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Characterization of nanoporous alumina using terahertz reflectometry and scattering imaging

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Abstract— The structure as well as morphology of nanoporous alumina (NP Al₂O₃) films on Al substrates are investigated by terahertz (THz) reflectometry and scattering imaging. An inhomogeneous area is identified in THz C-scan results off specular conditions at various angles. The thickness of NP Al₂O₃ films calculated based on THz results is in excellent agreement with destructive cross-sectional field emission scanning electron microscopy (FE-SEM) measurements.

I. INTRODUCTION

Ordered NP Al₂O₃ films were grown on Al substrate through a two-step electrochemical anodization process. It is critical to characterize the NP Al₂O₃ films with a nondestructive and contactless fashion. Several common approaches, such as atomic force microscopy (AFM), SEM, transmission electron microscopy (TEM), and x-ray diffraction (XRD), present some drawbacks that limit the widespread in industries. In this work, Terahertz (THz) reflectometry and scattering imaging is employed to investigate the morphology as well as the structure of NP Al₂O₃ films on Al substrate.

II. RESULTS

The surface morphology as well as the typical reflected signal from samples after electropolishing, the first, and the second anodization are shown in Fig. 1. Owing to the template formed in first anodization process, more uniform NP Al₂O₃ films are formed on Al substrate. The parameter of NP Al₂O₃ films, such as pore diameter and interpore distance, are obtained from top view SEM results and AFM results, which are 105 ± 5 nm and 33 ± 3 nm, respectively.

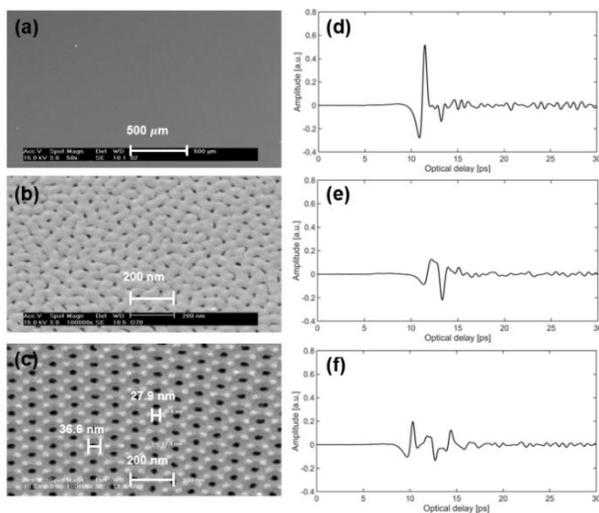


Fig. 1. FE-SEM showing surface morphology after (a) electro-polishing, (b) first anodization, and (c) second anodization, and the corresponding reflected THz signals are presented in (d)–(f).

We explore non-specular scattering by varying the detector angle ϕ while fixing the incidence angle. One inhomogeneity region resulting from non-specular scattering is clearly revealed

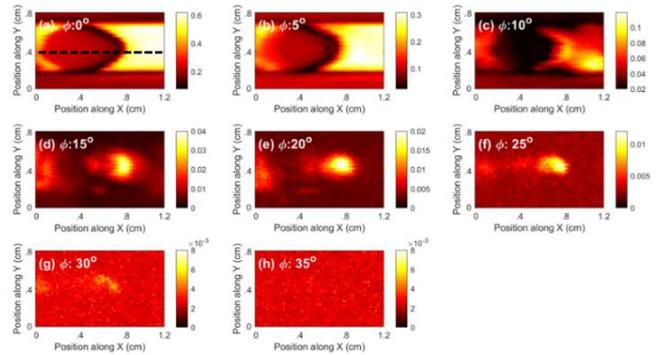


Fig. 2. C-scans of sample after the second anodization process for various reflection angles ϕ . The contrast mechanism applied here is the maximum amplitude of the scattered signal.

in Fig. 2. when $\phi > 10^\circ$. As ϕ increases further, the signal-to-noise ratio in the C-scans drops and is dominated by noise when ϕ reaches 35° . The THz results are also corroborated by FE-SEM measurements.

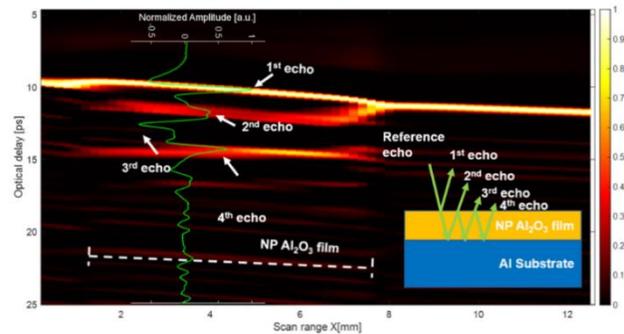


Fig. 3 B-scan based on the raw data with the cross-section $Y = 0.4$ cm. Inset shows origin of echoes in reflected THz signal: 1st air/NP Al₂O₃, 2nd NP Al₂O₃/Al, and 3rd and 4th multiple reflections.

The stratigraphy of the well-ordered NP Al₂O₃ film is also characterized based on the THz B-scans along the section indicated in Fig. 2(a). Two positive echoes, corresponding to the air/NP Al₂O₃ and NP Al₂O₃/Al interfaces are seen in Fig. 3. The thickness of the NP Al₂O₃ film can thus be estimated based on the optical distance between 1st and 2nd echoes.

III. SUMMARY

In this work, NP Al₂O₃ films were characterized based on THz reflective imaging and scattering imaging. One irregular area with rough morphology, and the structural information of NP Al₂O₃ films, are obtained and validated by SEM measurements.

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