Diffraction Free Surface Finish Using Corning's LEC Process

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Corning NetOptix

For years, single-point diamond turning has been associated with producing mirrors that are only suitable for infrared applications. Aluminum is typically the material of choice for diamond turned mirrors because of its relatively low cost, structural and thermal stability, and its compatibility with the turning process, but the diffractive effects of the diamond turning "grooves" were generally too severe to provide adequate performance in the visible and UV spectral ranges.

Newer process developments, such as diamond machining of high-purity aluminum that has been deposited on an aluminum blank, can be effective at reducing measured RMS roughness. However, these processes are costly and still tend to yield highly diffractive (and sometimes "streaky") surfaces that can be difficult to clean. Other quality problems such as "crazing" and poor adhesion of the aluminum, have also been reported. Diamond turning and subsequent post-polishing of electroless nickel plated aluminum can be an option for production of UV and visible quality mirrors, particularly if resistance to harsh environments is required, but this process also adds significant cost, weight, and complexity to metal mirrors while also having the negative effect of bimetallic stresses and the resulting instability over temperature change.

There have been efforts over time to develop a process for polishing aluminum directly. Some of these have met with limited success; most provide reduced surface roughness and diffraction but are time-consuming and risk significant change to the surface figure accuracy of the mirror.

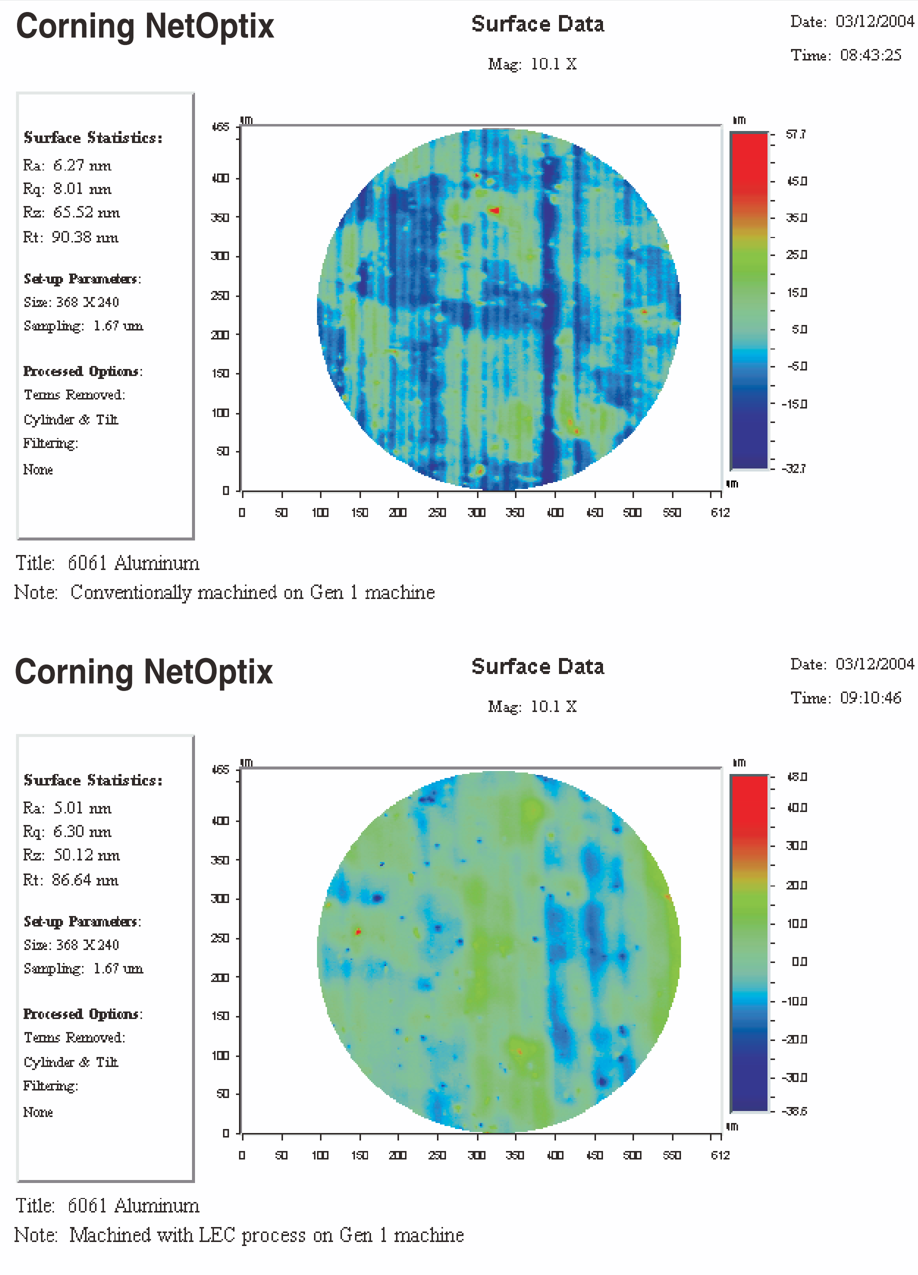

Figure 1

Corning NetOptix has developed a new evolution of the diamond turning process for dramatically reducing the diffraction effects of diamond turned aluminum mirrors. This process, called "LEC", combined with our most recent materials research, may finally allow production of deep UV-compatible mirrors in aluminum without added expense or negative side-effects.

