# Astronomical Mirror Coating Equipment

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Next-generation astronomical telescopes are designed to expand the boundaries of astrophysical science by enabling new insights into exoplanets, supermassive black holes, dark matter, and even the earliest moments of the Universe. While essential observation continues to be performed from outer space, an emerging class of extremely large ground-based telescopes is revolutionizing modern astronomy. Observatories located on the ground allow scientists to more easily maintain and service equipment, which enables the design of increasingly larger telescopes with primary mirror diameters up to 40 meters.

The backbone of every telescope is the optical mirror system, which collects light from distant objects for subsequent spectroscopic analysis. Larger mirror sizes increase the amount of surface area available to reflect light, which thereby increases spectral resolution. In order to see dimly-lit exoplanets orbiting distant stars, or galaxies more than 10 billion years old, next-generation ground-based telescopes must be designed with unprecedentedly large mirror sizes.

AGC Plasma Technology Solutions is a leading provider of astronomical mirror coating technology and counts over four decades of industrial experience in large area optical coatings and PVD equipment design. Engineers and scientists throughout the organization oversee the design, construction, transport, assembly, and on-site commissioning of a complete PVD coating system.

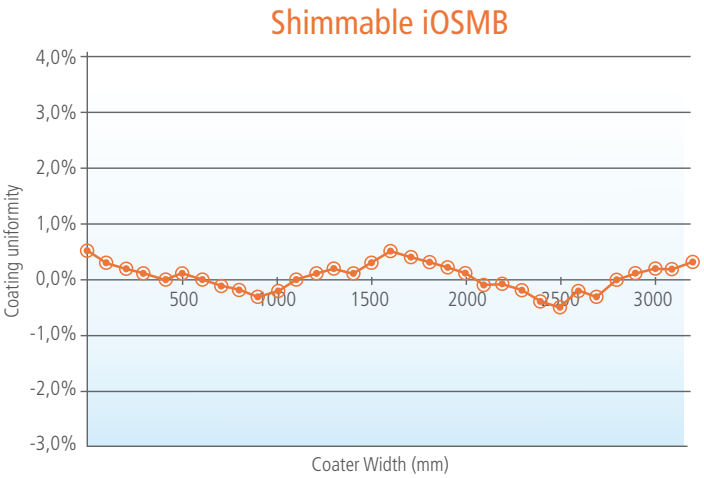

AGC is the world's number one producer of silver-based thin-film glass coatings and silver-based mirrors, having pioneered the development of copper and lead-free mirrors. It is with this unparalleled experience in designing and industrializing complex optical coating stacks for large area glass which AGC supports all aspects of astronomical mirror development and production.

Astronomical mirrors are produced by applying a reflective thin-film coating onto a ceramic mirror substrate using a low-pressure process called physical vapor deposition (PVD). The coating material can be a single metal layer or a complex multi-layer stack, depending on the targeted spectral range of light and environmental durability requirements. As mirrors grow increasingly larger and more complex, so do the engineering challenges to produce high-quality and uniform thin-film coatings on the ceramic substrate surface.

AGC M1 Mirror Coating Plant for ESO's Extremely Large Telescope (ELT)

Every telescope system is uniquely designed and therefore requires a customized coater design to allow for a range of mirror segment sizes and geometries. AGC offers batch and linear inline coating systems to enable the most technically reliable and operationally efficient coating process for any mirror design. Flexible design features allow easy future upgrade for new coating materials and processes.

AGC engineers rely on multiple pilot coaters, proprietary modeling software, and a world-class range of analytical laboratories to support process upscaling, coating optimization, and new coating development.

