Thermodynamic origin of placement errors for contact holes created by directed self-assembly

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Directed self-assembly of block copolymers is currently being studied as a means to increase the resolution of optical lithography. Lithographic patterns are used to guide the self-assembly structures. The self-assembly process itself is controlled by thermodynamics and/or kinetics. Directed self-assembly is attractive for its CDU reduction in e.g. contact hole shrinkage as well as pitch multiplication. The main challenges of directed self-assembly are defectivity and added placement. The latter is a topic of importance that has not been studied extensively.

In this paper we will present experimental work on DSA combined with 193i lithography on 300mm wafers. We will report the added placement of grapho-epitaxy of cylindrical phase block copolymer for staggered CHs (4 nm to 8 nm). We will show that the pitch of the block copolymer in open trenches is not fixed; rather a Gaussian distribution of pitches is obtained of 2nm (3σ). We will discuss the impact of the pitch spread on the placement error added by DSA. The experimental results on the pitch distribution will be compared to numerical simulations based on mean field theory. We will show that the pitch spread is caused by thermodynamics (free energy differences) and is *intrinsic* to DSA.

While the work above shows relative placement errors we will also show absolute overlay between two litho layers. NAND WLs created by lithography and etched into silicon are aligned to staggered CHs in an isolated trench created by DSA (figure 1). The absolute overlay in the confined (X) and unconfined (Y) direction will be discussed.

Finally we will look at CH shrink with DSA as it is the case of the highest confinement. Contact hole shrink of holes obtained by 193i of 70-80 nm were shrunk with DSA to 30 nm. Placement errors statistics of contact hole shrink of 3 nm (3σ) are obtained. Mean field theory simulations of contact hole shrink were performed and thermodynamically induced placement errors were calculated and are compared to the experimental results.

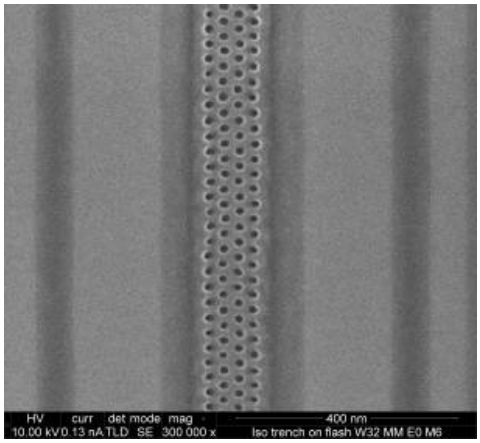

Figure 1. SEM top down image of staggered self-assembled CHs on top of a NAND FLASH WL structure.

50 words abstract:

The pitch of staggered CHs, formed by DSA, shows an intrinsic Gaussian distribution that originates from thermodynamic broadening. Absolute overlay between staggered CHs formed by DSA and NAND_WL will be shown. Ultimate confinement is found in CH shrink. Experimental placement errors will be reported and compared to mean field simulations.