LEC is a unique process that dramatically reduces, and in many cases completely eliminates the diffractive effects associated with diamond turning without the requirement for exhaustive polishing and without the danger of altering the surface figure of the mirror. Typically, the residual surface roughness of an LEC-processed mirror is dictated by the "grain" of the material (see fig. 1). The first surface roughness plot (measured with a WYKO NT2000 non-contact profilometer) shows roughness and surface map of a 1mm section of a traditionally diamond machined mirror. The second plot shows the same section of an identical mirror manufactured with the LEC process. We can see that surface roughness (measured in RMS) has been reduced by nearly 50%, but more importantly, that the scattering effects have been dramatically reduced and almost completely randomized. The particulate matter inherent in the alloy is now the most prominent contributor to surface roughness and scattered light. The LEC process has the added benefit of improved surface "cosmetics" (i.e. scratch-dig) over conventional diamond turning, and leaves a very pristine surface that is ready for any evaporative coating. The process is compatible with a variety of materials typically associated with diamond turning, including aluminum, copper, nickel, and others.

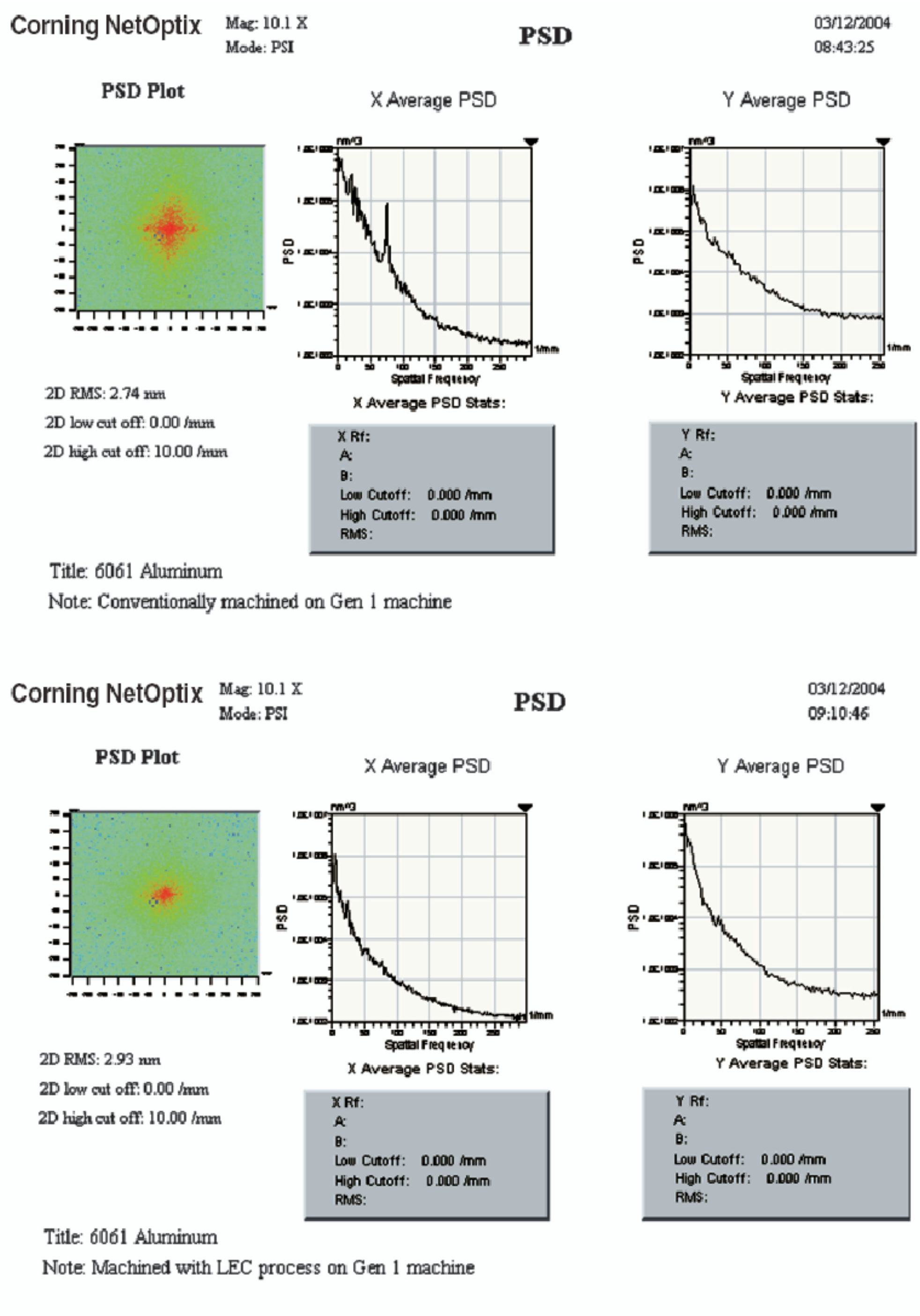

Figure 2

Functional analysis of the improvement in surface quality can be quanitified by measuring PSD and BRDF, which are generally accepted measurement standards for quantifying the effects of scattered light in numerous applications. Figure 2 shows PSD measurements for both a traditionally diamond machined aluminum mirror and for an LEC-processed mirror. Note that in the Y-axis, measurements are quite similar. This is because the incident rays of light run parallel to the diamond turning "grooves", which while still producing some scattering of light, does not yield a "grating" or diffractive effect. However, note the significant difference in PSD measurements in the X-axis, where the diffractive effects of the traditional diamond turned mirror are quite evident. The LEC mirror shows a very smooth PSD curve with relatively few "spikes".

An even more obvious difference between the two mirrors can be seen in Figure 3. Pictures taken of a 633nm laser spot reflected off both mirrors shows how the traditionally diamond turned mirror reflects numerous "satellite" spots (top photo), while the LEC mirror only reflects a single laser spot (bottom photo).

Since material grain structure tends to limit surface roughness when the LEC process is applied to diamond turned mirrors, Corning has utilized its materials expertise to try to identify ways to improve surface finish even further. Through innovative treatment methods applied to

