SILICONE-BASED ANECHOICS AT TERAHERTZ FREQUENCIES

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ABSTRACT

Silicone-based anechoics using wedge-type surface geometries have been designed for use at terahertz frequencies. These materials provide more than −50dB of reduction in reflectivity for large-scale quasi-optical measurement systems. The geometry of the grooved surface is manufactured, in 2' x 2' sheets, to precise tolerances through a pressure injection molding process. Considerations of both manufacturability and cost were addressed in utilizing an iron-oxide loaded silicone as vehicle for the anechoic. An evaluation of the materials currently available will be presented.

DESIGN AND MANUFACTURE OF THE ANECHOIC STRUCTURE

Design of quasi-optical measurement systems operating at terahertz frequencies require a wide variety of materials for component fabrication. Critical to implementation of these laboratory systems are far-infrared-radiation-absorbing-material (FIRAM) which may be used to suppress unwanted stray radiation. As demonstrated by Janz and co-workers in the millimeter wavelength regime\(^1\), wedge and pyramidal-structured surface geometries improve a material's absorption properties by increasing the number of surfaces incident radiation must encounter before backscattering to the receiver occurs. Measurements performed by these and other researchers\(^2\) have shown that the reduction in reflectivity achieved may be expressed as:

\[ R_s \approx R_f^{\left(180^\circ/\theta_g\right)} \]  

where \( R_f \) is the material's front surface reflectivity and \( \theta_g \) the structure's groove angle. Since this type of FIRAM is generally fabricated from homogeneous lossy dielectric materials which exhibit front surface reflectivities \( R_f \) of less than 10%, anechoic structures can be designed to provide more than −80dB of reflectivity reduction for a groove angle of 22.5°.

Using a silicone elastomer and electrically insulating siliceous filler, Prewer and Milner of Thorn EMI Technology Inc. fabricated the first samples of terahertz frequency anechoic in the form of pyramidal surface structured tiles\(^3\). Measurements performed during July of 1989 at the University of Massachusetts Lowell (UML) further documented their success when specular and diffuse reflectivity levels of better than −40dB were observed at 584 GHz for almost all incident directions. However wedge and pyramidal structured anechoic materials suitable for large-scale use at terahertz frequencies were not commercially available at that time.

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Therefore UML researchers initiated a project to design and fabricate silicone-based wedge-structure anechoic material for use with its submillimeter measurement systems. A method of estimating refractive indices was used to characterize a variety of materials in search for a lossy dielectric exhibiting low front surface reflectivity. Prospective dielectric materials such as the widely available plastics and elastomers promised to provide good anechoic properties when constructed, through cost-efficient molding techniques, with modified surface geometries.

Chosen as most suitable due to its mechanical and optical properties was iron-oxide-loaded silicone. The front surface reflectivity for a flat 0.25" thick sample of the material was measured at 1.56 THz and found to be $R_f = 5.57\%$. The transmissivity was also measured and found to be $T = 1.8\%$ for a $t = 1.9$mm thick sample of the same material. The Fresnel equations for the multiple reflection theory transmissivity:

$$T = \frac{\left(1 - r_f^2\right)e^{-2\pi Nn/\lambda}}{1 - r_f^2 e^{-4\pi Nn/\lambda}}$$

and front surface reflectivity: $R_f = |r_f|^2$ where $r_f = (N-1)/(N+1)$ were used to estimate a complex refractive index of $N = 1.62 - 0.03$ i, for the iron oxide loaded silicone. With more than a $-100$dB reflectivity reduction expected from a structure such as the design depicted in Figure 1, UML created a 3.5" x 24" prototype mold structure for conceptual evaluation. A reduction in reflectivity of better than $-80$dB was realized for all incident angles except normal incidence and those angles satisfying the grating equation, where values of better than $-40$dB were observed.

![Figure 1. Design parameters for the wedged-type anechoic structure implemented by UML researchers.

Therefore a contract was established to manufacture 24" x 24" iron-oxide-loaded solid silicone sheets with the wedge-type surface geometry. The final anechoic structure was evaluated at both 584 GHz and 1.56 THz using a CO$_2$ optically pumped submillimeter laser, and from 300 GHz to 3000 GHz using a Digilab FTS-80 spectrometer. Measurements performed on the samples produced a worst case, normal incidence, reduction in reflectivity of better than $-40$dB with a $-80$dB reduction in transmissivity. Full-scale production of this FIRAM is underway and submillimeter wavelength anechoic chambers are being fabricated. An evaluation of the submillimeter wavelength anechoic materials currently available will be presented along with discussions on their optimal use.

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4 R.H. Giles and T.M. Horgan: "Silicone-Based Wedged-Surface Radiation Absorbing Material", U.S. Patent Pending