Battery-powered thin film deposition process for coating telescope mirrors in space

David A. Sheikh
ZeCoat Corporation, Torrance, California, USA

INTRODUCTION

Coating telescope mirrors in space offers potential benefits to astrophysics. 1) Extend reflective aluminum observations down to 50-nm, 2) Change the coating in space from aluminum to silver for a "two-in-one" telescope concept, 3) Re-coat to repair a coating in space, 4) Remove dust contamination prior to coating for ultra-low scattering mirrors.

Recent developments in battery technology allow small lithium batteries to rapidly discharge large amounts of energy.

Method to coat a telescope mirror in space with BPD technology

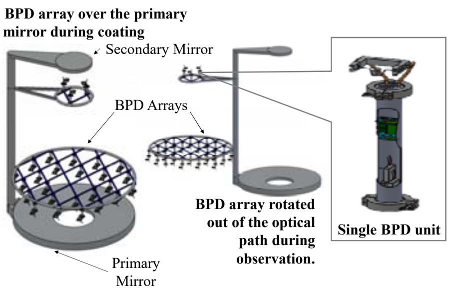

Fig. 1. Artist rendition of a method for coating a Cassegrain-style telescope concept using the battery-powered deposition (BPD) units fixed in a hexagonal array and a single BPD unit up close.

ZeCoat's BPD process uses an array of hot filaments powered by batteries in small pressurized vessels. The tungsten filament carries the evaporation material by surface tension; an evaporation process that will work in zero gravity and the evaporation material may be emitted in any direction.

Simultaneously discharging batteries through individual filaments allow large areas to uniformly coated in a few seconds.

EXPERIMENT

ZeCoat built and tested a prototype battery-powered deposition (BPD) device. The single BPD unit was placed inside a 1.2-m vacuum chamber, and below an uncoated mirror substrate. A quartz crystal monitor was used to determine deposition rate. The unit was engergized and aluminum deposition began a few seconds later. Approximately 2,400-Å of aluminum were deposited on the mirror substrate at a rate of ~40-Å/second and the total deposition time was 1-minute.

Prototype demonstration experiment

Fig. 2 **a**. In-house engineered and assembled prototype BPD unit shown before experiment, **b**. Type 26650 LiPO4 batteries used as the power source shown after experiment, **c**. The energized BPD filament during the demonstration experiment under high-vacuum.

RESULTS

Computer modeling of measured coating thickness distribution revealed that 34-cm and 23-cm source-spacing in a hexagonal pattern offer optimal thickness distribution. At 34-cm apart, a 1-m^2 area may be coated with (23) sources at 58-Å/second and achieve coating uniformity of +/-6 %. At 23-cm apart, a 1-m^2 area may be coated with (81) sources at 133-Å/second and achieve a coating uniformity of +/- 3 %.

The model shows a hexagonal array of sources could rapidly coat a mirror with uniformity less than +/- 3%.

Analysis of coating thickness distribution spaced apart at 34-cm

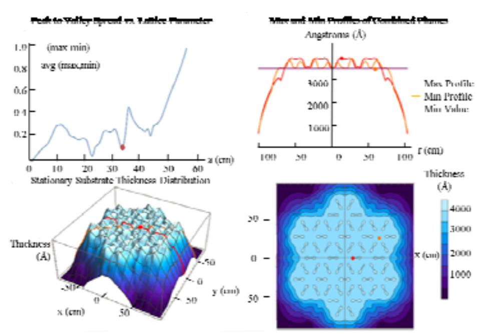

Fig. 3. Mathematical modeling of measured data indicate 34-cm is one of two ideal spacing between deposition units in order to minimize coating thickness variations. (An analysis of 56-cm, 34-cm, and 23-cm spacing are provided in the manuscript.)

CONCLUSIONS

1. **The vacuum of space offers the best possible place in the universe to manufacture a bare contamination-free aluminum coating.**
2. **High performance batteries may offer a simple path to coating optics in space.**
3. **ZeCoat has presented a preliminary experiment to demonstrate a reasonable method for coating an optic in space.**

ZeCoat is currently developing a smaller, more powerful BPD source with programmable evaporation rate and a mechanical shutter.

REFERENCES

1. H.W. Moos, et al., *FUSE: lessons learned for future FUV missions (2004)*
2. A.N. Bunner, *Optical Coating in Space Final Report (1983)*
3. J.B. Heaney, et al., *The Feasibility of Cleaning and Recoating Optical Surfaces in Space Environment (1988)*
4. Manuel A. Quijada, et al., *Enhanced far-ultraviolet reflectance of MgF2 and LiF over-coated Al mirrors (2014)*
5. Kunjithapatham Balasubramanian, et al., *Aluminum mirror coatings for UVOIR telescope optics including the far UV (2015)*
6. Ronald S. Polidan, et al., An evolvable space telescope for future astronomical missions 2015 update (2015)
7. Kunjithapatham Balasubramanian, et al., *Techniques and Instrument for Detection of Exoplanets IV (2009)*
8. Gary L. Peterson, *A BRDF model for scratches and digs* (2012)
9. Michael G. Dittman, *Contaminiation scatter functions for stray-light analysis* (2002)