Multi-Slit Mask Fabrication on Spherical Electroformed Shell Substrates

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ABSTRACT

We discuss the application of modern precision electroforming technology to the fabrication of multi-slit masks used for multi-object spectroscopy. Electroforming technology is capable of producing very accurate compound curved thin metal shells using nickel or nickel-cobalt material. The curved slit masks can be fabricated to conform to a curved focal surface of spherical, conic, or arbitrary shape. A variety of optical coatings including gold and extremely low reflectivity copper oxide can be applied to the electroformed mask substrate prior to cutting slits. Precise rectangular slits and apertures of arbitrary shape are readily machined in the nickel materials using a three axis YAG laser machining system.

Keywords: electroformed, multi-slit masks, optical coatings, laser machining

1. INTRODUCTION

Multi-slit spectroscopy using custom fabricated slit masks has become a powerful observational technique in astronomy. Unfortunately, telescope focal surfaces are typically conic sections - not planes - and as the field of view increases the deviation of the telescope focal surface from a "best-fit" plane increases rapidly. In order to minimize throughput losses at the slit it is necessary for the slits to be machined in a substrate that matches the shape of the focal surface.

The MODS spectrograph (Osmer et al. 2000), (Byard et al. 2000) is currently under construction for use on the Large Binocular Telescope (LBT; see Hill & Salinari 2000). The Gregorian focal surface of the LBT is closely approximated by a 1040mm radius sphere. The depth of curve (sag) of this surface from the center to the corner of the MODS spectrograph 6 arc minutes square field is 12mm which adds about 1.3 arcseconds to the image size in the corner of the field if the telescope were in best focus at the center of the field. This value could be reduced by a factor of two if the telescope focus were shifted by 6mm (half the sag). Nonetheless this mismatch between a planar mask substrate and the telescope focal surface exacts a serious penalty on instrument performance.

A technique for completely avoiding this problem is simply to machine the slits in a thin spherical shell substrate that matches the telescope focal surface essentially perfectly. The production of such a thin shell using electroforming techniques is the topic of this paper.

2. METAL SHELL FABRICATION

2.1 Mechanical Forming Techniques

Several techniques exist for producing axisymmetric thin metal shells including metal spinning and hydroforming. These techniques involve significant cold-working of the metal and therefore produce parts with high internal stresses making them less mechanically stable. Application of special coatings to the surfaces is not integral to the forming process and therefore must be done using additional processes and vendors.

2.2 Electroforming Technology

Electroforming has been used to create exact metal replicas of various shapes and textures since 1838. It is an electroplating technology where a metal layer is deposited onto a mandrel and is then separated from it.

The part thus obtained is called an electroform. The main advantage of electroforming is that it is an atomic scale process assuring replication fidelity that is unmatched by any other technology.

Electroforming is a net-shape manufacturing technology enabling cost-effective precision manufacture of thin parts with very low internal stress, tight tolerances, fine features, and controlled surface finishes in high strength engineering metals.

2.3 Integrated Coating of Electroformed Parts

An important benefit of electroforming is that a multiple layer part can be produced allowing the core to be made from a mechanically stable metal while the two outer surfaces are composed of thin metal coatings that possess the desired optical properties. Coating options include gold for highly reflective low emissivity applications and black copper oxide for extremely low reflectivity at optical wavelengths.

2.4 Electroformed Sample Parts Produced for MODS Spectrograph

A contract to supply several sample parts for evaluation was awarded to NicoForm Corp. of Rochester, New York (http://www.nicoform.com). The parts are made from a nickel cobalt alloy deposited to 150 micron thickness on a concave mandrel. The mandrel for the MODS parts has a bead blasted finish to provide a diffuse surface finish, however specular finishes can be produced if a polished mandrel is used. The parts were successfully produced with a variety of coatings: four with no coatings, five with flat black copper oxide on both surfaces, and two with gold on the side which faces the sky and flat black on the instrument side. The gold/black coating arrangement is ideal for slit masks located inside infrared instruments to minimize radiant heating of the mask while still presenting a black surface to the instrument interior.

