Bench-Top Precision Glass Molding Machine

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Introduction

Extensive growth of opto-electronic technologies has created a demand for high quality aspheric lenses and has driven the industry toward an environmentally friendly process for manufacturing of these lenses called Precision Glass Molding (PGM). Based on the current understanding of thermal and mechanical response of glass at elevated temperatures, there is a need for a new type of machine which will allow the user to control specific process parameters.

Our goal is to define the functionality and measure the accuracy of a bench-top PGM machine specifically designed to allow full control over process parameters.

Machine Functionality

•Mechanical

Electric actuator - provides movement along the vertical axis of the molds and the force needed for molding the glass.

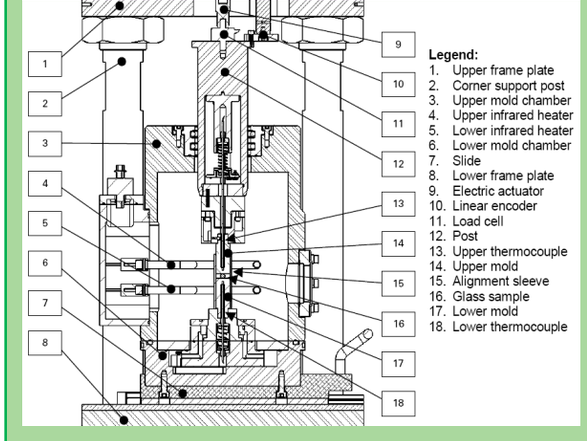
Upper molding chamber – provides a chamber which can be purged of oxygen and backfilled with nitrogen to create an inert atmosphere.

Pneumatic cylinders – raise and lower the upper molding chamber.

Upper post – connects the electric actuator and the upper mold.

Lower post – supports the lower mold and sleeve, slides horizontally toward operator to allow for easy placement and removal of glass sample.

Upper and lower molds – polished planar Tungsten Carbide (WC) molds, surrounded by an additional WC sleeve for alignment.



•Instrumentation

Spring loaded Thermocouples – placed inside each mold close to mold surfaces.

Load Cell– reads the force applied by the actuator during all stages of the molding cycle.

Linear Encoder – Measures the position of the top mold during all stages of the molding cycle.

Infrared heaters – two omega shaped heaters, one positioned slightly above and one slightly below the glass sample, providing infrared radiation.

PID controllers – manage the ramp rates of the heaters and are pivotal to the heaters maintaining a constant temperature.

•Molding Cycle

Purging – vacuum removes oxygen from the molding chamber and replaces it with inert Nitrogen to prevent oxidation of the WC molds.

Heating – IR heaters raise the temperature in the molding chamber to the molding temperature.

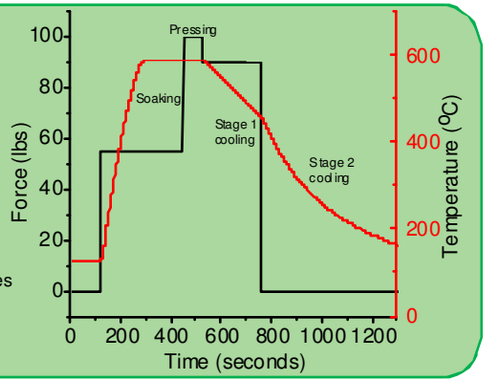
Soaking – a delay in the process where the temperature is held constant to allow for the glass to thermally equilibrate.

Molding – a force is applied to the glass, pressing it into the desired shape.

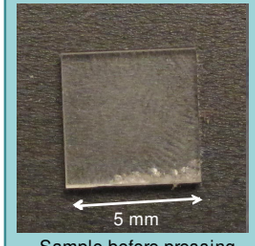
Cooling – multiple stage cooling in which the power to the heaters is reduced and nitrogen flows through the molding chamber.

Experimental Repeatability

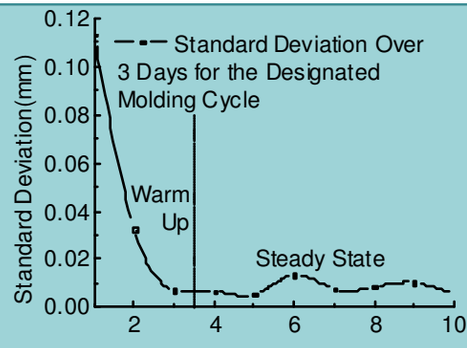
- Samples: 5mm x 5mm x 2mm LBAL-35
- Process parameters:
  - Molding Temperature – 587 ^{0}C
  - Soaking Time – 4 minutes
  - Molding Force – 100 lbs
  - Cooling Cycle – Two stages
    - Stage 1 – ~30 ^{0}C/min and 90 lb force
    - Stage 2 – max cooling and 0 lb force
- 10 samples were run in succession each day
- Thickness of each sample was measured several times after pressing

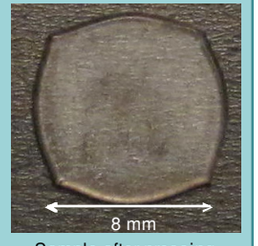


Results



Sample before pressing





Sample after pressing

	Individual (maximum)	First Cycle (across 3 days)	Warm Up (across 3 days)	Steady State (across 3 days)
Standard Deviation (µm)	2	113	73	9
Total Range (µm)	6	246	246	19

Standard deviations across cycles

Conclusions

- The GP-5000HT is a small scale glass molding machine with functionality similar to a full-production molding machine but with the versatility needed in scientific research.
- Standard deviation on the thickness of pressed LBAL-35 samples of 9 µm has been achieved using this bench-top precision glass molding machine.
- Two distinct phases are defined during the evolution of the molding cycles to explain performance:
  - A warm up phase which is characterized by a large standard deviation on the pressed thickness.
    First three pressing cycles — Standard deviation – 73 µm
  - A steady state phase in which the standard deviation decreases considerably.
    Fourth cycle onward — Standard deviation – 9 µm

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