High Precision Optical System Manufacture

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Diamond turning machines are used in the precision electro-optical industry to produce non-spherical surfaces on crystalline and metal materials in order to produce optical components mainly for use at Infra Red wavelengths in thermal imaging systems.

The requirements driving the use of diamond turning are the optical system demands for aspheric and diffractive surfaces and the use of materials that are not possible to produce by conventional polishing methods.

Materials commonly used include Germanium, Zinc Sulphide, Zinc Selenide, Silicon, and the Chalcogenide IR materials. Aluminium, Copper, Brass, Bronze, electroles nickel and plastic optical materials such as acrylics are also commonly machined. Steels and glasses cannot be reliably diamond turned as high temperature chemical reactions at the tool tip change the diamond structure to a graphite form.

Diamond turning lathes typically use hydrostatic slideways with straightness better than 0.15 mm and positional resolutions better than 8.5 nanometres. They typically employ air-bearing spindles, granite bases, and provide extreme loop stiffness. The machines can offer multi axis capability, with vertical revolving tool post B axis control to enable the manufacture of hyper hemispherical surfaces maintaining a tool normal to the substrate condition. Latest developments include slow tool servo control where the use of an encoded spindle allows the slides control to be linked to the spindle position allowing production of non-rotationally symmetric three-dimensional optical surfaces. This allows low frequency high amplitude features to be produced such as toric surfaces.

Fast tool servos, which again are linked to spindle position, are driven by piezo activators and provide a high frequency low amplitude features to be produced, such as prismatic surfaces on an underlying contour.

Conventional polishing has also been modified to allow production of aspheric surfaces by means of dedicated CNC controlled polishing machines that employ sub-aperture deterministic polishing systems controlled by software.

Removal of glass by polishing is an averaging process, not direct removal, hence the control software has to take into account the removal rate for specified conditions (influence function) when determining dwell times over any particular annulus of the lens being polished to remove the correct amount of material to reduce the measured lens profile to the desired profile. Aspheric polishing control software is therefore a more challenging area than straightforward diamond turning control software.

Various aspheric polishing methods are used, the key requirement being as near a gausian influence function as possible, and repeatability. These methods include magnetorhealogical polishing using magnetically stiffened polishing media, inflated bonnet precessional polishing, and fluid jet polishing.

All of these developments allow the production of more accurate, lighter, optical systems with a reduced number of components and will continue to be a growing component of the high tech opto-electronics manufacturing industry.