

# **How to control PGM (Precision Glass Molding) manufacturers from the customer's point of view and Consideration in Acceptance Sampling for PGM Optical Elements**

By Michael Hausner\* (April 2025)

## **Preface**

This article briefly refers to the process of molding optical elements, but mainly to how to test and inspect the molded elements, considering the process and the relationship between the manufacturer and the customer from the customer's point of view. The goal is to obtain elements that conform to the specified requirements in the shortest possible time, and to be confident after completing the tests (inspections) that the approved elements meet the requirements. Let us remember that the **PGM** process is primarily relevant for manufacturing **large** quantities of elements (thousands!), which makes this process significantly more economically profitable. Therefore, when designing the process, we need to consider how and what to test, the manufacturing process of **PGM** elements, and the control exercised by the customer according to their procedures. These procedures, essentially the customer's procedures, should also take the

The process of manufacturing optical lenses by Precision Glass Molding (PGM) differs from the traditional Spindle Polishing process and from the Diamond Turning (DT or SPDT - Single Point Diamond Turning) process. Therefore, some considerations in testing the elements made by the PGM process should be taken into account.

The test (inspection) of the molded elements is mostly based on the relevant statistical standards for Sampling Procedures: MIL-STD-105A (1989), ANSI/ASQC Z1.4-1993 or Zero Acceptance Number Sampling Plans by Squeglia (6<sup>th</sup> edition, 2023).

## **Short description on PGM (Precision Glass Molding)**

While in the traditional Spindle Polishing process or in the Diamond Turning (DT) process, each surface is manufactured separately by polishing or by the DT process, in the PGM process the glass gob is melted and pressed by a mold with the opposite side of the surface, so the actual surface of the optical element receives a precise replica of the required surface. The molds themselves are produced by the DT process, considering the requirements of the element's surfaces as specified in the relevant drawing.

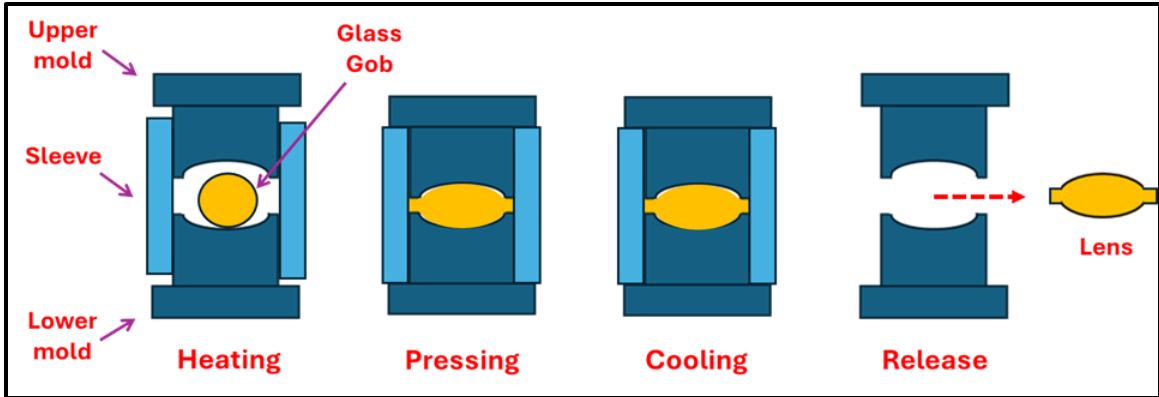


Fig. No. 1 - Basic PGM (Precision Glass Molding) process  
(For more details, see the references)

**The steps for controlling the PGM process of optical elements from the customer’s point of view**

**Assumption:** For manufacturing many (thousands or more) optical elements, the manufacturer needs, for example, five molding machines.

**The steps**

1. Each machine and its molding mold should be marked so that changing these elements between the five machines does not occur.
2. The marks can be as follows: for machine **No. 1**, we shall mark: Upper Mold will be **1u**, Lower Mold will be **1l**, and sleeve will be **1s**. Similarly, for machine **No. 5**: **5u**, **5l**, and **5s** (see Fig. No. 2). All molds should be marked in a consistent manner. The manufacturer’s procedure should ensure that during production, changing molds of different machines will not be possible.

