Design and Manufacture of Submillimeter-Wave Anechoic Structures

Using in–house expertise in the technique of tailoring artificial dielectrics and the polarimetric characterization of materials, a variety of composite structures have been created as far-infrared radiation absorbing material (FIRAM™)[1]. As demonstrated by Janz and co-workers[2] in the millimeter wavelength regime, 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[3] have shown that the reduction in reflectivity achieved may be expressed by:

$$R_s \approx R_f^{\left(180°/\theta_g\right)} \qquad (1)$$

where R_f is the material's front surface reflectivity and θ_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[4]. Measurements performed during July of 1989 at STL further documented their success when specular and diffuse reflectivity levels of better than –40dB were observed at 0.584 THz 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.

Therefore STL researchers initiated a project to design and fabricate silicone-based wedge-structured anechoic material for use with its submillimeter-wave 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. Using cost-efficient molding techniques, prospective dielectric materials such as the widely available plastics and elastomers promised to provide good anechoic properties if constructed with modified surface geometries.

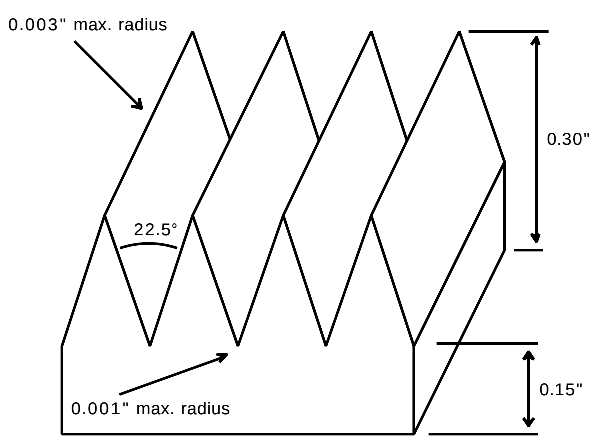

Figure 1. Design parameters for the wedged-type anechoic implemented by STL[9].

Shown in Figure 1 are the design parameters of the FIRAM™ 's wedge-type surface geometry. A –30dB reflectivity reduction or greater was achieved at normal incidence, however when appropriately oriented within quasi-optical measurement systems these materials reduce reflections due to unwanted stray radiation by more than –60dB. The geometry of the grooved surfaces shown in Figure 2 are manufactured in 2´ x 2´ sheets to precise tolerances through a pressure injection molding process. Considerations such as manufacturablility and cost were addressed in choosing the methodology to implement the anechoic structures.

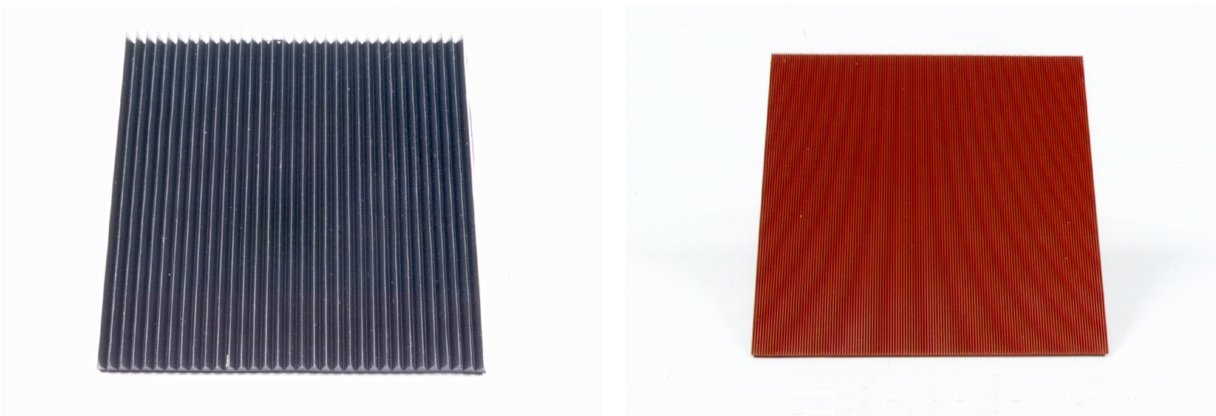

Figure 2 STL's FIRAM-160, and FIRAM-500, is shown on the left, and right, respectively.

FIRAM™ may be purchased from the University in two styles. The original FIRAM-500, red, is optimized for frequencies of 500 GHz and above. The FIRAM-160, black, is optimized for use at 160 GHz and has proven to also work efficiently at frequencies of 500 GHz and above. Please use the following part number when ordering.

part #	*description*	*availability*
FIRAM-500	iron oxide loaded silicone, ≈ 17 grooves/inch	in stock
FIRAM-160	carbon loaded silicone, ≈ 4 grooves/inch	in stock

If you need any further information for ordering the material, please use the address below.

University of Massachusetts Lowell
Submillimeter Technology Laboratory
450 Aiken Street
Lowell, MA 01854

References

1. R.H. Giles, T.M. Horgan, and J. Waldman, “Silicon-Based Anechoics at Terahertz Frequencies”, Proc. of the 17th Int. Conf. on Infrared and Millimeter Wave, Los Angeles, CA, Dec. 1992.

2. S. Janz, D.A. Boyd, and R.F. Ellis: "Reflectance Characteristics in the Submillimeter and Millimeter Wavelength Region of a Vacuum Compatible Absorber", International Journal of Infrared and Millimeter Waves, Vol. 8, No. 6, 1987, pp. 627-635

3. B.T. Dewitt: "Analysis and Measurement of Electromagnetic Scattering by Pyramidal and Wedge Absorbers", Ph.D. Dissertation, Ohio State University, 1986

4. B.E. Prewer, B. Milner: "Radiation Absorber and Method of Making It", U.S. Patent # 4,942,402 , July 17, 1990

5. R.H. Giles and T.M. Horgan: "Silicone-Based Wedged-Surface Radiation Absorbing Material", U.S. Patent Number 5,260,513, November 1993