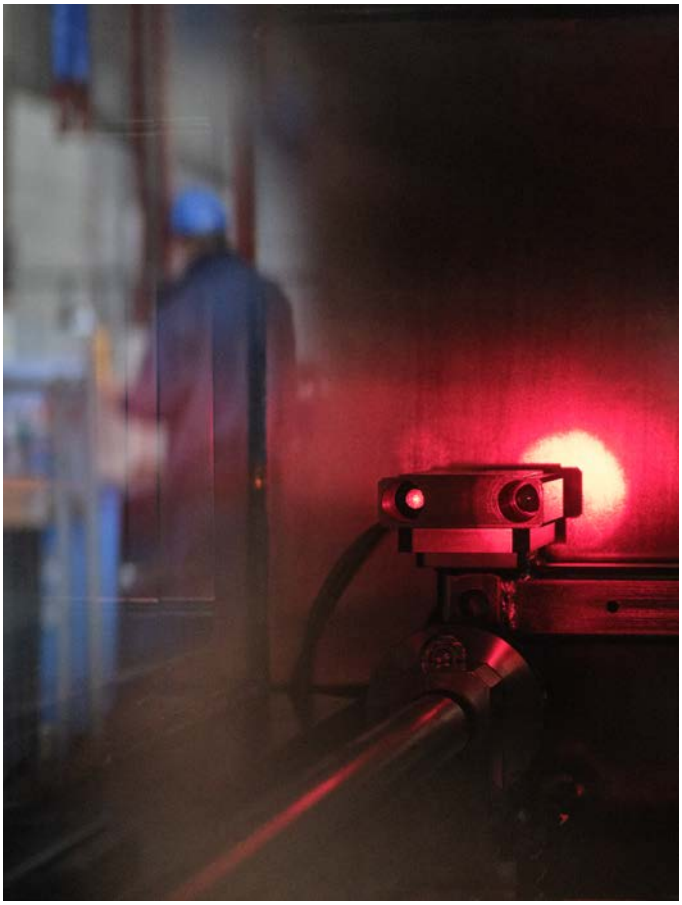



Mirror coating equipment exacts the most demanding performance specifications due to the high precision required by the telescope's instruments. Using AGC's iOSMB magnet technology, coating thickness uniformity of each individual coating layer across each mirror segment (up to 8 meters in diameter for an individual segment) is precisely controlled to within nanometers to ensure optimal reflectivity and performance. As most mirror segments are not flat, but rather convex or concave surfaces, iOSMB technology enables localized control across curved (3-D) substrates to maintain satisfactory uniformity.


Many observatories are located at high altitude to secure optimal viewing conditions with favorable weather and minimal light pollution from nearby cities. Such areas tend to encounter seismic activity which, if occurs during a coating process, risks damaging extremely valuable ceramic substrates. AGC astronomical mirror coaters are engineered with advanced stabilization mechanisms and safety features to withstand even the most aggressive earthquakes and ensure the safety of the ceramic mirror.

