Regularization techniques for 3D surface reconstruction from four quadrant backscattered electron detector images

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Regularization techniques for 3D surface reconstruction from four quadrant backscattered electron detector images

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In scanning electronic microscopy, four quadrants backscattered electron detectors (FQBSD) allow collecting signals from each quadrant separately and combine them to obtain a tridimensional reconstruction of the surface. The main challenge of this operation consists of the integration of the gradient field obtained as the normalized difference of the signal from each pair of opposite quadrants. Owing to the presence of electronic noise that eventually turns into image noise, a least square integration approach is widely adopted for surface reconstruction.

However, the reconstructed surface could still be affected by distortions due to sensitivity variations amongst the detector quadrants or an imprecise alignment of the FQBSD with the gun axis, which is quite a common occurrence, particularly in systems equipped with manual retractable FQBSD.

In the present work, we demonstrate the possibility of adopting classical regularization techniques to the surface reconstruction from FQBSD images allowing for a substantialimprovement in the 3D surface reconstruction quality. To this purpose, three types of regularization have been explored: background removal by polynomial regression, Dirichlet"s regularization, and Tikhonov"s regularization.

The procedures have been experimentally validated on AISI 316L stainless steel polishedsurfaces with microhardness indentation and on laser-patterned aluminum and silicon samples, showing promising results.

Concerning the indented samples, Dirichlet"s regularization returned the best result, whereas the other two regularization methods introduced some distortions of the indentation mark. On the other hand, for the laser-processed samples, Tikhonov"s regularization allowed the best reconstruction of surface details, whereas Dirichlet"s reconstruction forced the edges of the sample to be flat, thereby strongly altering the surface profile. This points to the need for an application-driven selection of the regularization technique that is easily implementable in commonly available software.

Finally, we will also present paths for further development of the technique to demonstrate the possibility of a quantitative analysis of laser-processed surfaces as an alternative to more expensive and time-consuming optical profilometry and atomic force microscopy.