Non-iterative Reconstruction for Detecting Buried Deviant Structures in Integrated Circuits using Coherent Hard X-ray Diffraction

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We have demonstrated the use of coherent soft x-ray diffraction and the signed magnitude algorithm for the detection of deviant structures fabricated on SiN membrane[1]. It is more challenging, however, to efficiently detect buried deviant structures in IC's due to: (1) iterative phase retrieval requires the field of view (FOV) to be at least twice as large as feature size, i.e., feature should be sufficiently surrounded by a uniform, featureless area, while IC's have extended patterns which are usually larger than the FOV; (2) missing data at the center need to be filled by additional measurements (usually by low resolution SEM/x-ray images[2] or by varying sample-detector distance and beam stop size[1]); (3) the use of hard x-ray and thick substrate (figure 1a) results in an exit surface wave (ESW) of low contrast and low signal-to-noise ratio (SNR).

In this paper, we propose a non-iterative reconstruction approach to overcome those problems. The method has the following steps: (1) collect coherent hard x-ray diffraction data of the sample with CCD detector; (2) simulate the diffraction pattern of the design based on design specifications (feature size, linewidth, thickness, materials of sample, etc.) and experiment conditions (x-ray wavelength, CCD pixel size/number, sample-detector distance, etc.); (3) fill the missing data blocked by beam stop with corresponding magnitude information from the simulated diffraction pattern, and combine the phase information from step 2; (4) use inverse Fourier transform to reconstruct the image, and compare it with the design to locate deviance. The simulation results are shown in figure 1. This method does not require oversampling or additional measurements therefore it appears to be a good candidate for inspecting buried extended patterns in IC's.

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[1] L. Baghaei Rad, et al, X-Ray Diffraction Microscopy: Reconstruction With Partial Magnitude And Spatial A PrioriInformation, *EIPBN 2008*

[2] J. Miao, et al, High Resolution 3D X-ray Diffraction Microscopy, *Phys. Rev. Lett.*, **89**, 088303, 2002

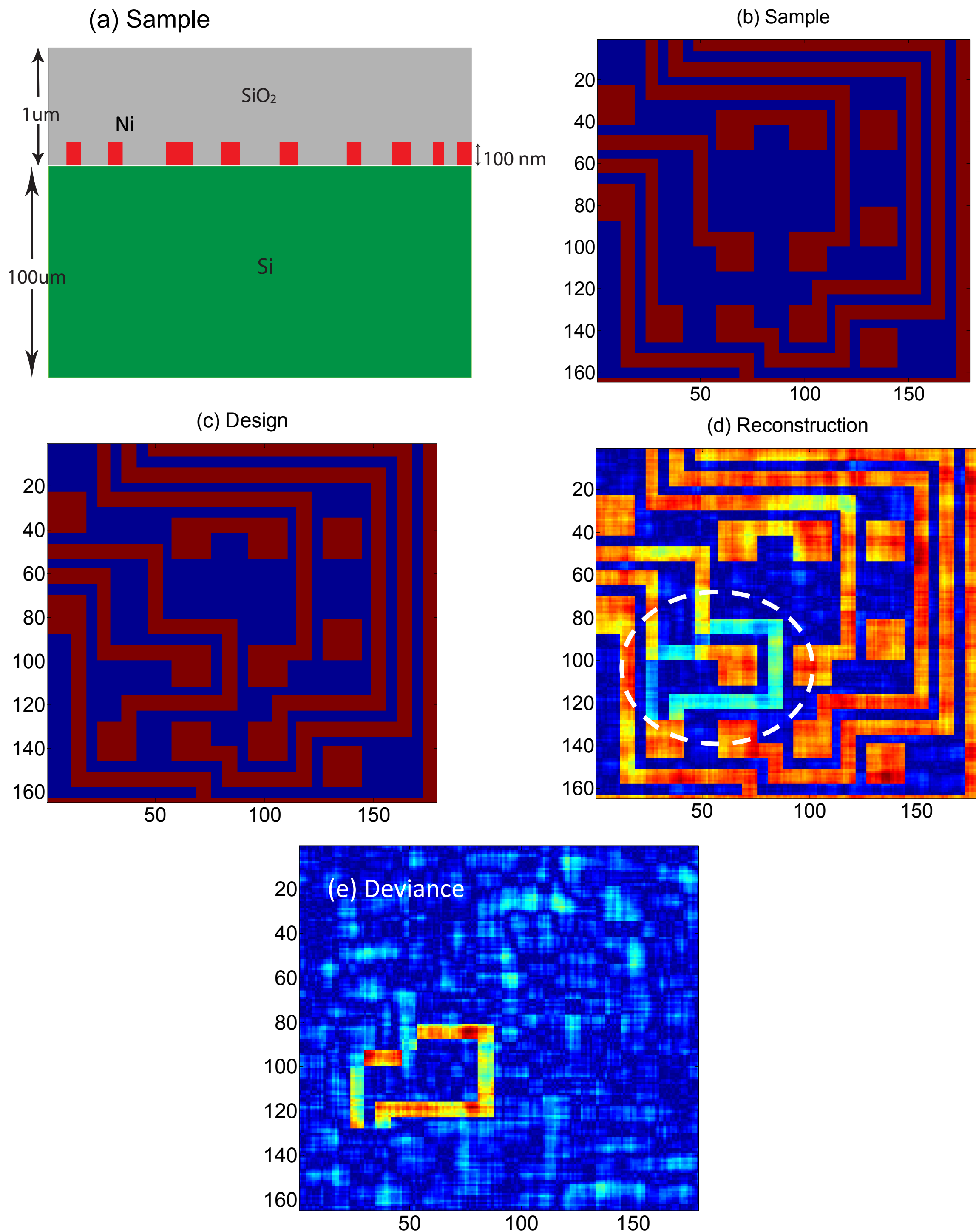

Figure 1: Simulation results for non-iterative reconstruction for buried deviance structures in IC's. λ = 1.499A. Beam stop blocks 1% of diffraction signal. SNR = 100 and the total number of photons collected by the CCD detector is 10^{10}. (a) Cross-section of sample. (b) The top-view 'image' (ESW) of sample. (b) The top-view 'image' of design. Note there are some deviances around (50,100). (d) The reconstruction shows the location of deviant structures (circled) compared with (c). (e) The deviance by subtracting (d) from (c). It does not necessarily need to reconstruct the detailed image of the sample.