4C-005-O

Morphology and Conductance Properties of Metal/oxide nanostructures formed by low-voltage anodising of Al/Ta layers

A. Mozalev [1*], A. Plihauka[1], A.W. Hassel[2]

[1] *Belarusian State University of Informatics and Radioelectronics Brovka Str. 6, Minsk, 220013, Belarus*

[2] *Max-Planck-Institut für Eisenforschung (MPIE), Max-Planck Straße 1, 40237 Düsseldorf, Germany*

sasha@nsys.by

hassel@elchem.de

Recent study has shown that anodizing of a thin Ta layer clad with an Al layer (Al/Ta), at potentials 21 to 53 V, results in the formation of metal/oxide nanostructures with unique and useful electrical properties [1]. Further progress in the development of such films is associated with systematic reducing the formation potential, which mainly decides their dimensionality. We have now anodically oxidized the Al/Ta layers at potentials down to as low as 2 V and inspected the films to obtain new insight into the growth and conductance behavior of these extraordinary low-size nanostructures.

Initial samples were 8-nm Ta layers followed by 500-nm Al layers sputtering-deposited onto oxidized Si wafers. The Ta/Al systems were anodized in $H_2C_2O_4$ solutions modified by the addition of NH_4F [4] at a constant anode potential E_a varying 18.5 to 2 V vs Ag/AgCl. The specimens were also reanodized to a higher potential E_R. Electron transport phenomena in the films were examined by measuring the in-plain impedance as a function of the formation conditions in a wide temperature and frequency range.

It was found that, under the porous alumina layer, the films are composed of arrays of tantalum oxide 'hillocks', with distinct substructure, percolating completely or partly through the tantalum underlayer towards the substrate, thus defining either concaved or mesh-like structure of the residual tantalum film (Fig. 1). The width and length of the metallic nano-channels (black areas) can be systematically varied 15 to <5 nm and 35 to 10 nm, respectively, while E_a is lowered from 18.5 to 3.0 V. The tantalum nano-channels further narrow with increasing E_R until the electrical resistivity of the tantalum network comes close to the ionic resistivity of the anodic oxides.

The three-dimensional confinement in the tantalum nano-channels due to their net-like, low-size morphology results in a wide range of R_S (10^2-10^8 Ω/sq), depending upon the formation potential. Negative TCRs, ranging 10^3-10^2 ppm/K proportionally to hillock sizes, imply an increased transition to hopping or tunnelling conduction at elevated temperature. With rising E_R, oscillations occurred in the high-voltage part of the R_S-E_R curve. The unconventional electron conductance of the films is due to quantum-confinement effects in the arrangement of the extremely short quantum wires, sandwiched between the SiO_2 substrate and alumina film [1].

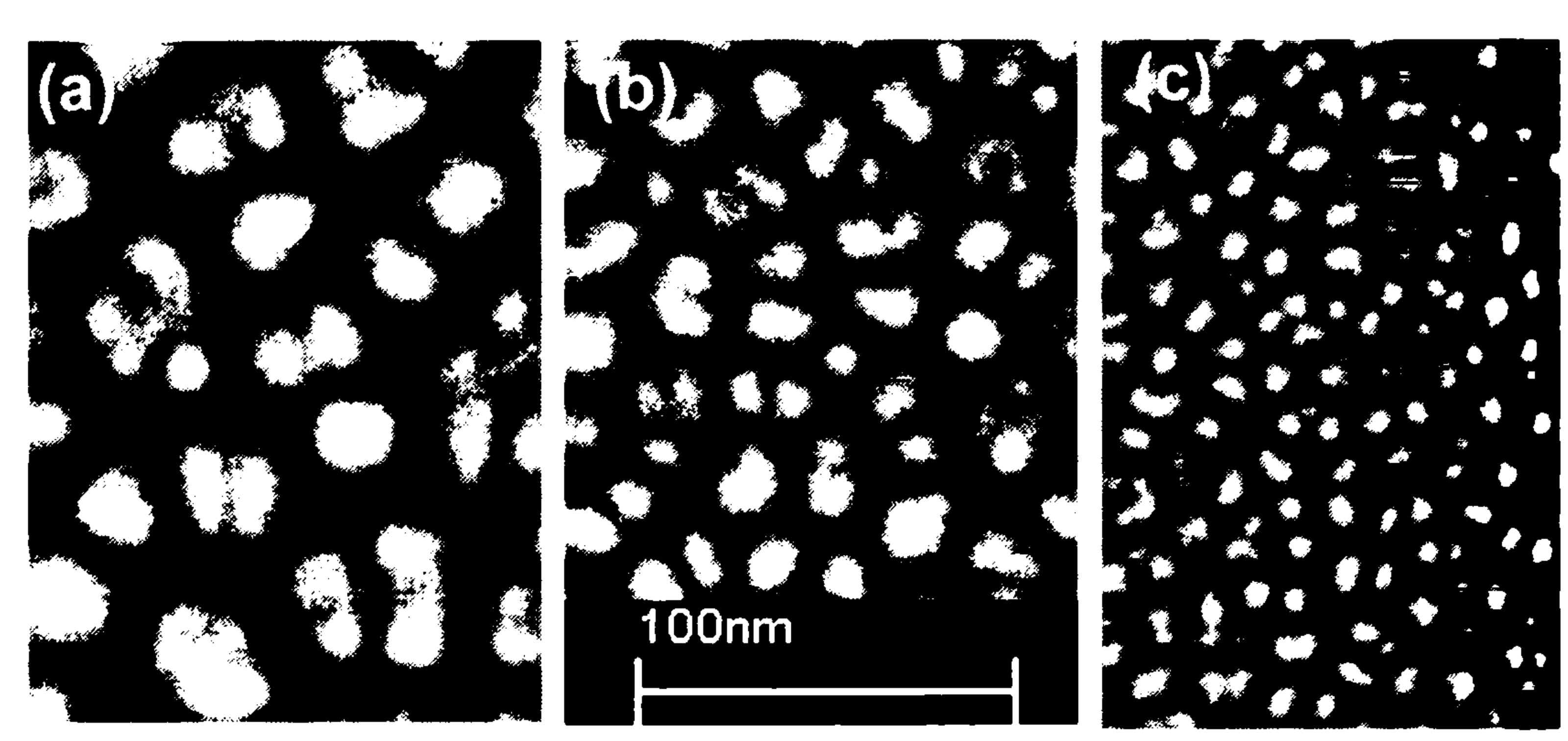

Fig. 1. SEM surface views of a Ta layer anodized under the porous alumina film at (a) 18.5, (b) 10 and (c) 3V

References

[1] A. Mozalev, G. Gorokh, M. Sakairi, H, Takahashi, J. Mater. Sci., in press

[2] A. Mozalev, A. Poznyak, I. Mozaleva, A.W. Hassel, Electrochem. Commun. 3/6 (2001) 299