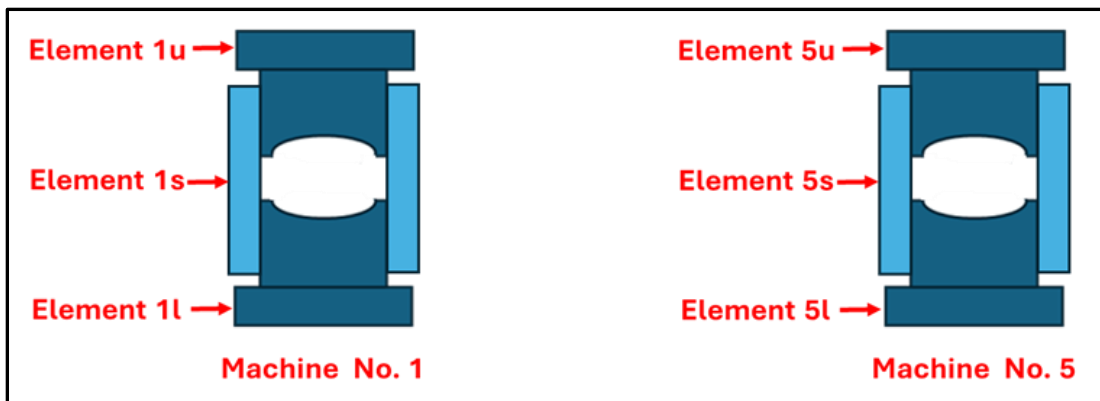


Fig. No. 2 – Marking

**Marking possibilities:**

**Element 1upper or Element 1u or Element 1up or just 1u or 1up and so on or any other way according to manufacturer's priority or elements size limitations**

3. During the molding process, the molding lot/batch number should identify the molding of each machine. This identification is important for the next step, which is the coating. Essentially, we will have five different lots related to the molding. The number of components in each lot will be decided by the manufacturer.
4. Coating. The best practice is that coating lots should be traceable to the molding lots. The manufacturer should always establish a correct process so that it will be possible to identify which molding elements or coating batches being tested belong to.
  - All the above steps should be reviewed and approved by the customer.
  - For every new element's (FA – First Article) production – the customer will perform FAI (First Article Inspection) for each machine.
  - If for any reason (damage, wear or else), any Mold of the molding machine will be replaced by the manufacturer, the customer should be informed and decide whether to perform a new FAI for the elements connected to the machine with the new Mold.
  - Now, an important issue: if molding and coating lots are properly identified for their traceability, then when a deviation is found, only the relevant lot should be addressed, rather than the entire shipping lot, which may include elements from all molding machines and all coating lots.

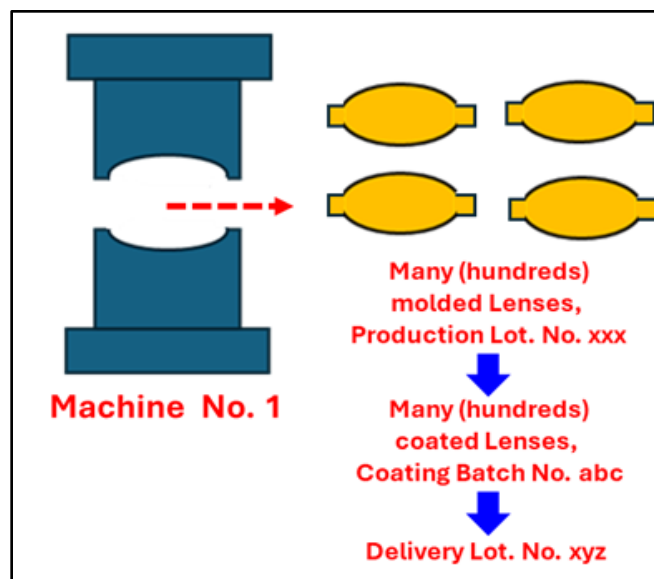


Fig. No. 3 - Traceability for production of PSG - Inspection Records of Delivery Lot. No. xyz from Machine No. 1, which includes the clear identification Production Lot. No. xxx and Coating Batch No. abc.

## Consideration in Acceptance Sampling for PGM (Precision Glass Molding) Optical Elements

Replicated main surfaces of the mold represent drawing and element requirements. Optical surfaces in the drawing of Fig. No. 3 are spherical, but they can be aspherical, aspheric/diffractive, or flat, so drawing requirements will differ accordingly.