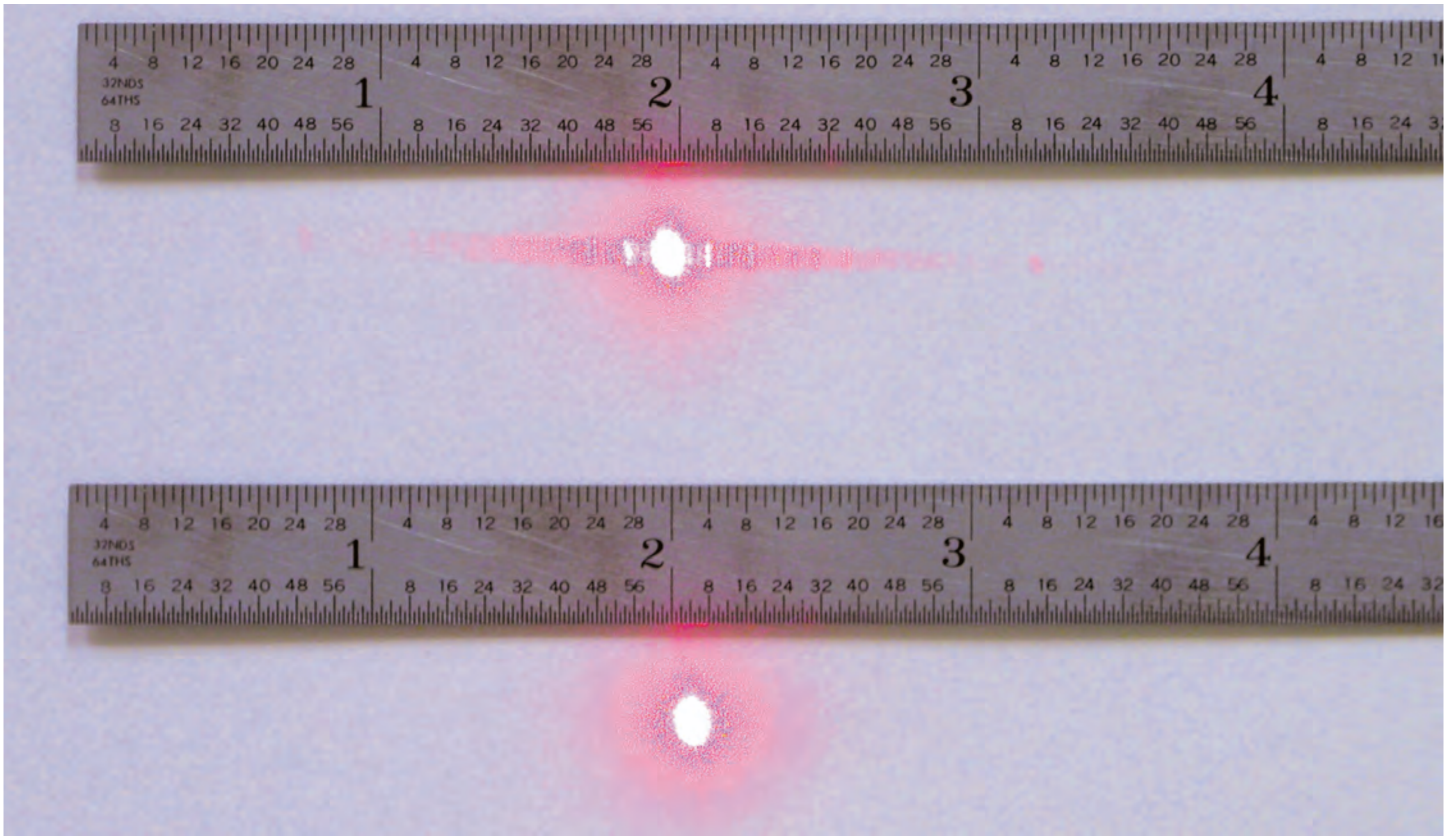

Figure 3

existing aluminum alloys, we have been able to produce aluminum mirrors that, after LEC processing, yield surface roughness typically thought to be unachievable for diamond turned aluminum (see fig. 4), and more importantly, the mirrors are completely free of any diffraction effects. Surface roughness on the example shown is approximately 21Å RMS.

Through use of these highly specialized processes, aluminum mirrors can be produced which are fully functional for imaging use in deep ultraviolet applications, while retaining all of the structural, weight, and thermal advantages of aluminum.

Latest-generation 3-axis diamond turning equipment, combined with creative fixturing and programming techniques, can also produce completely non-symmetric (or "freeform") surfaces. This capability opens up numerous opportunities for maximizing optical systems designs. In addition, this