Validation of Improved Compact Model in Grapho-Epitaxy Directed-Self-Assembly (DSA)

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Abstract

Directed Self-Assembly (DSA) is a promising candidate for sub 10 nm nodes in the integrated circuit (IC) industry. DSA is being considered as a cost reduction complementary process to multiple patterning (MP) and an enabler of new technology nodes. However, to realize the potential of this technology, it is essential that the necessary infrastructure from the point of view of materials, hardware, software, process integration, and design methodologies is available for its deployment in large volume manufacturing. One key aspect of enabling DSA processes is the full chip mask synthesis and verification method that returns the functionality of existing masks used in production. One of these critical components is the ability to accurately model the placement of the next patterns in the DSA process, as well as determining the conditions at which innovative processes start to occur. Self-consistent field theory and Monte Carlo simulations have the capability to probe and explore the mechanisms driving the different phases of a diblock copolymer system. While such techniques are important to study the nature of the self-assembly process, they are computationally expensive and they cannot be used to perform mask synthesis operations nor full chip verification. The nature of a compact model is to make a series of approximations allowing a simpler description of the problem to be solved, but the placement of patterns can be significantly improved from an in or in the expression of its generality. Figure 1 shows an example of a Monte Carlo simulation of a complex 3D structure and a compact model simulation of the same structure.

Phase Transition

We define phase transition as a type of DSA defectivity where the morphology of the DSA cylinders is undefined.

When applying the DSA model, it is assumed that the data is not in a phase transition [1,2], the cylinders are straight [1,2], and the cylinders have a circular cross-section [1,2]. We also define metrics that we can use in simulation such as 'uncircularity', which is the ratio of the area to perimeter of the DSA film. Another metric is 'punchthrough', which is the alignment of the planes of DSA hole through the thickness of the DSA film.

New Contour Metrology Flow

Data collection and Model calibration to experimental data using Calibre ContourCal

Compact model calibration to experimental data using Calibre ContourCal

Synthetic data was generated from Monte Carlo simulations using the material parameters from imec’s process. 1055 different cylindrical structures were used in generating the synthetic data set. The CDSA model is capable of predicting position and average CD of DSA cylinders. The model can also be used in verification to determine the likelihood of defects forming due to guiding pattern shapes that are not commensurate to the natural pitch of the diblock material. The term ‘energy’ is used to describe this likelihood.

Conclusion & Future Work

Data collection and Model calibration was completed on imec’s ps wetting DSA process. A compact model was calibrated to experimental data as well as synthetic Monte Carlo data. Placement error was also compared to Monte Carlo results, showing a similar trend with guiding pattern shape, the guiding patterns with a low confinement had a high placement error. A new contour based calibration flow is presented and fit principles test was completed. Further work will include optimizing metrology recipe and implanting metrology on double structures as well as validating phase transition detection of the compact model on experimental data.

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References