Progress toward high-performance astronomical coatings

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Introduction:
University of California Observatories (UCO) has undertaken a program to develop more efficient coatings for astronomical optics. The efficiency of observations generally scales with the reflectivity of mirrors, and better anti-reflection (AR) coatings for transmissive optics has a direct benefit to observational astronomy. Furthermore, if mirror coatings can maintain their maximum performance for longer periods of time, operational costs involved in periodic mirror recoating can be significantly reduced.

The requirements and challenges for astronomical optics are discussed in detail by Phillips et al. (2008), and are briefly reviewed here:

1. Coatings must be durable, chemically stable and in their performance for as long as possible; realistically for 4 years or longer.
2. If the coating lifetime is less than that of the optic, we must be able to strip the coating and deposit a new coating without damage to the underlying surface.
3. Most astronomical coatings have two additional challenges. The first is that they must generally have high-performance over broad ranges in wavelength, e.g., from the atmospheric cutoff to at least the mid-IR (0.31 μm ≤ λ ≤ 12 μm) for telescope mirrors, and either the full optical (0.31 μm ≤ λ ≤ 1.1 μm) or near-IR (0.8 μm ≤ λ ≤ 2.5 μm) range for AR-coatings.

An additional modification we have made to our broad-band sol-gel design is to include a thin layer of Y2O3 to the interface between the substrate and the MgF2 layer. Since Y2O3 is attacked by acids, these coatings are easily stripped by conventional techniques.

The future: Major Chamber Upgrades
We intend to upgrade our chamber in the near future with three new capabilities allowing us to explore new materials, compare coating processes, and explore how to coat large optics:

1. Install a large cryopump to increase pumping speeds by a factor of several. This is particularly important to allow reaching the high vacuum levels required to reactively deposit nitrides. Water tends to react with materials to form oxides, so the presence of residual water will tend to produce oxynitrides rather than pure nitrides. The increased pumping speeds of a large cryopump, especially for water, will allow us to reliably deposit nitrides. In particular, we will explore metal nitrides that could replace the NiCr nitride in the Gemini LLN coating. NiCr nitride has very poor optical properties and so must be deposited in a very thin layer, but it appears crucial for the formation of a good AlN barrier layer above silver.
2. Fabricate and install a "swing-arm" radially-moving stage (figure below). This follows the work of Surface Optics Corporation (SOC), who developed a radially-moving stage used in conjunction with e-beam/IAD to deposit very uniform coatings on large surfaces. Our approach will use a pivoting arm to carry the e-gun and gas source from center to edge of the chamber. This design allows us to move all flexible electrical, cooling and gas lines to the atmosphere side of the chamber, those lines within the chamber will be out of the way. We would like to thank Michael Fulton of Ion Beam Optics, and Dave Sheikh and Steve Connell of Surface Optics Corporation for generously sharing their expertise in coating techniques and processes. In addition, we thank TMF for their help in finding some of the facilities that enable us to perform our work.

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References:

See also Schwab and Phillips, 7739-66, for more on coatings developments.