Directed Self-Assembly Via Shrink Process with Lamella-forming Block Copolymers

Chi-Chun Liu,[a] Joy Cheng,[c] Cheng Chi,[a] Yongan Xu,[a] Daiji Kawamura,[b]
Lovejeet Singh,[b] Kota Nishino,[b] Martha Sanchez,[c] Kristin Schmidt,[c] Jed Pitera,[c]
Eugene Delenia,[c] Leslie Thompson,[c] Richard Farrell,[d] Nihar Mohanty,[d] Hongyun
Cottle,[d] Luciana Meli,[a] Kaushik Vemareddy,[e] Ryota Harukawa,[e] Venkat
Nagaswami,[e] Kafai Lai,[f] Tsuyoshi Furukawa,[b] Ken Maruyama,[b] David Hetzer,[d]
Daniel Sanders,[c] Nelson Felix,[a] Sean Burns,[a] Matthew Colburn[a]
*[a]IBM Albany NanoTechnology Center, Albany NY 12203, [b]JSR Micro Inc, Sunnyvale CA, [c]IBM
Research-Almaden, San Jose, CA 95120, [d]TEL Technology Center, America, LLC, Albany, NY
12203, [e]KLA-Tencor Ltd Milpitas CA 95035, [f]IBM Semiconductor Research and Development
Center, Hopewell Junction NY 12533*
cliu@us.ibm.com

Directed self-assembly (DSA) of block copolymers (BCPs) has become a promising patterning technique for the contact/via shrink process for use in semiconductor manufacturing due to its critical dimension (CD) uniformity and process simplicity.[1]For such application, cylinder-forming BCP system has been extensively investigated compared to its counterpart, lamella-forming system, mainly because cylindrical BCPs will form multiple vias in non-circular guiding patterns (GPs), which is considered to be closer to technological needs.[2-5] This technological need to generate multiple DSA domains in a bar-shape GP originated from the resolution limit of lithography, i.e. those vias placed too close to each other will merge and short the circuit. In practice, multiple patterning and self-aligned via (SAV) processes have been implemented in semiconductor manufacturing to address this resolution issue.[6] The former approach separates one pattern layer with unresolvable dense features into several layers with resolvable features, while the latter approach simply utilizes the superposition of via bars and the pre-defined metal trench patterns in a thin hard mask layer to resolve individual vias. With proper design, using DSA to generate via bars with the SAV process could provide another approach to address the resolution issue.

In this paper, DSA of lamella-forming BCP was evaluated as a candidate for forming SAV, which requires the DSA process to support structures from circular via to lines and spaces. The basic process flow is similar to general graphoepitaxy method as shown in Fig. 1. The correlation between DSA CD and GP CD, dry and wet PMMA removal process, and pattern transfer process were investigated, as illustrated in Fig. 2. The morphologies of the DSA vias derived from lamellar BCPs were found to be less sensitive to the BCP coating thickness compared to the cylindrical BCP system of similar L_0. This implies that lamellar BCP may provide a larger process window and higher tolerance for local pattern density variation. The profile and the thickness of the residual PS layer of DSA structures were studied using Monte Carlo simulation and FIB cross-section SEM, as illustrated in Fig. 3. Furthermore, a preliminary defectivity study using the lamellar system will be presented as well.

1. Younkin, T. R.; Gronheid, R.; Rincon Delgadillo, P.; Chan, B. T.; Vandenbroeck, N.; Demuynck, S.; Romo-Negreira, A.; Parnell, D.; Nafus, K.; Tahara, S.; Somervell, M. In *Progress in directed self-assembly hole shrink applications*, 2013; pp 86820L-86820L-11.
2. Gronheid, R.; Bekaert, J.; Murugesan Kuppuswamy, V.-K.; Vandenbroeck, N.; Doise, J.; Cao, Y.; Lin, G.; Sayan, S.; Parnell, D.; Somervell, M. In *Process optimization of templated DSA flows*, 2014; pp 90510I-90510I-7.
3. Somervell, M.; Yamauchi, T.; Okada, S.; Tomita, T.; Nishi, T.; Iijima, E.; Nakano, T.; Ishiguro, T.; Nagahara, S.; Iwaki, H. In *High-volume manufacturing equipment and processing for directed self-assembly applications*, SPIE Advanced Lithography, International Society for Optics and Photonics: 2014; pp 90510N-90510N-11.

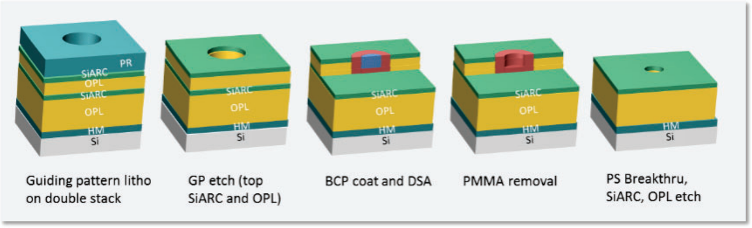

Figure 1: Process flow of DSA via process used in this work.

