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An Iterative Estimation Approach to Simultaneously De-Curtain and De-Noise FIB Damaged Nuclear Fuel Microstructures

To evaluate the performance of a fuel in a nuclear reactor, post-irradiation examination is performed to determine the effect of the reactor conditions on the material and assess irradiation-induced phenomena, such as swelling, phase decomposition, and component migration. Focused ion beam scanning electron microscopy (FIB-SEM) serial sectioning has recently been used to investigate the three-dimensional microstructure of nuclear fuels due to the recent nuclearization of characterization equipment and specimen preparation tools. Sectioning with a FIB-SEM has numerous advantages, including the ability to select a specific microstructural region of interest and maintain consistent sectioning depth in finer detail than traditional mechanical sectioning or chemical etching methods. One limitation of FIB-SEM serial sectioning is the development of curtains parallel to the beam, caused by uneven specimen milling due to pores and cracks present in the microstructure, which are common microstructural features observed in nuclear fuel. These physical artifacts can distort image features and cause errors in automatic segmentation and other quantitative procedures. To alleviate the issues associated with curtains, it is necessary to remove them through image processing, a process known as de-curtaining. Traditional methods to remove repeating artifacts include applying a mask to the Fourier region or using a scalable Fourier filter. The main limitation of these techniques is the removal of other image information along with the vertical curtains that reside in the masked regions in Fourier space. This results in a blur around feature boundaries or other image distortion artifacts. The current work establishes a de-curtaining algorithm, using a plug-and-play framework consisting of a Bayesian estimation function to minimize the deviation from the original image, a Fourier mask operation, and a state-of-the-art denoiser. The resultant reconstruction maintains the quality and accuracy of the original image, while simultaneously reducing signal noise and physical artifacts.