Niobium and Tantalum-Anodic-Oxide Nanocolumn Arrays for 2-D Reflective Photonic-Crystals

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Abstract — Niobium and tantalum anodic oxide nanocolumn arrays by porous anodic alumina assisted anodizing were produced and the optical reflectance was studied.

Keywords— porous anodic aluminum oxide, anodizing, Nb, Ta

I. Introduction

Nowadays valve metal anodic oxides with a column-like nanostructure [1, 2] represent more interest for nanophotonics and is an array of vertically arranged oxide nanocolumns on a common oxide base. To control periodicity, diameter and height in a wide range by changing anodizing conditions is a great advantage. The oxide nanocolumn array (ONA) sizes are commensurate with the long wavelength of UV–VIS light. The morphology of ONA study showed high reproducibility and uniformity. For example, such arrays can be used to form 2-D photonic crystals.

In this work, Nb and Ta ONA with different morphological characteristics were produced by porous anodic alumina (PAA) assisted anodizing, and optical reflectance was studied.

II. Experimental

Al/Nb (1000/50 nm) on glass and Al/Ta (1500/300) on Si wafer were successively deposited by magnetron sputtering. The anodizing was in 0.2 mol·dm^{-3} tartaric solution at 200V for Ta ONA and in 0.2 mol·dm^{-3} oxalic solution at 200V for Nb ONA, re-anodized in the mixed solution of 0.5 mol·dm^{-3} boric acid and 0.05 mol·dm^{-3} sodium tetraborate in potentiodynamic mode at increase of potential until 400V for Ta ONA and 200V for Nb ONA. To remove PAA of 50% phosphoric acid at 50°C within 40 minutes was used.

Morphology was investigated by scanning electron microscopy (SEM) in a Hitachi S-4800 operated at 10–15 kV. Optical characteristics were measured on Spectrophotometer MC-121 (UV–VIS–NIR) by SOL instruments Ltd. The spectral scanning step was 2 nm in the range from 190 to 1100 nm at an incident angle of 10°.

III. Results

Figs. 1a-c show SEMs and 3-D view for Nb and Ta ONA. ONA have a fairly typical and uniform nanomorphology, size and hexagonal arrangement. This can be considered a good result, taking into account carrying out the formation without using any methods of increasing nanostructuring and using nanoimprint stamps. Ta ONA large areas have regions ONA-free while for Nb ONA only minor point defects present. Diameter, height, periodicity for Nb and Ta ONA were respectively: 60, 330, 119 and 172, 542, 500 nm.

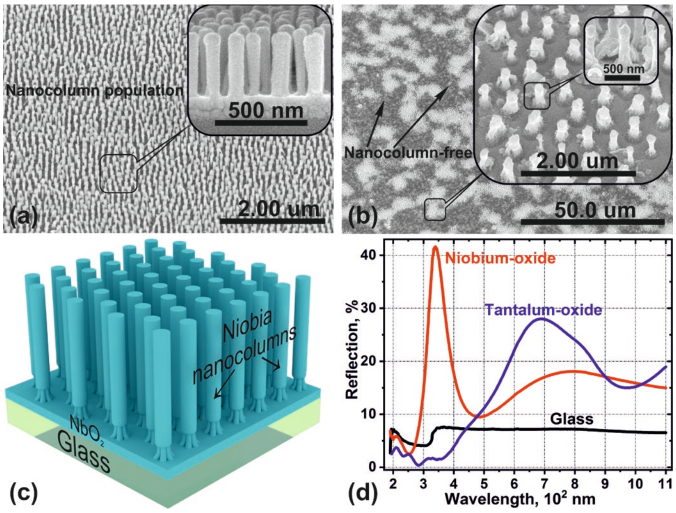

Fig.1. (a) Nb ONA and (b) Ta ONA SEMs, (c) Nb ONA 3-D view and (d) Nb and Ta ONA optical reflectance

Fig. 1d shows Nb and Ta ONA optical reflectance spectrum. Nb and Ta ONA absorption is present throughout the ultraviolet range. Approximately at a 360 nm wavelength, the Ta ONA reflectance begins to grow and reaches its peak at a wavelength of 690 nm. However, due to poor uniformity, the reflectance is strongly stretched in the spectrum and max amounts are about 28%. Ta ONA absorption is present up to 252 nm, after which begins to increase sharply to 340 nm where the reflectance level is the maximum value of 42%. The peak is very sharp with the width of all 232 nm.

IV. Conclusion

Nb and Ta ONA with different morphological characteristics were produced by PAA assisted anodizing. Diameter, height, periodicity for Nb and Ta ONA were respectively: 60, 330, 119 and 172, 542, 500 nm. Ta ONA showed an extended optical reflectance peak of 28% at 690 nm. Nb ONA showed a very sharp optical reflectance peak of 42% at 340 nm.

References

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