### 1. Drawing requirements for our example

a) See Fig. No. 4

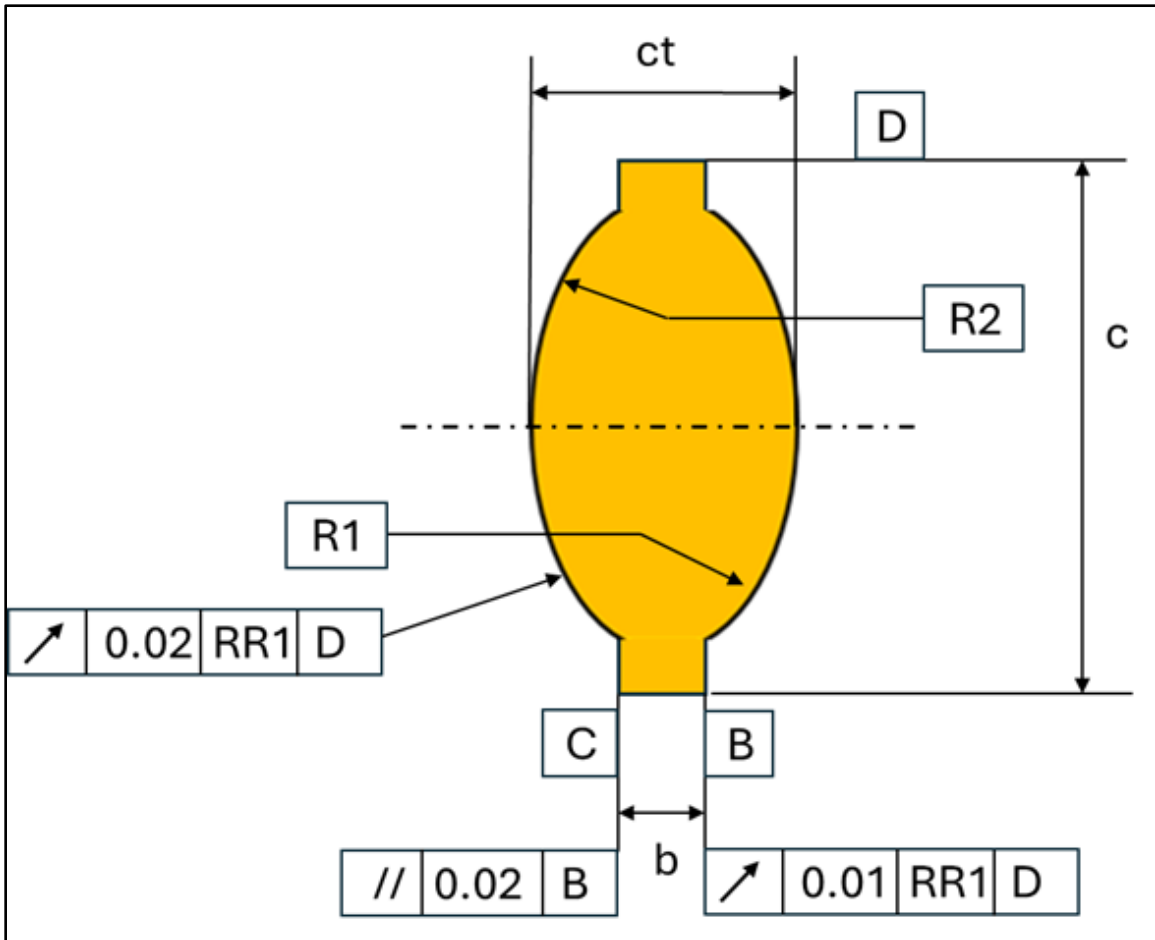


Fig. No. 4 – Drawing requirements

b) Additional requirements: surfaces Power, irregularity, Flatness, RMS, Roughness, Scratch and Digs.

