OPCO Laboratory, Inc.
Focused on optical applications

Introduction to Optical Replication

What Is Optical Replication?

Optical replication is a method of re-producing a reflective surface with the identical surface figure and optical performance of a master part. This process facilitates low- to large-volume production of various optic shapes, such as concave and convex spheres, flats, toroids, and diffractive optics (mirrors and gratings).

Replication involves compressing a thin epoxy layer between a master optic and a replica substrate in a manner that, upon separation of the master and substrate, results in a high fidelity transferred copy of the master's optical shape and figure onto the replica substrate. Typically, a reflective coating is applied as part of the process, resulting in a replica with the desired reflectivity.

Why Optical Replication?

The process of manufacturing custom optics by traditional methods is costly, time-consuming, and requires highly trained opticians. The gating factor is labor. While the same can be said for the production of a replication master, that is where the similarities end. Once a single master has been created, the gating process shifts from labor driven to tooling driven. This is a huge benefit when designing new products. During prototyping and early production, when demand is low, a small number of replicating tools is sufficient. As volume builds, additional tooling can be built to accommodate the volume and rate of production (cost is tailored to demand). Replication is both scalable and has the advantage of higher part to part fidelity/optical performance when compared to traditional optical fabrication methods.

Optical replication also gives manufacturers greater control over other factors that may influence product cost. For example, lighter substrates can be utilized to produce lightweight or low inertia optics. Reflective replicas can also be integrated with mounting features; thus reducing part count and lowering manufacturing costs.

How Is Optical Replication Done?

The replication process begins with an original, or master optic, fabricated using conventional methods such as machining, grinding, and polishing, typically on a glass substrate. The master can be engineered and designed to the required specifications of the final product, or, it can be derived from the customer's existing part or component.

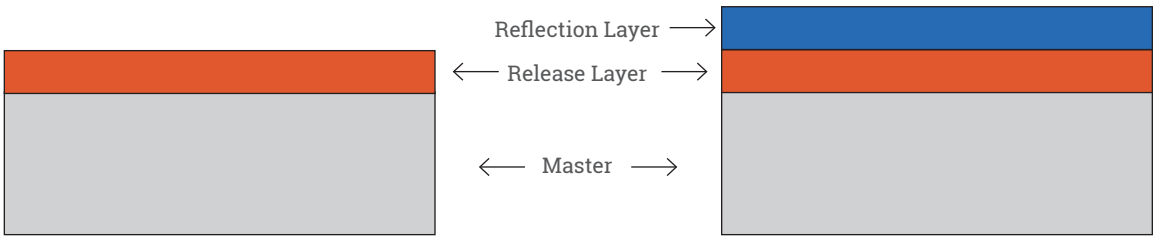
Master optics that are designed from scratch are thoroughly tested and validated using various techniques to ensure the properties of the resulting replicas meet the desired specifications. Once the master has been developed and validated, the desired substrate material is then machined. Machining tolerances are sufficient to provide a substrate suitable to the process. Optical tolerances and finishes are unnecessary. The epoxy layer will accommodate surface mismatches of this scale between the master and the replica.

The process is illustrated below.

The Replication Process

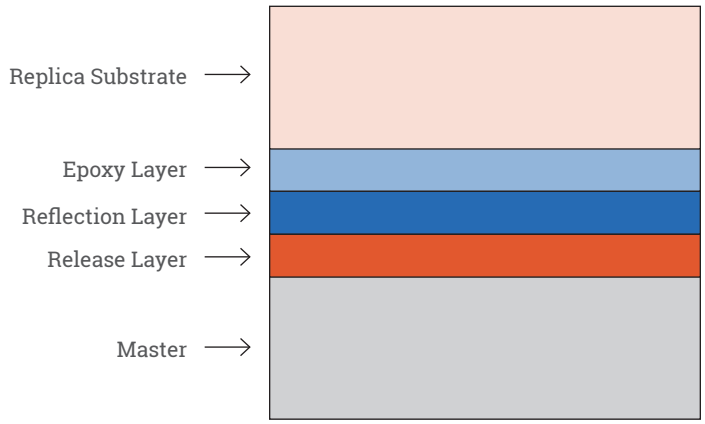
1. The master is prepared by applying a release layer prior to evaporating a metallic reflective layer. The release layer will facilitate a post cure separation of the replicated optic from the master.

A) Deposit Release Agent onto Master **B) Deposit Aluminum Reflection Layer**



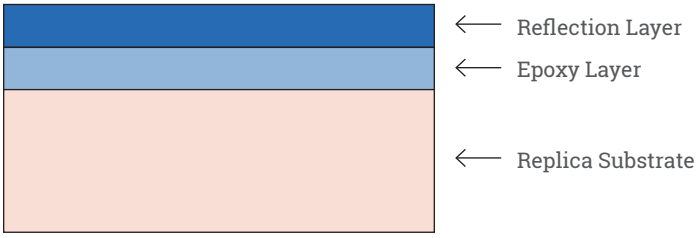
2. Next a thin layer of epoxy is applied onto the master and the replica substrate is compressed over the master.

C) Pour Epoxy and add Replica Substrate



3. Once the epoxy has cured, the replica is separated from the master with the epoxy and reflective coating intact. The surface properties of the master have now been transferred to the substrate.

D) Separate Replica



For concave reflective surfaces (where the surface curves inward), an additional tool is required. The first tool is a concave master, used to create one or more convex submasters which function as the production tooling.

The final step of the optical replication process, when warranted, involves the application of a protective coating onto the replicated substrate.

Advantages of Optical Replication

- lower per unit cost
- shorter lead times
- scalable/prototype to production
- wide choice of replica materials
- high part to part fidelity relative to conventional optical fabrication
- ability to utilize light weighted "ribbed" replicas and integrate mounting features
- integrated mounting features offer reduced assembly time and part count in final product

Technical Challenges When Selecting Optical Replication

Thermal Environment: The epoxy used in the replication process has thermal properties that must be managed. For lower temperatures, below –40°C, the concern is typically the mismatch of thermal expansion coefficients between the substrate material and the epoxy. For temperatures above 100°C, the softening point of the epoxy, optical figure degradation needs to be evaluated.

Thermal Degradation Due to Incident Radiation: The energy and power contained in the incoming light/energy and how efficiently the optical coating reflects that energy needs to be considered. Evaluating those scenarios is beyond the scope of this article. As a general guideline, as the power absorbed into the replica increases, the need to understand the effect on replica performance becomes increasingly critical in making this design trade (fabricated vs. replicated optics).

Part Count: For applications where the number of optics is limited to a single part or a few parts and is not expected to lead to production quantities, traditional fabrication methods likely offer a lower cost point.

OPCO LABORATORY Is Here to Help

The technical experts at OPCO LABORATORY, Inc. are ready to work with you and assist in the evaluation of your application to determine if optical replication is right for you. Regardless of your fabrication needs, the OPCO LABORATORY, Inc. team has the expertise and capability to provide products that meet your optical specifications. If you would like to learn more about the replication process or are interested in engaging OPCO LABORATORY, Inc. for your next optical project, contact our technical team today!

ABOUT US

We, at OPCO Laboratory, are an extension of your team. With our over 40 years of optical design and manufacturing experience, we provide total solutions from prototypes through production.

Being vertically integrated ensures we have total control over the entire process, from design through fabrication, coating, assembly, and testing, resulting in higher quality, lower cost, reduced lead times.

We serve a variety of markets, such as: Life Sciences, Analytical, Spectroscopy, Defense, Aerospace, Semiconductor, and other related industries and are ITAR Registered.

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