Non-Destructive Evaluation of Low Observable Coating Degradation Using Terahertz Time-Domain Spectroscopy

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Abstract

Terahertz Time Domain (THz-TD) reflection spectroscopy is utilized as a non-destructive test evaluation method to assess the degradation of Low Observable (LO) coatings. Accelerated aging techniques including temperature, UV light exposure and humidity, were performed continuously on multilayer paint samples. The exposed samples were measured using established testing methods as well as THz-TD techniques at various points throughout the degradation. Using an effective medium model for terahertz propagation in a paint sample combined with a non-linear least squares fitting method, the refractive index was extracted. Established materials characterization techniques suggest degradation begins with pitting of the top coat layer followed by catalytic degradation of rain erosion polymer. THz-TD measures show an increase in the magnitude of the imaginary refractive index with degradation.

Methods

- Two measurements required for analysis:
  - Reference THz waveform
  - Sample THz waveform

- \( r(\nu, \delta) = c \gamma \nu \sign(\nu \delta) \) is the THz frequency
- \( s \) and \( r \) denote sample and reference respectively
- \( \gamma[i] \) denotes the magnitude of the Fourier transform of the THz waveform

- Best Fit – Rain Erosion Coating
- Extracted THz Refractive Indices for all Layers

Degradation Protocol

- Method #1: Degradation Conditions:
  - Humidity – 95%
  - UV light (254 nm) - 124 nm wavelength
  - 254 nm wavelength

- Method #2: Degradation Conditions:
  - Humidity – 90%
  - UV light (254 nm) - 145 nm wavelength
  - 0.5 molar NaCl solution in water

Results

- Undegraded Multilayer Stack
  - THz Waveform
  - Best Fit

- Sample 353-AIA-025
  - Real Refractive Index
  - Imaginary Refractive Index

- THz Property Changes – Degraded Samples
  - Real Refractive Index
  - Imaginary Refractive Index

- Degraded Samples:
  - Change not statistically significant

Degradation Mechanism

- Pristine multilayer stack coated with platinum
  - NaCl solution in water with UV illumination
degraded multilayer stack

- Humidity and UV degraded multilayer stack
  - Begins in the top coat layer
  - As the topcoat layer becomes more porous, it allows water vapor to permeate the topcoat layer and interact with the rain erosion layer
  - The presence of the salt accelerates the pitting degradation.

References (selected)


References available upon request.