Reducing insulating substrate charging in electron beam lithography without using charge dissipation layer

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Reducing insulating substrate charging in electron beam lithography without using charge dissipation layer

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We investigate charging effect in electron beam lithography for patterning resist on electrically insulating substrate. We find that the charging effect can be mitigated without using a charge dissipation layer with an optimized exposure writing order strategy. We successfully fabricate an AlGaAs-on-sapphire (AlGaAsOS) miroresonator with intrinsic quality factor ($Q$) as $\sim180,000$ with the optimized EBL process.

In EBL systems, pattern generators fracture device patterns into segments that will be exposed to electrons in a certain sequence. We investigate the influence of the exposure writing order and we find out the charging effect can be mitigated by using an optimized writing order strategy. Writing order strategies at sub-field level and segment level are examined for patterning microring resonators in HSQ on AlGaAs-on-sapphire (AlGaAsOS) wafers, which has been demonstrated as an ultra-efficient nonlinear integrated platform for nonlinear photonics applications [4, 5]. The AlGaAsOS samples are spin-coated with a 350-nm thick HSQ (FOX-15) layer and then microring patterns are exposed in 100-kV EBL system (JEOL JBX-9500FS) (12000 μC/cm² dose, 6 nA current). Patterns are fractured by GenSys software BEAMER. Fig. 1 compares the exposure writing order at sub-field level for patterning 34-μm diameter ring patterns. The default writing order strategy in the JEOL system is “raster scanning” along a certain axis as shown in Fig. 1(a). The writing order “follow geometry” ensures the pattern are defined consecutively following the device pattern direction as shown in Fig. 1(b). (c,d) shows the scanning electron microscopy (SEM) pictures for developed patterns and severe pattern distortions was observed for “raster scanning” strategy while the “follow geometry” strategy allows for a smooth pattern definition. Fig. 2 compares the exposure writing order at segment level for patterning 3-μm diameter ring patterns. For the writing order “array compaction”, the exposure jumps between segments as shown in Fig. 2(a), which results in severe segment placement errors (see Fig. 2(c)). Smooth patterning can still be obtained in the case of “follow geometry” as shown in Fig. 2(b, d). We use this optimized writing order to fabricate a 17-μm radius AlGaAsOS microring resonator with an integrated bus waveguide as shown in Fig. 3 exhibiting an intrinsic $Q$ up to 180,000.

In conclusion, we find that exposure writing strategy is critical element in EBL and “follow geometry” writing order can be utilized to mitigate charging effect in resist without applying CDL. With the optimized writing order in EBL, the fabrication process for devices residing on insulating substrate is simplified.