Development of mm/submm broadband anti-reflection coating exploiting the various expanded PTFEs measured with THz-TDS

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Large scale sky survey in the millimeter/submillimeter bands with broadband multi-color continuum camera utilizing the highly sensitive low temperature detectors is indispensable for promoting the sciences such as efficiently estimating the redshift of distant star-forming galaxies, studying the internal structure of hot plasma in clusters of galaxies using the Sunyaev-Zel'dovich effect, and constraining physical properties of the dust in star--forming regions. Especially, recent increase in the number of observing colors and expansion to higher observing frequencies has pushed the optical components of the camera to fully cover the multiple frequency bands up to ~ 1 THz. Furthermore, rapid growth in the aperture size of the low temperature detectors requires vacuum windows of higher mechanical strength which results in thick windows. Thus the broadband antireflection (AR) of the vacuum window is essential. Therefore, we are developing a broadband AR covering the frequency bands of aforementioned astronomical interest.

Widely used conventional ARs are composed of mono- or multi-layer of expanded PTFE (polytetrafluoroethylene) such as Zitex and Porex glued on polyethylene substrate. However, lack in the variety of refractive indices of these expanded PTFE has limited the flexibility in optimizing the transmissivity of frequency bands of interest. Therefore, we have conducted a survey and evaluated the expanded PTFEs such as Poreflon and C-porous of various porosity and thickness with THz-TDS. The range of porosity and thickness were 40 to 80 % and 60 to 400 μm, respectively.

In order to precisely quantify the optical properties of highly transparent and thin materials, uncertainty due to the low frequency power level fluctuation in the source and detector must be circumvented. For this purpose, a sample holder was built that automatically moves the sample in and out of the beam every 30 second and measures background and sample spectra in an interleaved manner. The achieved repeatability of the transmissivity and refractive index were better than 0.5 % and 0.004, respectively, at 0.1 to 3 THz.

As a result, the obtained refractive indices of expanded PTFEs varied from 1.06 to 1.27 with the fine spacing of ~ 0.03. Exploiting the improved flexibility in choice of the refractive index, AR capable of covering the observing bands of interest was designed. In Fig. 1, we show an example of simulated transmissivity of tri-layer AR with the atmospheric transmissivity at Atacama, one of the best mm/submm observing site.

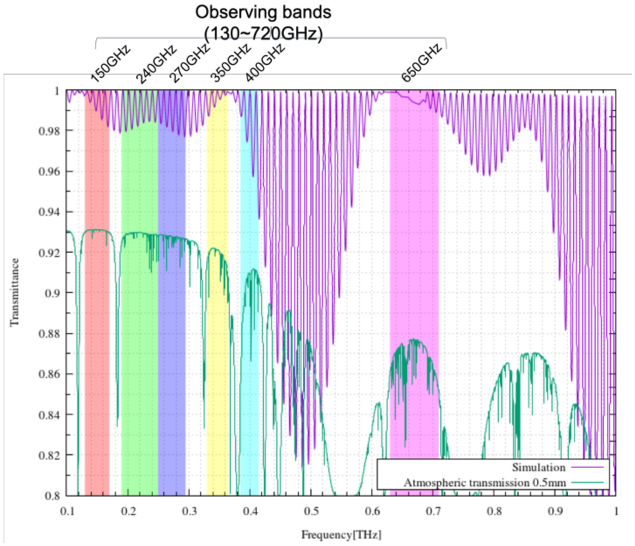

Fig. 1. (cyan line) An example of transmissivity curve of a vacuum window with AR composed of tri-layer expanded PTFEs. (green line) Typical atmospheric transmissivity at Atacama. (Colored boxes) The observing frequency bands of interest.

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