Trilayer process for *T*-gate and *Γ*-gate lithography using ternary developer and proximity effect correction superposition

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The need for faster and higher performance transistors are the driving force behind the development of special geometry compound semiconductor high electron mobility transistors (HEMTs). It is well known that short gate length and low gate resistance are essential for the high frequency operation of these transistors. One common method to reduce the parasitic gate resistance is to increase the cross-sectional area of the gate by adding material on the top of the gate while maintaining a short foot region that defines the gate length. This leads to a *T*- or *Γ*-gate geometry. This method has been pursued since the early 1980's [1] and new methods are still under investigation [2].

To this date, electron beam lithography using multilayer resist films, and metal liftoff, is the dominant method to fabricate these devices [2]. In this paper we present one more alternative that utilizes acrylate/methylstyrene triple resist stack, a ternary developer consisting of an acetate/alcohol/water mixture, and a proximity effect correction (PEC) superposition approach that, when combined, simplifies the fabrication of these gates.

In our approach the bottom resist layer is a methylstyrene-based resist such as CSAR62, Allresist, (could also be ZEP 520, Zeon), the next layer is MMA EL11, a methacrylate monomer, and the top layer is PMMA 495K, a methacrylate polymer. The developer used is a mixture of an acetate, isopropanol, and water, to a specific ratio and is used at room temperature. No need for cold development. The PEC superposition approach approximates that the image in each layer is a modified sum of the images of all layers, separated by a dose factor multiplier unique to each layer. In addition to the superposition of images, a dose gap is introduced to further decouple the images of each layer [3].

The selection of resists is coupled to the developer used. It is known that the dose to clear for CSAR62 using 100 KV ebeam lithography, under standard single component developers such as acetates, xylenes, MIBK, is of the order of 200 $\mu C/cm^2$ to 350 $\mu C/cm^2$. We have found that diluting an acetate in isopropanol pushes the dose to clear to much higher values, to the point that at room temperature it is less sensitive than PMMA 495K. The addition of water allows for hydrogen bonding with the alcohol [4] and improves contrast for the MMA and PMMA from the CSAR resist. Figure 1 illustrates the contrast curves for these three resists using the ternary developer which we are denominating "991" developer.

The PEC superposition assumes that each resist layer is allocated an "image" that is fully proximity effect corrected, and the PEC dose is then scaled by a dose factor that roughly corresponds to the ratios of the dose to clear found in the contrast curves. The exposed region that is unique to each layer is extracted from the resist image, and stacked with the other scaled resist images. An example of this approach is shown in Figure 2. The CSAR image is only where CSAR dose is indicated. The PMMA 495K image includes the CSAR exposure region. The MMA image includes both the CSAR and PMMA 495 k exposed regions.

We believe this approach simplifies the data preparation and resist processing for multilevel lithography used in the fabrication of high-resolution *T*- and *Γ*- gates. Details of PEC image superposition approach and experimental results will be presented at the conference.

References:
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3. L. E. Ocola, D. M. Tennant, P. D. Ye, *MNE* 67-68 (2003) 104
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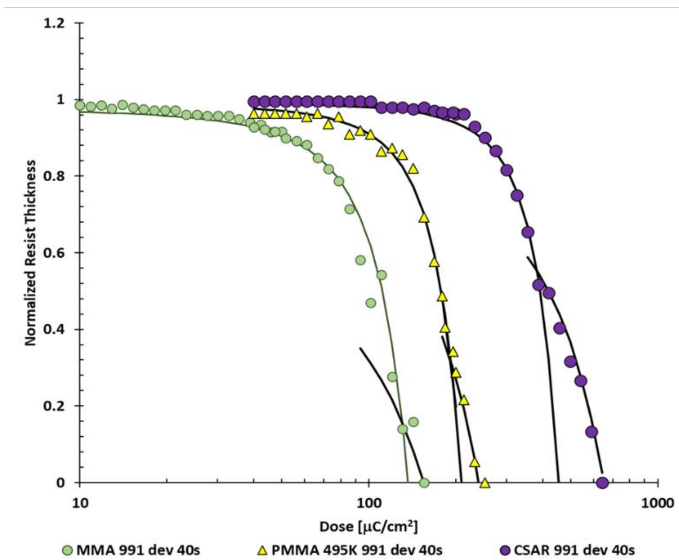

Figure 1. Contrast curves for MMA El11, PMMA 495 K, and CSAR62, all developed for 40 s at room temperature. Rinse is IPA for 30s. Fits follow equation (1) from Ref. [4]

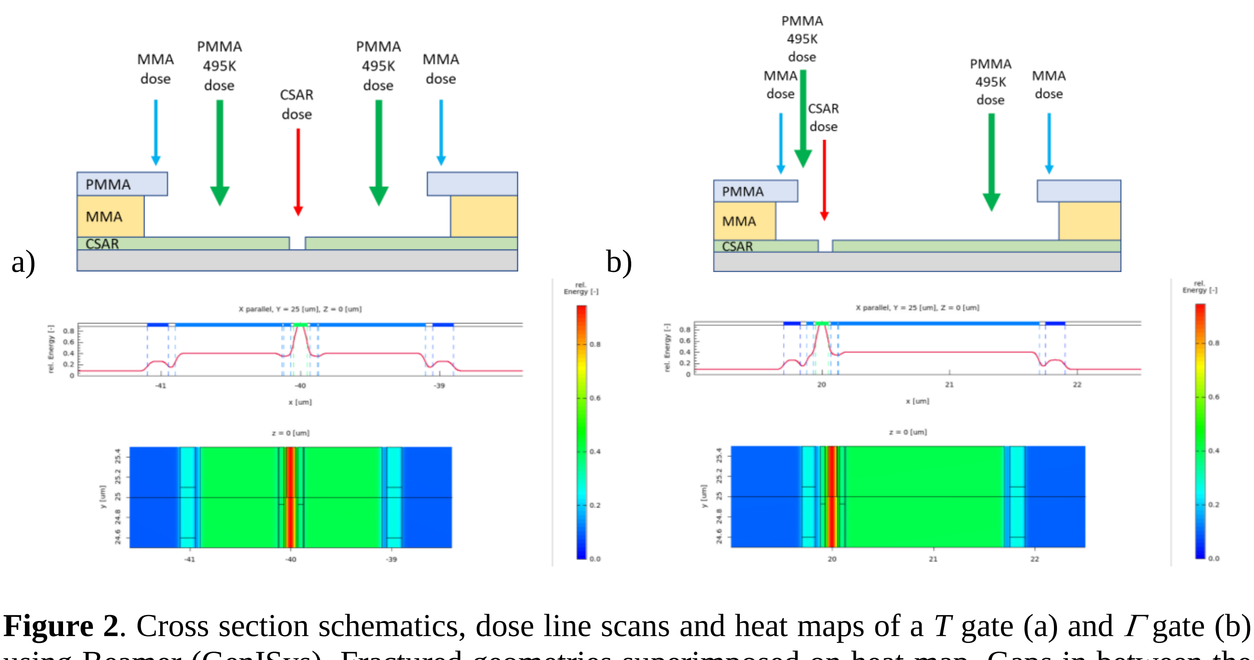

Figure 2. Cross section schematics, dose line scans and heat maps of a *T* gate (a) and *Γ* gate (b) using Beamer (GenISys). Fractured geometries superimposed on heat map. Gaps in between the resist images are shown as dotted lines on the dose profiles. Highest dose region corresponds to CSAR62, middle dose to PMMA 495K, and lowest dose to MMA. Image gaps allows for retaining critical feature dimensions as feature edges are not overexposed.