nique. By arranging the shear so that it lies along the direction of the texture, the texture is absent from the interferogram. Figure 1 shows two interferograms from a surface with a regularly grooved texture. The interferogram on the top shows both the surface defect and the regular surface texture. However in the lower interferogram, the shear lies along the direction of texture and hence only the surface defects are seen.

This work is being done in conjunction with Shell Research Ltd and we will present the design of the interferometer and also experimental results.

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8:30 am

Deconvolution of local surface response from surface topography in optical profilometry by a dual-scan method

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In optical profilometry the measured raw data represent a convolution of local surface response to the probing light and surface topography. For example, the reflectivity variation or the spatial gradient of surface modulate the profilometric signal. Almost all the existing methods use interferometric lock-in techniques to eliminate the effect of local surface modulation. However, these methods (e.g., Refs. 1–3) employ complicated servo-feedback circuits and/or data-coding procedures, and most of them are not general enough to be useful for other profilometries such as atomic force microscopy (AFM) or near-field optical microscopy.

In optical profilometry, a sample-height-dependent signal is measured and then translated into surface profile by calibration procedures. The measured signal I and the surface profile $z(x, y)$ are related by:

$$I(x, y, z) = S(x, y)F[kz(x, y)], \quad (1)$$

where S represents local surface properties that modulate the signal, F is the height-sensitive function, and k is a proportional constant representing the sensitivity of measurement. We developed a simple method to separate $S(x, y)$ from $z(x, y)$, which enables one to obtain both the topography and the surface response profile from the same measurement. The idea is to scan the sample twice, with a small offset in z for the second pass. This gives two independent equations for solving the two unknowns $S(x, y)$ and $z(x, y)$. If the offset Δz is small compared with the linear region of the measurement technique, Eq. (1) can be linearized for rapid data processing. Because the measurements can be done without a feedback loop, this method is capable of real-time two-dimensional optical profiling.

We demonstrate this dual-scan method with a new nanometer surface profiling and imaging technique, differential confocal microscopy (DCM).⁴ DCM is capable of fast open-loop measurements with a height resolution as great as 2 nm. However, because the surface profile is deduced purely from optical

CMD3 Fig. 1. (a) Convolved profile of a gallium-ion implanted silicon surface. The apparent height-difference is due to reflectivity inhomogeneity. (b) True surface profile obtained by the dual-scan method with $\Delta z = 0.5 \mu\text{m}$. The height is magnified by 100 fold to show the residue 10-nm uncertainty.

CMD3 Fig. 2. Profile of an aluminum strip coated on fused silica. Points: obtained by dual-scan DCM with $\Delta z = 0.5 \mu\text{m}$. Curve: profiled by AFM.

signal, the raw data is convoluted with local optical properties. Figure 1(a) is a DCM image of a gallium-ion implanted silicon surface. The reflectivity on the gallium-implanted area is 30% larger than that of the silicon surface, producing a false signal of elevation. The actual height difference, measured by AFM, is less than one nanometer. The dual-scan method reveals the correct flat surface profile, as shown in Fig. 1(b). Figure 2 is the profile of an aluminum strip coated on fused silica. The points are obtained with dual-scan DCM and the curve is measured by AFM. Even though the reflectiv-

CMD3 Fig. 3. Surface profile of a 12- μm latex sphere. Dash-dot curve: raw data from DCM. Dashed curve: corrected profile by the dual-scan method with $\Delta z = 0.4 \mu\text{m}$. The dual-scan result is within 30 nm of a perfect sphere (solid curve).

ity of aluminum is 20 times larger than that of fused silica, the dual-scan method still gives the correct profile of the strip.

This dual-scan method can also eliminate the signal dependence on spatial gradient due to the finite numerical aperture of the optical system. The dash-dot curve in Fig. 3 is the profile of a 12- μm radius latex sphere deduced from DCM raw data. Away from the top of the sphere, the signal is falsely reduced due to the increasing surface gradient. With the dual-scan method we obtain the dashed curve, which is within 30 nm from a perfect sphere (solid curve).

Dual-scan is a general method that also works for other surface profilometric techniques in which the signal is modulated by local surface properties. For example, the slopes of the (repulsive) force-separation curves in AFM is directly proportional to the elastic modulus of sample surface.⁵ The effect of elastic modulus on AFM is the same as that of reflectivity on optical profilometry. By applying this dual-scan method, one can measure not only the true surface topography, but also the profile of inhomogeneous elastic moduli with AFM.

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