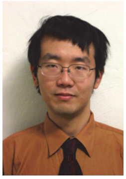
Efficient Variation Decomposition via Robust Sparse Regression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In this work, we propose a new technique to accurately decompose process variation into lot-to-lot, wafer-to-wafer, wafer-level spatially correlated, wafer-level random, within-die spatially correlated and within-die random variation components. Performing such variation decomposition narrows down the main variation sources in the manufacturing process, and offers valuable information for process engineers to prioritize their goals in yield improvement to meet today's stringent time-to-market requirements. An important contribution of this work is to develop a physical dictionary which captures more spatially correlated systematic variation sources than the traditional quadratic modeling approach. We further propose the DCT (i.e., discrete cosine transform) dictionary to discover spatial patterns that are not modeled by the physical dictionary. Moreover, we propose to apply sparse regression to accurately extract the most adequate templates to represent spatially correlated variation for a particular process/design without over-fitting. In addition, a robust sparse regression algorithm is proposed to automatically remove measurement outliers. Finally, we develop a fast numerical algorithm that may reduce the computational time of sparse regression by several orders of magnitude over the traditional implementation.

The proposed variation decomposition technique has been validated by several synthetic data sets and silicon measurement data from advanced CMOS processes, which demonstrates that the proposed variation decomposition technique accurately models the spatially correlated systematic variation in the presence of outliers, and our improved numerical algorithm achieves significant speed-up over the traditional implementation for large-scale problems. For example, Fig. 1 shows a synthetic wafer map with 3 outliers. Fig. 2 shows the decomposed spatial variation containing quadratic, edge, center and random effects, each corresponding to different variation sources, where the outliers are automatically detected and removed.

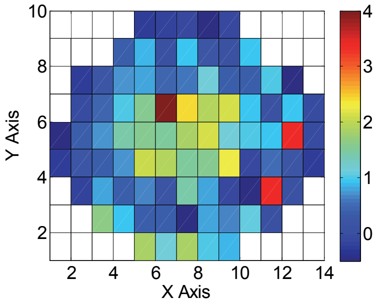

Fig. 1: Synthetic wafer map with 3 outliers.

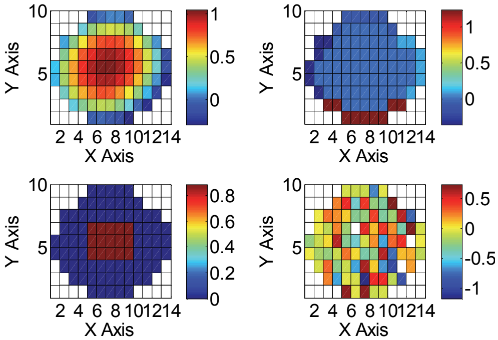

Fig 2: The wafer map is decomposed into quadratic, edge, center and random effects.