Introduction

The manufacture of micro-optic lenses for the mobile phone industry continues to grow with the increased use of smartphones. The mass production of micro-optic lenses has become easier than ever, particularly since the introduction of molding techniques for glass lenses and injection molding methods for the popular plastic lens.

The ease in making aspheric and other structured lenses makes automated production of these lenses possible, and significantly reduces the lens production time. In addition, to the use of plastic injection or glass molding techniques, advanced coating technology has greatly reduced mass production costs.
Importance of the lens mold measurement and its key parameters

Quality control of lens molds is very important for lens development and production, particularly for the popular plastic lens, whose quality is mainly depends on the lens mold. Precise measurement of the camera lens mold is becoming more challenging for metrologists seeking to optimise the complete process chain in an industrial environment. This is because the slope of lens surfaces is getting steeper (up to ~65° or more), their size is getting smaller (down to ~1mm), and tolerances are getting tighter in the lens mold industry.

The common type of lens mold used in most industries is an aspheric shape. Aspheric form error and the absolute position error to the peripheral rim/mold mounting shafts are important parameters because they are directly reflected in the quality of the lens products. These factors affect the focus quality, and therefore reduce the optical efficiency.

Measurement techniques

Due to the requirements of the mobile phone lens mold industry a fast, accurate 3D non-contact measurement technique with large slope measurement capability and flexibility is desired.

Contact measurement techniques are used by most lens mold industries for quality control of the lens mold. These kinds of measurement lack flexibility for checking relationships between the axes, such as the absolute position error of the aspheric lens mold to its peripheral rim/shafts. Non-contact techniques such as CSI (coherence scanning interferometry), are not suitable for smart phone lens mold measurement, due to the limitations of slope measurement for the objective lens. For scanning confocal microscopy, although the surface slope capability is much improved in comparison to CSI; its limited vertical range, long measurement time and inability to measure lens off-axis error excludes it from smart phone lens mold applications.
Advanced optical metrology tool for lens mold (LuphoScan platform)
- Multi-Wavelength Interferometry (MWLI)

The LuphoScan platform is a patented interferometric scanning metrology system based on multi-wavelength interferometry (MWLI). The systems are designed to perform precise non-contact 3D form measurements, mainly of rotationally symmetric surfaces such as aspheric lenses. The system is based on a combination of scanning four-axis geometry and a non-contact interferometric (MWLI) probe. The basic principle for measuring the 3D form error of spherical, aspheric or other rotational objects, is that the probe is guided in a programmed curve over the surface of the object such that the distance between the probe and the object is kept constant and the probe is always presented perpendicular to the surface of the object. The absolute measurement capability of the MWLI sensor technology makes its function flexible, even catering for surface measurements such as segmented objects as it allows for interrupted beams.

Benefits of LuphoScan measurement
- Non-contact
- 3D
- Super-fast
- High accuracy
- Function flexible

The scanning process is accomplished by means of a MWLI point sensor; its position being controlled by 2 precise linear stages and 1 precise rotary stage. The MWLI point sensor continuously measures the distance to the object surface by following a programmed curve, while the object is rotated on a high precision air bearing spindle, so as to perform a spiral scan over the whole surface. As a result real 3D topography can be obtained quickly (normally in a few minutes) to reveal the true surface form error from the designed shape and the defects of the object surface.
LuphoScan platform
- Multi-Wavelength Interferometry (MWLI)

Metrology frame
- 4 – axis geometry:
  - 2 linear roller bearing stages (R, Z – positioning of the probe)
  - 1 rotational roller bearing stage (T – tilt of the probe)
  - 1 rotational air bearing stage (C – rotation of the object)
- Independent metrology frame to compensate for axial errors in the principal plane
- 3 reference probes determine the position of the object probe within the reference frame
- Temperature compensation

Scanning point measurement
- Spiral scan
- Probe presented normal, equidistant to the measurement surface
- Probe follows the designed curve while measuring the distance to the object surface

Non-contact 3D topography measurement for rotational parts
- Applications – optimized for rotationally symmetric parts; can also handle some complex shapes like axicon, segmented, annular and asphero-diffractive lenses and slight free form parts
- Form measurement accuracy – ± 50 nm (2σ) over the whole measurement range
- Absolute measurement – flexible functions
- Measurement range – ~1.0 mm to ~ 420 mm (diameter)
- Maximum slope – up to 90° for convex lens and 65° for concave lens
- Materials – capable of measuring various materials and surface finishes
Case study

In this note, the measurement method of a LuphoScan system is illustrated using an example of a very small lens mold measurement.

Characterisation of smart phone camera lens mold

A typical concave aspheric camera lens mold was tested using a LuphoScan system, with a 2.4 mm clear aperture, 0.5 mm sag and 55 deg maximum slope. The tests were carried out by applying the ‘Interlignment Module’ in LuphoScan software. The form error of the aspheric optical surface and its absolute correlation to the mold rim and mountings were measured. In addition, its tilt and decenter error (off-axis error) with respect to the selected mold mounting shaft axis can also be determined in the same software module.

Procedures

• Measurement of the aspheric optical surface form.
• Position error measurements of the aspheric optical surface to the user defined reference ring/shafts
  a. Measure tilt error with the user defined reference rim along with its height with respect to the optical surface form axis
  b. Measure decenter (with plane A)
  c. Measure decenter (with plane B)
Measurement process of a cell phone lens mold

1. Measure the aspheric optical surface

2. Measure tilt error and height with the user defined reference rim

3. User defined reference plane A

4. User defined reference plane B

Notes - the reference ring/planes and axes for calculating the position errors including the decenter errors and tilt errors, can be defined freely by the user such as roundness planes or 3D cylindrical sections
Example of measurement results from a lens mold

Aspheric optical surface form measurement results

Position error results
Application note A150: Smart phone lens mold

All the measurements were completed automatically in one cycle, without operator intervention. The user only needs to type in the aspheric designed parameters once and select the desired reference rim/planes or 3D cylinders before the measurements. The lens mold form measurement was completed in about 3 minutes, the position error measurements were done in 3 minutes. All the required results, such as form error and position errors, can be displayed at the end of the measurement.

Summary

A LuphoScan system combines the advantages of high precision non-contact 3D profilometry, and large slope measurement capabilities. It is a fast, non-destructive, precise and function flexible 3D non-contact metrology tool. Accurate 3D topography of the lens mold and its position errors can be obtained automatically within a few minutes.

LuphoScan systems can greatly help the lens mold manufacturer to improve the optical surface of a lens mold and its position relative to the mold rim and mold mounting shafts.

Some other relevant application notes

A139 High precision measurement of steep-sided miniature aspheres
A140 Advanced contact and non-contact metrology for characterisation of optical lenses
A141 Unique measurement capability for steep-sided miniature hemispheres
A142 Unique measurement capability for steep-sloped small hemispheres
A143 New software to reduce set-up time for grinding and diamond turning
A144 Definitive assessment of radius accuracy and form error for steep moulds
A148 Advanced metrology solutions for small optics