Spatial Dose Control for Fabrication of Saw-tooth Structures

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Three-dimensional structures are often used in various devices such as optical elements, MEMS and NEMS. Their performance is known to be highly sensitive to their dimensional fidelity. Therefore, it is essential to control the feature size accurately, in order to be able to fabricate such devices with the desired characteristics. One flexible approach to fabrication of such structures is to employ electron-beam (e-beam) grayscale lithography. However, electron scattering in the resist and the isotropic resist development process can make dimensions of the written features in a device substantially different from the target ones. Hence, spatial distribution of e-beam dose is to be controlled in order to achieve the exposure (energy deposited in the resist) distribution which can lead to the target structure. This dose control becomes a challenging task for saw-tooth structures, widely used in blazed gratings, where the depth in a resist profile continuously varies in space. In such structures, the isotropic process of resist development coupled with the non-linear relationship between exposure and developing rate makes it difficult to derive the optimal dose distribution for a target structure. Note that if there is no lateral development, derivation of the dose distribution would be easier since vertical columns of resist would be independent of each other during the developing process.

We are developing an effective and practical scheme for determining the spatial dose distribution, given a periodic saw-tooth structure. The dose distribution for a single tooth is derived based on the relationship between exposure and developing rate, considering the isotropic, i.e., *lateral* as well as *vertical*, development of resist (see Figure 1). The dose distribution of a single tooth is replicated to form a periodic saw-tooth structure and then each period of the replicated dose distribution is adjusted depending on its relative location in the structure, in order to compensate for proximity effect. One of the objectives in this study is to analyze dependency of the lateral development (accordingly the final resist profile) on the tooth slope (see Figure 1) and make the procedure for deriving the dose distribution adaptive to the dependency. A distinct feature of the proposed scheme is that the lateral development of resist is separately modeled in dose control. In Figure 2, an early experimental result from fabrication of saw-tooth structures is provided. It can be seen that teeth are well defined including the target tooth slope of 1 (45 degrees). In this paper, the dose control scheme for fabrication of saw-tooth structures will be described in detail along with experimental results.

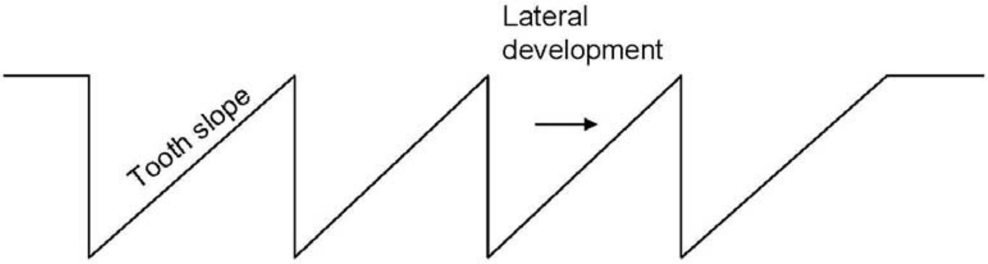

Figure 1. Tooth slope and lateral development in a saw-tooth structure

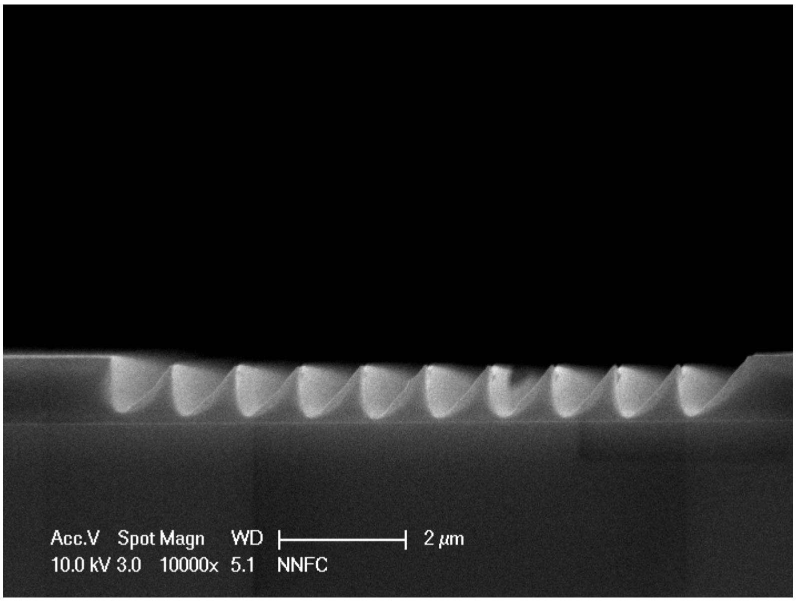

Figure 2: The resist profile of a saw-tooth structure fabricated by e-beam grayscale lithography (50 keV). The substrate is composed ot 1000 *n*m PMMA on Si and the width of a tooth is 1000 *n*m.