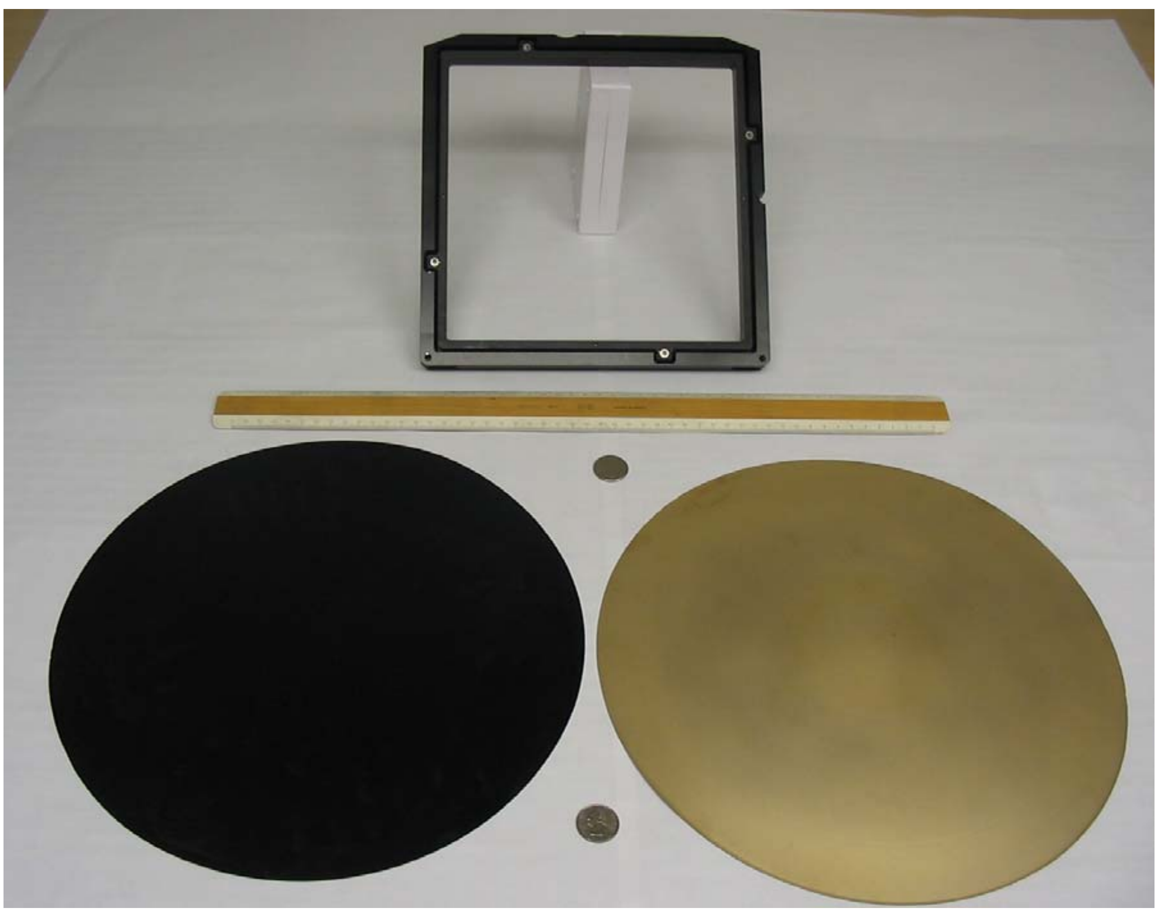

Figure 1. Photograph of two electroform substrates, one with black copper oxide coating and the second with a diffuse gold coating. A MODS mask frame is shown in the

background

3. LASER MACHINING OF SLITS

The mask substrates should be readily machinable with either CO2 lasers or YAG lasers. The optimal laser cutting parameters are under exploration with several commercial vendors.

4. SUMMARY

Electroforming technology offers an attractive option for the production of multi-slit mask substrates. The technology is well suited to the fabrication of very thin shells with tight tolerances and very low internal stress which results in excellent dimensional stability. The ability to incorporate both high and low reflectivity coatings into the part in a single process is an additional benefit. The process can be scaled to provide production rates and part costs that should be competitive with alternate approaches.

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