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Optical Permittivity and Permeability in the THz Band from Independent Measurements of Normal Transmission and Reflection

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An accurate retrieval procedure has been developed in order to extract both the dielectric and magnetic response of thin and thick samples in the THz band. Differently from a previous approach [1], the exact expressions of the complex reflection \tilde{R} and transmission \tilde{T} of the THz beam normally impinging on the sample surface are used. The core of the methodology consists in the independent employment of the experimental \tilde{R} and \tilde{T} values, processed by a total variation technique [2] to retrieve the complex impedance \tilde{z} and refractive index \tilde{n} , namely $\tilde{z}_R, \tilde{z}_T, \tilde{n}_R, \tilde{n}_T$. From here the dielectric function $\tilde{\epsilon}$ and permeability $\tilde{\mu}$ are obtained through $\tilde{\epsilon}_i = \tilde{n}_i^2, \tilde{\mu}_i = \tilde{n}_i / \tilde{z}_i$ to achieve $\tilde{\epsilon}_R, \tilde{\epsilon}_T, \tilde{\mu}_R, \tilde{\mu}_T$. The technique is applied to a thin film of BiFeO₃ showing a small but finite magnetization and a phononic resonance at about 2 THz [3]. The BiFeO₃ films have been grown on quartz, following a procedure similar to that previously optimized for the deposition on Si (100) substrate [4]. In particular, the films have been deposited in the temperature range 600–800 °C for 60 min using the Bi(phenyl)₃ and Fe(tmhd)₃ (phenyl = -C₆H₅, H-tmhd = 2,2,6,6-tetramethyl-3,5-heptandione), as precursors. The X-ray diffraction patterns, recorded in grazing incidence mode (0.8°), have confirmed the formation of pure, polycrystalline BiFeO₃ films, while the field emission scanning electron microscopy image indicates the presence of grains of about 500-600 nm.

References 1. H. Němec, F. Kadlec, P. Kužel, L. Duvillaret, and J. L. Coutaz, “Independent determination of the complex refractive index and wave impedance by time-domain terahertz spectroscopy,” *Opt. Commun.* 260(1), 175–183 (2006). 2. L. Duvillaret, F. Garet, and J. L. Coutaz, “A reliable method for extraction of material parameters in terahertz time-domain spectroscopy,” *IEEE J. Sel. Top. Quantum Electron.* 2(3), 739–745 (1996). 3. G. A. Komandin, V. I. Torgashev, A. A. Volkov, O. E. Porodinkov, A. A. Pronin, L. D. Iskhakova, and A. A. Bush, “Effect of BiFeO₃ ceramics morphology on electrodynamic properties in the terahertz frequency range,” *Phys. Solid State* 54(6), 1191–1198 (2012). 4. Q. Micard, G. G. Condorelli and G. Malandrino, “Piezoelectric BiFeO₃ Thin Films: Optimization of MOCVD Process on Si”, *Nanomaterials* 10, 630/1-630/10 (2020).

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