Broadband Anti-Reflection coating for THz waves developed with Si nanoparticle–polymer composite material

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***Abstract*—THz optical elements, typically made of silicon (Si), suffer from large reflection due to the large gap in refractive index at the interface between Si and air. In this research, anti-reflection (AR) coating for THz region using polymer and Si nanoparticle (SiNP) composite was developed to minimize the reflection loss. Low absorbance and small diameter of SiNPs allowed the THz waves to transmit the composite without absorption and scattering. The AR layer coated on a THz optical element successfully demonstrated transmittance exceeding 90 % in amplitude as wide as Δf = 0.8 THz 1 THz.**

I. INTRODUCTION

THz wave is expected to be utilized in such applications as next-generation telecommunication, non-destructive testing and security monitoring. The optical elements for THz waves are typically made of Si, as Si has a negligible absorbance in THz region.[1] One drawback of Si is large reflection loss at Si-air interface due to the large refractive-index gap between air and Si (n = 3.42).

Several materials have been proposed as AR layers, including sputtered-SiO_2 film or organic films such as parylene, to minimize the reflection. These materials, however, have relatively-high absorbance in THz region. Furthermore, lack of controllability in refractive index limits the flexibility of optical design of AR layers.

Si nanoparticles (SiNPs, Fig. 1) are promising candidate for an optical material for THz region. The SiNPs have a refractive index as high as Si (n = 3.42), absorption of THz is minimized as the SiNPs has high purity and high resistivity, and THz wave scattering is expected to be negligible as the diameter of particles (~30 nm) are 4-5 orders smaller than the wavelength of THz waves.

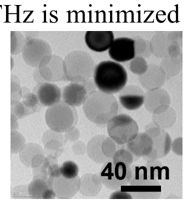

Fig. 1 Transmission-electron microscopy image of SiNPs.

In this research, AR coating for THz wave was developed using SiNPs in combination with polymeric materials to control the refractive index of the composite material.

II. RESULTS

Transmission properties of SiNPs was examined using a SiNP film formed on a highly-resistive Si wafer. The transmission spectra showed good agreement with the calculated spectra from its thickness, porosity and refractive index of Si. This result indicate that the SiNP has negligible absorbance and wave scattering, and favorably employed as a material for refractive-index control of composites with polymer.

Next, the composite film of SiNP and polymer is fabricated and refractive indexes were evaluated from their THz-transmission spectra. Fig. 2(a) shows refractive index of the SiNP-polymer composite as a function of volume fraction of SiNP. The refractive index shown to be controlled between 1.52~1.95 depending on the fraction of SiNP.

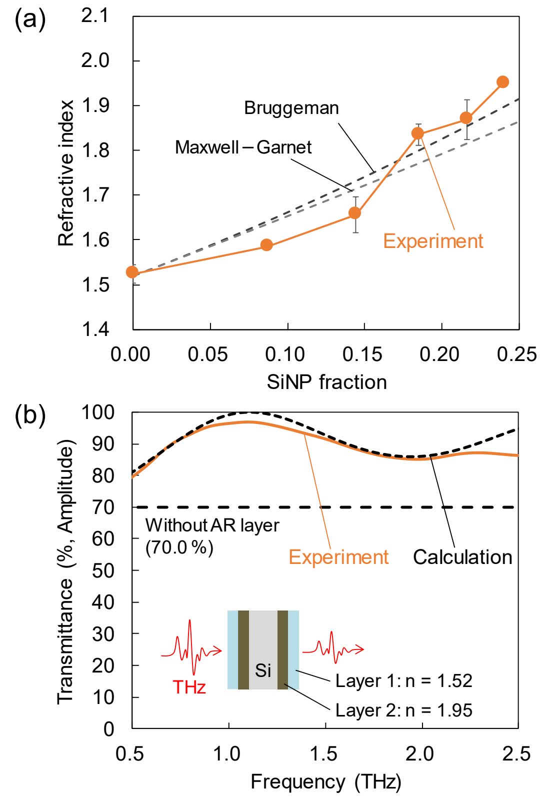

Fig. 2 (a) Measured and calculated refractive index of the SiNP-polymer mixture as a function of SiNP volume fraction. (b) Measured and calculated transmission spectra of Si plate with two-layer AR coating.

Finally, we designed 2-layer AR coating, and examined its AR properties. A stack of SiNP-polymer composite (n = 1.95) and polymer (n = 1.52) films were applied onto the both sides of Si substrates. The AR layer coated on a THz optical element successfully exhibited an amplitude transmittance exceeding 90 % as wide as Δf = 0.8 THz around 1 THz, as shown in Fig. 2(b).[2]

III. SUMMARY

Present SiNPs showed negligible absorbance and wave scattering in THz region, revealing that the excellent capability as a material for refractive-index control of polymer composite. The AR coating developed with the SiNP-polymer composite found to drastically improve the transmittance of Si and can be adopted extensive range of optical elements for THz waves.

REFERENCES

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