machining technique allows production of far-off-axis components that previously would have required either conventional grinding and polishing or an enormous swing capacity on a conventional diamond turning lathe.

By combining current state-of-the-art diamond turning technology with innovative new processing techniques, Corning NetOptix has been able to bring the functional capabilities of diamond-machined mirrors to an entirely new level of performance. The benefits of this technology are significant. Lightweight, thermally stable, high-accuracy mirrors with integral mounting features can be produced in volume with exceptional accuracy and consistency for visible, ultraviolet and multispectral applications. Even in low volumes, the benefit for military, aerospace, and remote sensing applications could be tremendous.

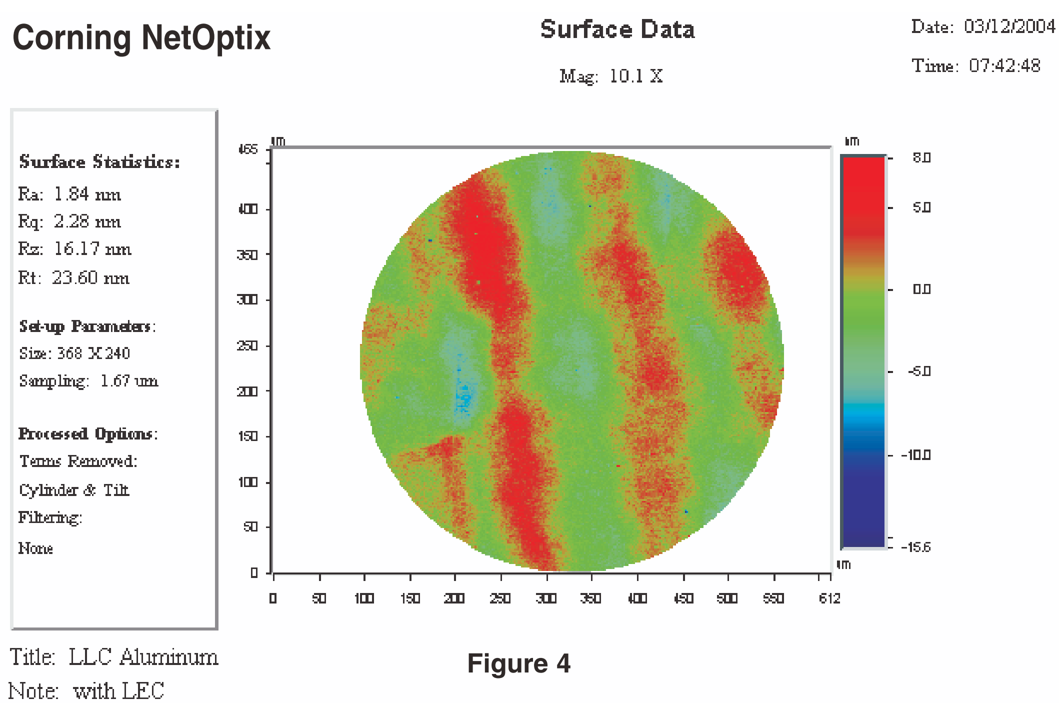

Figure 4

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