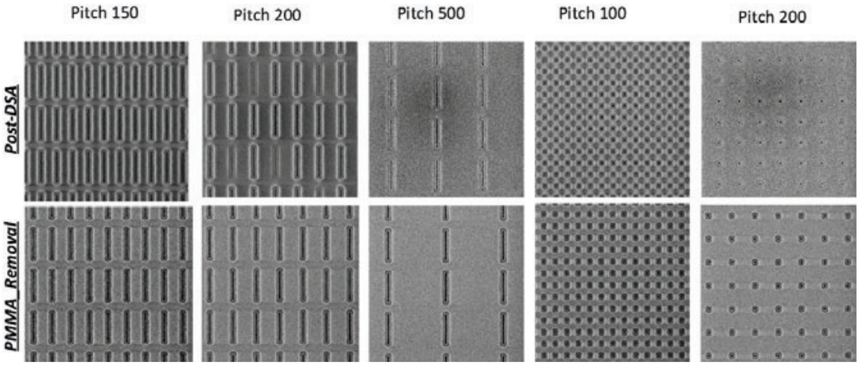

Figure 2: Examples of lamella-forming BCP in GPs with different aspect ratio and pattern density.

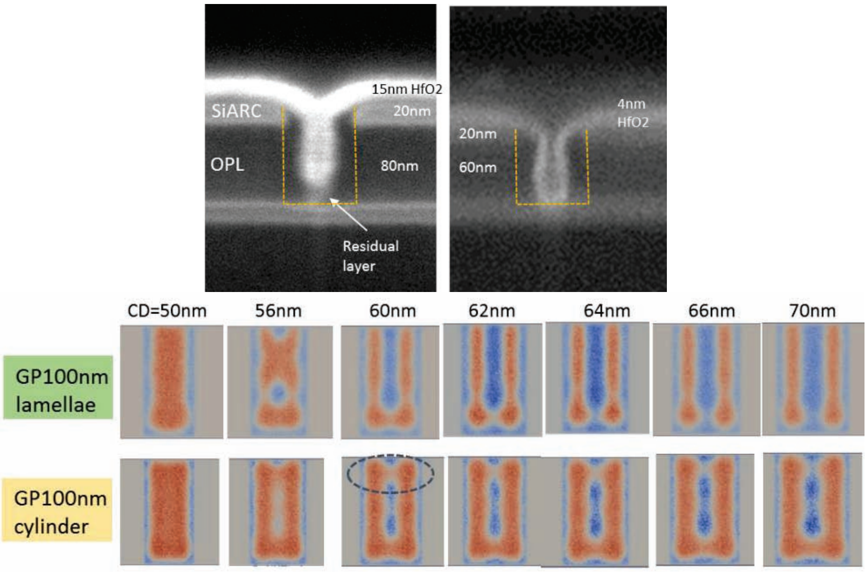

Figure 3: (upper) Cross-sectional SEM images of lamella-forming BCP in different GP. Different thickness of HfO2 decoration is used for contrast enhancement purpose.(lower) Monte Carlo simulation comparing lamella- and cylinder-forming BCPs vs different GP CD.

Acknowledgement

This work was performed by the Research and Development Alliance Teams at various IBM Research and Development Facilities.

4. Fukawatase, K.; Yoshimoto, K.; Ohshima, M.; Naka, Y.; Maeda, S.; Tanaka, S.; Morita, S.; Aoyama, H.; Mimotogi, S. In *DFM for defect-free DSA hole shrink process*, 2014; pp 90491K-90491K-8.

5. Liu, C.-C.; Pitera, J.; Lafferty, N.; Lai, K.; Rettner, C.; Tjio, M.; Arellano, N.; Cheng, J. In *Progress towards the integration of optical proximity correction and directed self-assembly of block copolymers with graphoepitaxy*, SPIE Advanced Lithography, International Society for Optics and Photonics: 2012; pp 83230X-83230X-7.

6. Narasimha, S.; Chang, P.; Ortolland, C.; Fried, D.; Engbrecht, E.; Nummy, K.; Parries, P.; Ando, T.; Aquilino, M.; Arnold, N. In *22nm High-performance SOI technology featuring dual-embedded stressors, Epi-Plate High-K deep-trench embedded DRAM and self-aligned Via 15LM BEOL*, Electron Devices Meeting (IEDM), 2012 IEEE International, IEEE: 2012; pp 3.3. 1-3.3. 4.