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Curvature Interferometry based In-Situ Measurement of Stresses Associated with Electrochemical Reactions

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Abstract
Anodization1 as well as dissolution2 of reactive metals such as aluminum results in buildup of significant levels of stresses on the reacting surface. In-situ measurement of stress evolution can provide remarkable insights into the associated electrochemical reactions and help in understanding the governing mechanisms. We report a curvature interferometry based technique for in-situ monitoring of stress evolution. Curvature interferometer is incorporated into the electrochemical cell and is used to monitor the curvature changes of the samples in order to determine the stress-thickness product of the film formed on the reacting surface.

Keywords
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Disciplines
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Curvature Interferometry based In-Situ Measurement of Stresses Associated with Electrochemical Reactions

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Anodization[1] as well as dissolution[2] of reactive metals such as aluminum results in buildup of significant levels of stresses on the reacting surface. *In-situ* measurement of stress evolution can provide remarkable insights into the associated electrochemical reactions and help in understanding the governing mechanisms. We report a curvature interferometry based technique for in-situ monitoring of stress evolution. Curvature interferometer is incorporated into the electrochemical cell and is used to monitor the curvature changes of the samples in order to determine the stress-thickness product of the film formed on the reacting surface.

Principle of curvature measurement is schematically represented in Figure 1[3,4]. The interferometer apparatus consists of a convex lens, a reflecting mirror, and a reflective sample surface arranged such that the sample surface and the mirror are located on the two focal planes of the lens, respectively. With this setup, the sample surface becomes the image plane of itself for the lens as shown in Figure 1. In this manner, both beams are reflected twice from the sample surface and accumulate a phase difference proportional to the curvature of the sample surface. The beams are interfered to measure the phase difference and monitor the real-time stress development in the sample.

Without phase shifting, the intensity of the interfered beam is proportional to the cosine of the phase difference and may limit the resolution of curvature measurement when phase difference approaches multiples of 180^o. In order to overcome this limitation and enhance the resolution of curvature measurement, in-line phase shifting optics consisting of quarter wave plate and polarizers are used to divide the interfering beams into two components that are polarized along mutually perpendicular planes. The quarter wave plate introduces a phase shift of 90^o among interference signal polarized and allows direct measurement of the phase difference between the two beams. The phase shifting optics provides unambiguous determination of the sign and magnitude of sample curvature change and consequently, stress evolution on the sample surface.

Compared to other curvature measurement techniques, the curvature interferometer has some unique advantages: 1) the paths of the two beams can be arranged to be close to each other so that influence of environmental disturbances on the measurement can be minimized; and 2) since the sample and mirror are located at the two focal planes of the lens, small tilt, translation or vibration of the sample has no influence on the curvature measurement.

Electrochemical cell is designed such that chemical reactions are confined on the front surface of aluminum samples. Back surface of the samples are coated with a reflective coating so that curvature interferometer can be used to monitor the sample curvature. The cell is used to monitor stress evolution in 1 mm thick aluminum samples during both anodization and anodic dissolution.

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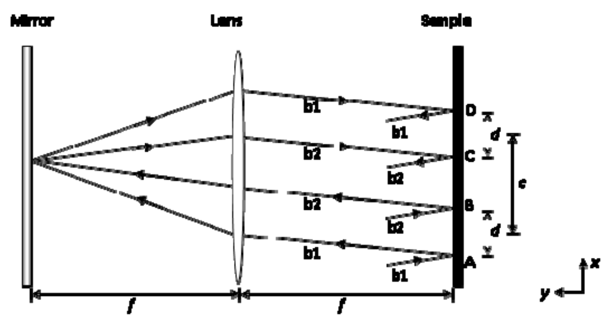

Figure 1. Schematic of the curvature measurement setup.