Enhancement of Sub-50 nm Channel Length Definition Using Removable Dummy Structure-Assisted Electron Beam Lithography

Tsai-Ming Huang, Dang-Nhut Hao, Chia-Wei Chang, Hsu-Chun Cheng, Meiyi Li, Chun-Chi Chen

Taiwan Semiconductor Research Institute, National Institutes of Applied Research, Hsinchu, Taiwan

tmhuang@niar.org.tw

In advanced semiconductor fabrication, lift-off processes are instrumental in defining source/drain (S/D) electrodes, where the photoresist linewidth serves as the critical determinant of the achievable channel length. However, scaling S/D patterns down to the 50 nm regime using electron beam lithography (EBL) introduces significant challenges, including pronounced line width roughness (LWR) and proximity effects. Particularly in isolated configurations, non-uniform backscattering and local dose variations often lead to pattern collapse, delamination, or profile degradation, severely constraining the process window[1, 2, 3].

This study presents a removable dummy structure-assisted EBL technique designed to overcome these limitations. By strategically placing temporary dummy features in proximity to the target patterns, the local electron dose distribution and backscattering environment are homogenized. This approach effectively mitigates proximity effects and reinforces photoresist profile integrity. Crucially, these dummy structures are designed to be automatically removed during the development stage due to a lack of mechanical anchoring, ensuring enhanced resolution without increasing process complexity or requiring additional etching steps.

Experimental results demonstrate that the integration of these removable dummy structures significantly optimizes photoresist profiles, successfully extending the minimum achievable critical dimension from 60 nm down to 50 nm. This work provides a robust and manufacturability-compatible framework for enhancing structural fidelity and expanding the process window for next-generation devices with sub-50 nm channel lengths.

---

[1] Jussot, J.; Pargon, E.; Icard, B.; Bustos, J.; Pain, L. Line Width Roughness Reduction Strategies for Patterns Exposed via Electron Beam Lithography. Proc. SPIE 2014, 9054, 905405.

[2] Zhao, X.; Lee, S.-Y.; Choi, J.; Lee, S.-H.; Shin, I.-K.; Jeon, C.-U.; Kim, B.-G.; Cho, H.-K. Dependency Analysis of Line Edge Roughness in Electron-Beam Lithography. Microelectron. Eng. 2015, 133, 78–87.

[3] Mao, Q.; Zhu, J.; Cheng, X. Proximity Effect Correction in Electron Beam Lithography Using a Composite Function Model of Electron Scattering Energy Distribution. Discover Nano 2025, 20, 84.

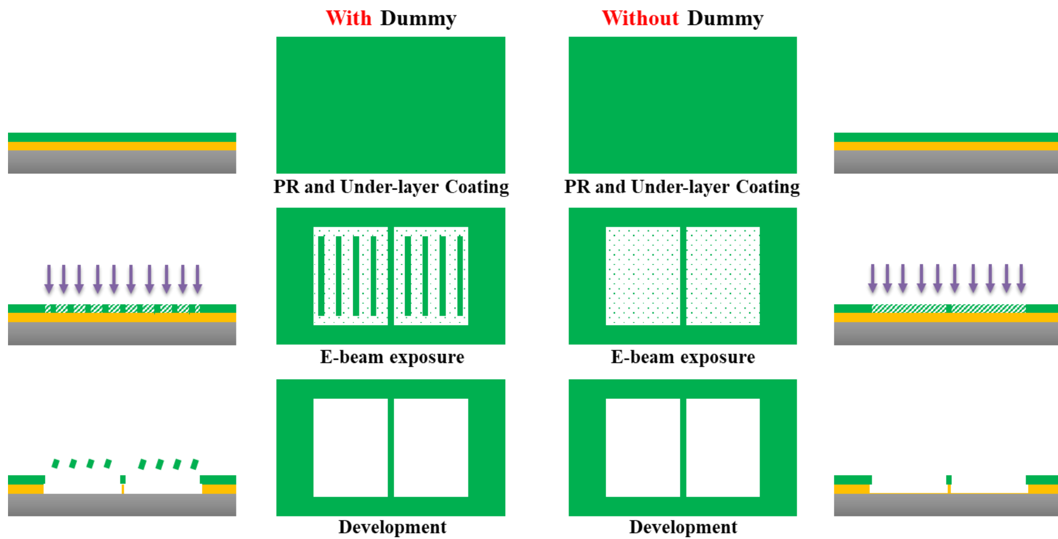

Figure 1: Comparison of E-beam lithography processes with and without dummy structures: The schematic illustrates the sequential steps: PR/under-layer coating, E-beam exposure, and development. The left column demonstrates that incorporating dummy patterns prevents the collapse of fine structures by improving local dose uniformity. These dummy patterns are subsequently flushed away during development due to a lack of anchoring support. Conversely, the right column shows structural failure and profile degradation in the absence of dummy patterns

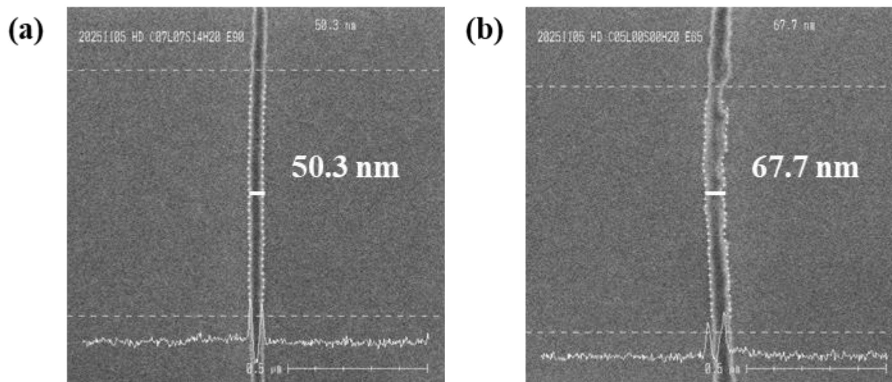

Figure 2: Comparison of SEM images with and without dummy structures after development: (a) Result **with dummy structures**, showing a well-controlled critical dimension (CD) of 50.3 nm and superior edge smoothness. (b) Result **without dummy structures**, where the line exhibits a wider CD of 67.7 nm and significant line-edge roughness, likely due to the proximity effect and uneven pattern density.