Specifying, Applying and Measuring Thin Film Coating

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This paper will explain general process of specifying, applying and measuring thin film coating.

SPECIFYING THIN FILM COATINGS

At a minimum, specification for a thin film coating must include a performance requirement and a spectral range[1]. Performance is specified as a percentage, and it may refer to reflection, transmission or both. Additional specifications may be added to emphasize additional areas of interest and performance requirements. Example additions include:

Angle Of Incidence (AOI)

This is the angle of incident ray measured relative to optical axis. Performance will vary with increasing AOI, with optimum performance shifting to shorter wavelengths[2].

Absorption

Incident light may be absorbed by the coating, resulting in light loss. This may be due to the composition of the coating or trapped contamination[3]. Commercially available coatings typically exhibit absorption on a parts-per-million scale with properly selected coating materials and contamination controls [4].

Polarization

When light strikes a surface at a nonzero AOI, its different polarizations are reflected and transmitted in unequal amounts[5]. Coatings may need to take this into account, and requirements for each polarization may need to be stated. Without separate indication, reflectance and transmission specifications are taken to be at random polarization, an arithmetic mean of the s-polarization and p-polarization values[6].

Laser Damage Threshold

Thin film coatings can exhibit damage when exposed to laser radiation[7]. For applications using high energy lasers (>1mJ/cm^2), a specification of how much power the coating will be expected to withstand needs to be considered. Specification needs to include wavelength, pulse width and repetition rate for pulsed systems and average power for continuous wave systems.

Witness Sample/Environmental Requirements

Parts to be coated are typically accompanied by a witness sample, a representative material coupon polished on one side or plane parallel. In most cases, coating performance is tested using the witness sample rather than the part itself, including required environmental durability tests. Environmental durability testing is explained in MIL-F-48616 or MIL-C-48497A in detail.

Coating Aperture

If there is concern about the size of the coated area, a Coating Aperture in addition to the Clear Aperture may be specified. The additional aperture is used to address concerns about coating margins, edge effects or overspray into bondment areas.

COATING TECHNOLOGY

Coating is designed using software[8], with design goals established through the coating specification. The main design variables are number of layers, type and thickness of coating material, and the order of deposition. Additional consideration may also need to be given to how material is evaporated.

Evaporative coatings begin with vaporizing the coating material at an elevated temperature in a vacuum chamber. The evaporant condenses on the comparatively much cooler substrate, and the condensed material generally forms columns that join together on the surface[9]. The surface formed relies on overlap of the columns for continuity, and voids can be managed but not regularly eliminated[10].

Voids serve as a route for moisture intrusion[11], which alters coating performance and will absorb in the infrared. A major tool in addressing voids is evaporation source choice. The evaporation source influences how densely the coating material packs on the surface, changing the mechanical characteristics of the coating as well.

Choosing an Ion-Assisted source over basic thermal evaporation can increase density of the coating. This increases ruggedness and limits moisture intrusion, but it does add stress to the coating[12].

Another option is Ion Beam Sputtering (IBS), where individual coating material molecules are energized. Coatings produced using IBS are among the densest available, with properties most closely modeling that of the bulk material. The process runs at far, far lower temperatures, allowing plastics to be coated[13], and is nearly stress free. However the process is slow and most expensive by far[14].

Process control is mainly accomplished through quartz crystal or optical monitoring[15]. The thickness of each coating layer is measured as it is deposited, and deposition time is altered based on actual versus modeled targets. It does not accommodate for moisture absorption, which will shift the coating[16].

TESTING COATING PERFORMANCE

Coating performance can be broken down into two fundamental categories: optical and mechanical performance. The first is how well the coating works optically, while the second is more about physical characteristics like adhesion and durability.

Optical performance is generally measured on a witness sample using a spectrophotometer. The resulting data is fit to a model, and particular care is given to calibration of the unit[17]. Other optical performance parameters (absorption, LDT) are tested using specialized, direct tests of the parameter itself.

Mechanical performance is measured according to methods established in published thin film coating standards. Adhesion and durability testing is explained in detail in a number of MIL specs such as MIL-F-48616 or MIL-C-48497A.

CONCLUSIONS

- Thin film coating specification must include a performance requirement and a spectral range.
- Coating is designed using software and applied under vacuum.
- Thin films are deposited surfaces, controlled to closely match modeled performance.
- Coating performance testing has two fundamental categories: optical and mechanical performance.

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