Manufacturing Science and Technology Group
Room On Demand - Session MS-Contributed On Demand

Manufacturing Science and Technology Contributed On Demand Session

MS-Contributed On Demand-1 Machine Learning and Simulation Assistant Technology to Facilitate 3d Memory Analysis of Cross Section Sem Images*, M. Bryan, J. Foucher,* ***Julien Baderot,*** POLLEN Metrology, France

We present a method for fast, enhanced cross-section SEM metrology of 3D memory channels through simulation and machine learning. Using simple geometric models of the channel structure and certain assumptions on the behaviour of the electron beam we demonstrate that our method provides increased robustness to acquisition errors and gives more physically meaningful measurements of 3D memory when compared to traditional image processing-based techniques. We show also how this technique can be integrated into the Process Engineer workflow during semiconductor research and development, providing actionable results faster and reducing overall time-to-production

MS-Contributed On Demand-4 Atomic-Precision Position Error Correction for Dopant-Array Quantum Devices*,* ***James H.G. Owen****, E. Fuchs, M. Haq, J. Randall,* Zyvex Labs

For dopant-based atomic-scale devices such as the ‘single atom transistor’ [1] and 2D Quantum Metamaterials[2], arrays of dopant patches need to be fabricated with atomic precision for both the size of the patches (to control the number of dopants in each patch) and the relative positioning of the patches in the array (to control the interactions between patches). As the number of patches scales up from a 3x3 array to a 32 x 32 array, this requires an automated writing process, without losing atomic precision patterning.

Various types of positioning errors are evident in the arrays. ‘Staircasing’ is the gradual upward drift of the boxes along each row, in alternating directions. ‘Phase shift’ is the misalignment of the boxes from one row to the next, which can reach a 180° phase shift. ‘Curvature’ or ‘shearing’ are distortions of the overall array shape. Various different sources of tip position error cause these distortions, including lattice lock misalignment, piezo creep and hysteresis, and thermal drift.

We are working to remove as many of these sources of imprecision as is possible, so as to achieve atomic precision dopant arrays of arbitrary size. Performing simulations of array fabrication which include deliberate errors of one type or another helps to isolate the source of the observed distortions, so that they can be corrected. ‘Staircasing’ is the result of drift, which can also affect the lattice lock, and therefore cause misalignment of the patterning with the lattice. 'Phase shift', however is indicative of xy creep. Shear and Curvature can be caused by uncorrected slow creep, or by variation in the rate of drift caused by temperature fluctuations in the lab.

By comparing the simulations with experimental data, we can determine which parameter, i.e. creep, hysteresis or drift correction, needs to be adjusted. We show that after adjustment we are able to draw arrays where the positioning errors are no more than 1 px.

Even with perfect positioning, the patches may not be the correct size due to sub-px position errors, stochastic errors such as tip changes, and incomplete lithography. We are working on machine-learning-based image recognition techniques to identify these defects, and correct them in an automated process.

In this way, we hope to be able to draw large arrays while maintaining atomic precision, which will enable Analog Quantum Simulations, and eventually 2D Quantum Metamaterials.

1: M. Fuechsle, J. A. Miwa, S. Mahapatra, H. Ryu, S. Lee, O. Warschkow, L. C. L. Hollenberg, G. Klimeck, and M. Y. Simmons *Nat Nano***7** 242-246 (2012) DOI: 10.1038/nnano.2012.21

2: https://www.zyvexlabs.com/2d-workshop/workshop-overview/

Author Index

Bold page numbers indicate presenter