2. Replicated surfaces for our example (see Fig. No. 5)

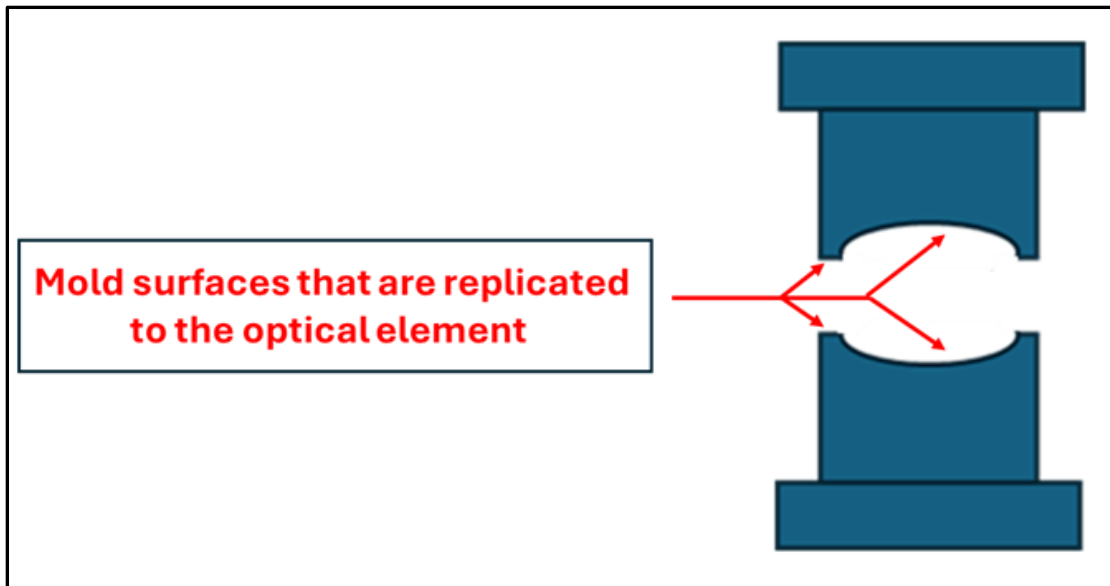


Fig. No. 5 – replicated surfaces

3. If the steps for controlling the PGM process of optical elements are implemented correctly, and we know that the surfaces of the elements are being replicated completely from the mold's surfaces—albeit in an inverted manner—consideration should be given to Acceptance Sampling when determining the sample size for different requirements related to item characteristics. This is because certain parameters are copied and will not change, while other parameters may exhibit deviations. Therefore, in accordance with the requirements of a specification or procedure that defines the sample size for inspection (e.g., AQL of 2.5%), the sample size for parameters that are replicated can be significantly reduced, whereas the sample size for other parameters—where nonconformance might occur—may need to be increased.

In our example, the following replicated parameters and sample size can be significantly reduced: spherical surface radii and irregularity (for other surfaces: irregularity and power or flatness for flat surfaces, and roughness along with additional requirements specified in the drawing for aspheric and diffractive surfaces). Other following parameters' sample size can be increased: central thickness (ct), run out ( $\nabla$  centering), shoulder width (b), parallelism ( $//$ ) of the shoulder, diameter (d) and others according to drawing parameters. Of course, the basis for reducing or increasing the sample size is the AQL specified in the drawing or procedure requirements.

## Actual Replicated Spherical Surfaces of Optical Lens

As we can see clearly in Fig. No. 6, the replicated surfaces display the processing marks resulting from the Diamond Turning (DT) process of the mold. The marks indicate the roughness of the surface, which is defined in the element's drawing. In Fig. No. 7, we observe the scan of the replicated aspheric surface, also showing the roughness marks.

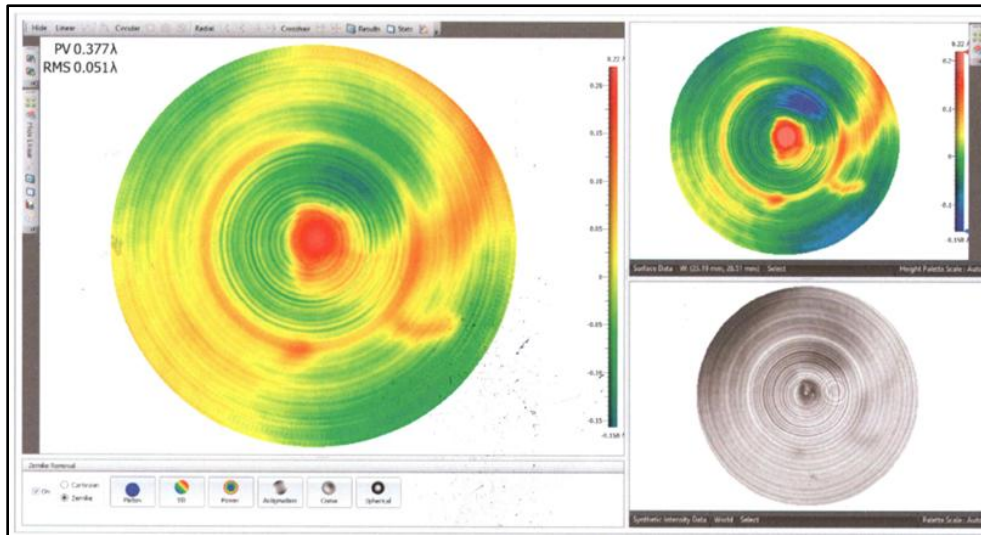


Fig. No. 6 – spherical surface of molded optical element as seen by ZYGO Interferometer

