Image Invariant and Information Content Comparisons across Sub-32nm Technologies

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During the design of imaging systems, invariants are often used to understand certain performance properties and trade-offs. Such metrics are useful for comparisons of the image capacity for systems within a well defined design space. It becomes challenging to establish these metrics for use across a variety of system architectures, such as the several lithography options under consideration today for 32nm device generations and beyond. The challenge lies not only in comparing different imaging technologies, including 193nm immersion, EUV, maskless lithography, imprint, directed self-assembly, and interference lithography but also in the post-imaging schemes that may be employed at stages beyond primary imaging, such as double patterning and trim.

The goal of this paper is to present a general metric approach developed to compare image capacity and content for lithography alternatives as well as the complexity of additional steps involved. Primarily, the image metric is based on an extended Lagrange invariant - a product of image field and numerical aperture scaled by wavelength and pupil utilization. A study has been undertaken using current and next generation patterning approaches and their evolution toward sub-32nm. As an example, the information content for 90nm gate design rules has been reduced compared to earlier generations through implementation of orientation and minimum pitch rules. This has been extended through 65nm generations with restrictions limited to a single direction and a single pitch starting with 45nm designs. An image content metric for alternating PSM used for sub-40nm gate level patterning must include the measure of information content (in bits) of the PSM step (based on the field area, NA, wavelength, and effective k_1 for the constraints applied), the trim mask step (based on the corresponding image parameters), as well as initial, intermediate and subsequent processing operations and costs. The situation becomes more involved for a template-based lithography example where several trim exposure steps are required with low information content imaging but followed with a number of operations that may lead to higher costs than initially suspected. Comparisons with EUV lithography also become more complex as illumination becomes more customized and the probability of PSM for sub-32nm generations increases. Comparisons to other ‘non-optical’ imaging technologies will also be presented.