applied force:1.5nN, detection range: 0.01-100nA, scan rate: 0.2-1Hz/x-axis, tip radius: about 30nm.

RESULTS (CAFM images)



(a) surface image **(b)** current image **(c)** synthesized image from (a) and (b) at the first cycle of the procedure (ii)

(d) synthesized image at the first cycle of the procedure (iii)

(e) synthesized image at the second cycle of the procedure (iii)

SUMMARY: We have observed a bi-polar resistive switching effect and the current paths at the vertexes of cell boundaries by CAFM. Repetitive switching was confirmed for a part of the current paths. These results suggest that filaments are formed as the current paths and that a part of amorphous alumina structure and/or composition in the current paths is possibly modified during the switching operation.

ACKNOWLEDGEMENT: This work was executed under a subsidy of Elements Science and Technology Project of the Ministry of Education, Culture, Sports, Science and Technology (MEXT).

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