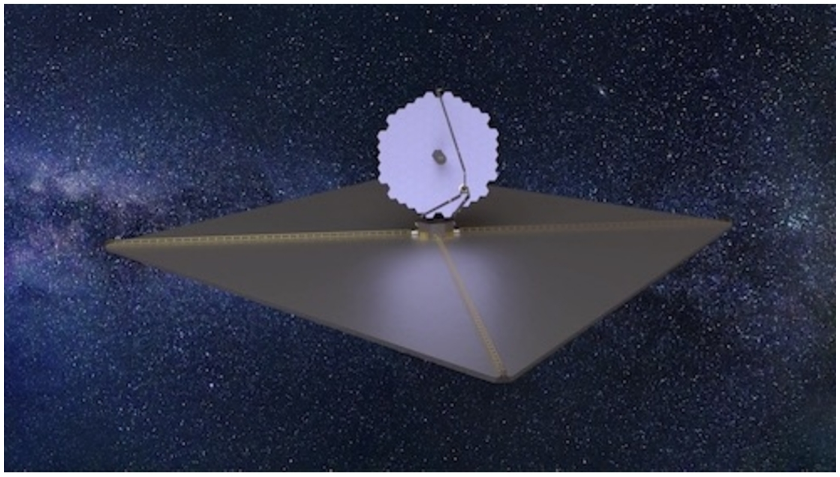

National Aeronautics and Space Administration

TECHNOLOGY SOLUTION

Materials and Coatings

Advanced AlF3-Passivated Aluminum Mirrors

Enhanced far-ultraviolet reflectivity for next generation optics

Pure aluminum (Al) exhibits an intrinsically high reflectance in the 90 – 2500 nm wavelengths and is commonly used for mirrors in optical applications within this range. However, in order to be used in the far-ultraviolet (FUV) range between 90 – 130 nm, an optical thin film overcoat is needed to protect the Al and prevent the formation of an Al2O3 layer, which occurs upon exposure to oxygen. Conventionally, fluoride overcoat layers such as LiF or MgF2 have been used to solve this challenge. However, these coatings are opaque between 90 – 102 nm and generate residual absorption even above 102 nm, limiting reflectance at these short wavelengths. Furthermore, such fluoride coatings are hygroscopic and environmentally unstable.

To address this issue, engineers at NASA's Goddard Space Flight Center have developed an alternative method to prevent the oxidation of Al coatings without the drawbacks associated with fluoride coatings (opaqueness, residual absorption). This NASA innovation is an Al mirror passivation process that produces a thin AlF3 overcoat layer, preventing further oxidation. The resultant AlF3 overcoat layer offers enhanced reflectivity at shorter (FUV) wavelengths compared to MgF2 and is more environmentally stable relative to LiF. Furthermore, Al mirrors receiving this innovative NASA treatment maintain 90% reflectance at longer wavelengths, enabling the development of mirrors with broadband reflectivity (e.g., from 90 – 2500 nm).

BENEFITS

- Enhanced FUV reflectivity: Enables Al mirrors to operate in the spectral range of 90 – 160 nm without oxidation of the surface and while maintaining optical transparency.
- Ultrathin, conformal coating: NASA’s process creates a monolayer coating that is approximately 2 nm thick and conformal to a surface of arbitrary geometry.
- Broad spectral range: The thin film AlF3 layer produced by this NASA invention enables Al mirrors with high reflectivity from 90 nm to 2500 nm or higher.
- Environmental stability: This NASA process generates Al mirrors with improved thermal stability relative to those with fluoride overcoats.
- Room-temperature process: NASA’s passivation process generates an AlF3 overcoat layer in-situ at ambient temperature. No high-temperature fluoride deposition required.
- Scalability: NASA’s passivation process highly scalable for large-area and curved optical elements.

THE TECHNOLOGY

NASA's innovative passivation process consists of exposing in-situ Physical Vapor Deposited oxide-free Al samples in a high or ultra-high vacuum chamber at ambient temperature to a low-pressure reactive gas of xenon difluoride (XeF_2) immediately after depositing the Al layer. In this chemisorption process, the XeF_2 is adsorbed on the surface of the Al layer, and due to the affinity of Al to fluorine molecules, the weakly-bound Xe dissociates and is pumped out of the chamber. A thin AlF_3 overcoat layer is produced as a result.

Other embodiments of the invention include the use of alternative processing gasses for the passivation treatment, or the utilization of a plasma source to increase the ion/atom ratio of the incident fluorine species resulting after XeF_2 dissociation. Similarly, different mirror substrates materials with suitable surface characteristics in the FUV could be employed.

In addition to the improved FUV reflectance, environmental stability, and maintained efficiency at higher wavelengths of the resulting Al mirrors, this NASA process has several unique features. Firstly, the entire process is carried out at ambient temperature, eliminating the need for high-temperature fluoride deposition. Secondly, the process is highly scalable, limited only by the size of the coating chamber where the passivation of XeF_2 is carried out. Finally, the process can be manipulated to conform to any geometry, enabling its use for curved optics.

While NASA originally developed the passivation of oxide-free aluminum coatings to realize reflectivity enhancement in the Far-Ultraviolet for the Large UV/Optical/IR Surveyor (LUVOIR), it may also be useful to companies that manufacture ground-based or space-based optical systems with sensitivity to the FUV spectrum. Examples include optics for space telescopes with reflective elements, vacuum-ultraviolet (VUV) plasma analysis tools, photolithography instrumentation, and wafer inspection tools.

APPLICATIONS

The technology has several potential applications:

- Ground-based & satellite telescopes
- Laser optics (FUV mirrors, laser beam lines, F_2 lasers operating at 157 nm, Xe lasers operating at 172 nm, higher order harmonic generation, plasma checking)
- Photolithography
- Batteries (as a passivation mechanism for Al in Li-containing batteries)
- Laboratory instrumentation (spectrometers, monochromators, gratings)
- High frequency wiring
- Vacuum ultraviolet (VUV) plasma analysis tools
- Wafer inspection tools

PUBLICATIONS

Patent Pending

"Plasma based production of AlF_3-passivated aluminum mirrors for UVOIR astronomy," Quijada, M.A. et al., 08/31/22

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More Information

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