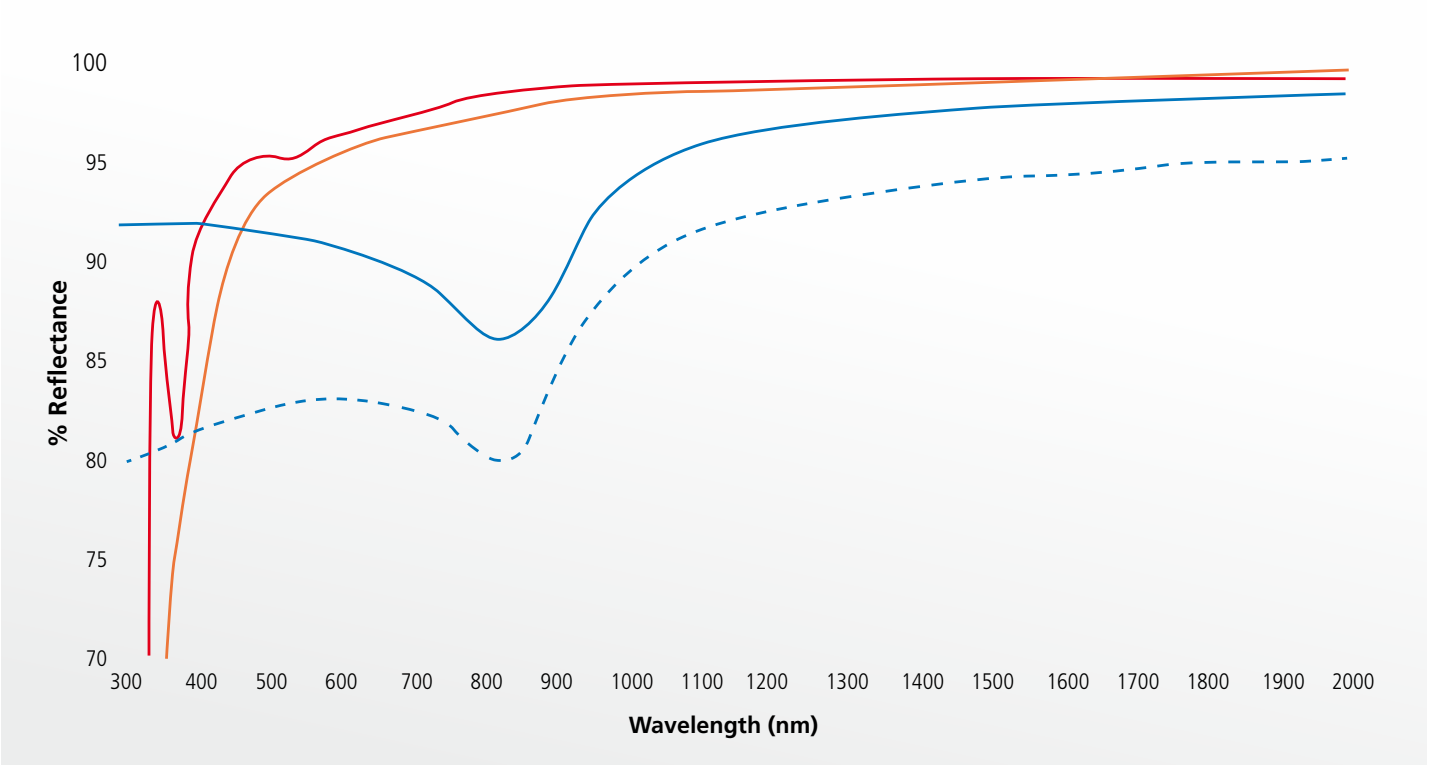

Mirror segments require periodic stripping and re-coating due to coating degradation from environmental exposure. It is therefore necessary to maintain on-site coating equipment at the observatory to maximize operational time of the telescope. Multi-segmented mirror designs with hundreds of individual segments can require an essentially continuous coating operation to ensure that every mirror segment is of satisfactory quality at any given time.

AGC Plasma Technology Solutions is a worldwide manufacturer which relies on an experienced global logistics network to safely ship large-scale goods and equipment to every region of the world. AGC coordinates with local and regional infrastructure operators to ensure safe transit of oversized cargo across oceans, canals, and mountainous roads. This is particularly important in the case of astronomical telescopes, which are typically located in remote, high-altitude regions around the world.



Advanced safety systems and sensor technologies ensure stable operation of the coater and protection of both the ceramic mirror substrate and the operators. AGC Plasma Technology Solutions relies only on state-of-the-art safety and process hardware in all its coating equipment. All equipment is designed to meet all relevant health & safety standards.

## Reflectivity of Typical AGC Mirror Coatings




## BENEFITS

- Flexible equipment platform designs allow for wide range of mirror substrate geometries and sizes up to 8 meters in diameter
- Precise nanoscale coating thickness uniformity control across large area and 3-D surfaces
- Coating stack design support of world's leading large area optical coating producers
- Earthquake-resistant design ensures safety of mirror substrate during seismic activity

| Technical Specifications | |
|---|---|
| Mirror substrate size | Up to 8 meters diameter and larger |
| Mirror substrate geometry | Flat, convex, concave |
| Equipment platforms | Semi-continuous linear inline, batch |
| Coating sources | Magnetron sputtering, PECVD, thermal evaporation |
| Coating materials | Aluminum, silver, NiCrN, SiN, $SiO_x$, others |
| Coating thickness uniformity | +/- 0.3% with iOSMB magnet technology |
| Spectral range | 330 nm – 25,000 nm UV-Vis-IR |
| Base pressure | Down to 10^-7 mbar |
| Quality control | QCM, RGA, customized mirror jig for direct reflectometry |

**AGC Plasma Technology Solutions** is the industrial coatings unit of the world's largest glass producer AGC Inc. (Asahi Glass Company) and a one-stop provider for plasma-based vacuum coating equipment. The group leverages decades of thin-film coating experience on large area glass products to innovate and develop new industrial solutions from proof-of-concept to mass production. AGC Plasma Technology Solutions operates R&D and production facilities across the US, EU, and APAC.

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