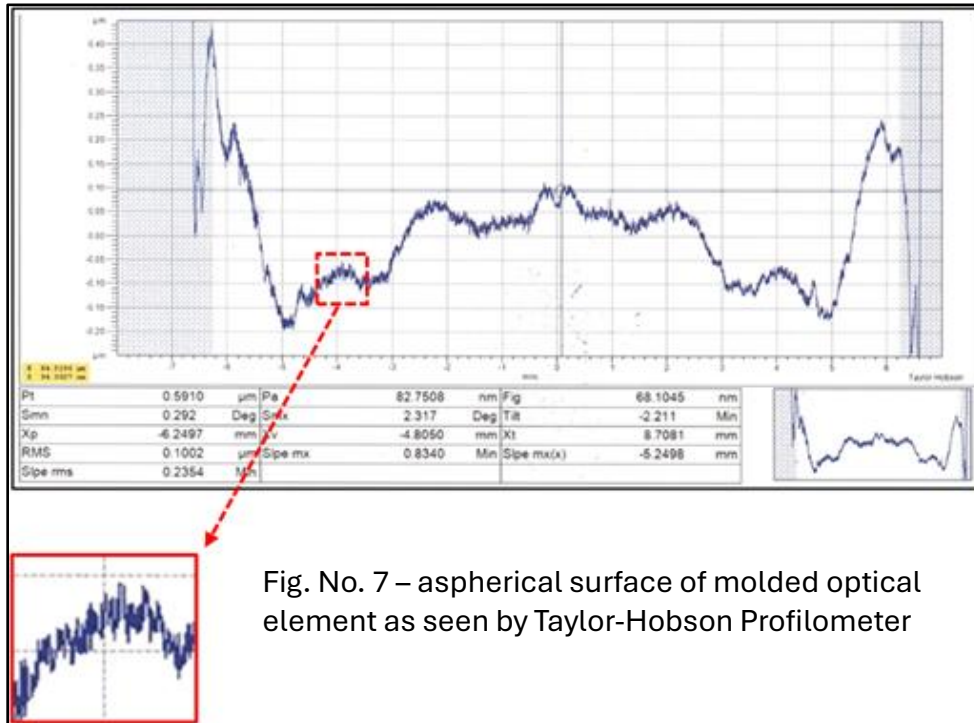


Fig. No. 7 – aspherical surface of molded optical element as seen by Taylor-Hobson Profilometer

## **Conclusion**

All the above is based on experience. It is the customer's duty to decide how to control the manufacturer's PGM (Precision Glass Molding) process for optical components. The customer's organization should establish proper and clear procedures that will serve the inspection process of molded elements. The procedure should include the relevant necessary AQL, which indicates the sample size according to the lot size and should consider the parameters related to the molding process that need to be inspected.

The purpose of consideration is to improve the inspection process and to reduce inspection time without reducing the tested element's quality.

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\* **Michael Hausner** – I have about 40 years’ experience in inspection and tests of optical elements: incoming and at the source of production, review of optical elements suppliers, writing procedures for optics inspection, handling of nonconformance optical elements and corrective actions, consulting, and training for inspection of optical elements and Quality Assurance. You can visit my website: <https://www.michael-hausner.com>

## **Acknowledgments**

I would like to express my gratitude to the following experts in optical engineering and in the inspection of optical elements from whom I received help in reviewing and correcting:

**Tali Mutat.** - Optical Engineer with a M.Sc. from the Technion, Institute of Technology, Haifa, Israel. Faculty of Physics. Specializes in designing optical systems for imaging and non-imaging applications in the IR and VIS range.

**Avinoam Fishman** - has about 50 years’ experience in inspection and tests of optical elements: incoming and at the source of production, review of optical elements suppliers, writing procedures for optics inspection, handling of nonconformance optical elements and corrective actions, consulting, and training for inspection of optical elements.