Nanometer-scale Gaps in Hydrogen silsequioxane Resist for T-gate Fabrication

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As the scaling of high electron mobility transistors (HEMTs) progresses into the nanometer-scale regime, it is increasingly difficult to achieve sub-50-nm gate lithography utilizing conventional multi-layer resist techniques. Multiple electron beam exposure of multi-layer resists for T-gate dimensions down to 25 nm have been demonstrated [1]. However, the stability and filling of such gate structures is not reliable due to the small footprint and large metal overlayer. Electron beam exposure and etching of dielectrics, such as silicon nitride, have alternatively been utilized to fabricate nanometer-scale T-gates with suitable structural stability [2].

Hydrogen silsequioxane (HSQ) is a low-k dielectric that has been used as a high-resolution negative electron beam resist with features as small as 6 nm demonstrated. In this paper, we present the use of HSQ to fabricate T-gates with footprints as small as 30 nm on InP-substrates. Our process for T-gate fabrication is demonstrated in Figure 1 where a) HSQ is patterned with electron beam to achieve a gap which serves as the footprint of the gate, b) another electron beam exposure is performed on a trilayer resist to achieve a wider geometry aligned onto the fabricated gap, and c) metal deposition and lift-off are performed to obtain the T-gate structure. The gate overlayer rests on the HSQ which as a dielectric itself can act as passivation material for HEMTs. Therefore stability is ensured while achieving ultra-small gate length structures. This process eliminates the dielectric etching step in [2]. We have investigated the minimum gap width that can be achieved as a function of HSQ thickness.

Figure 2 shows the gap-width obtained as a function of electron beam dose with the inset showing nominal gap width for a 40-nm-thick HSQ film on InAlAs/InGaAs/InP HEMT substrate. The exposure tool used in this work was a JEOL JBX-6000FS electron beam nanowriter with a beam voltage of 50 kV. A maximum dosage was observed where electron scattering/proximity effects resulted in web-like formations across the gaps for specific nominally designed gaps. Gap-width dependence on HSQ film thickness is shown in Fig. 3. Figure 4(a) shows ~ 32 nm-wide gap in 40 nm-thick HSQ film. This minimum gap is clear throughout its 50 μm-length without any web-like formation in the gap. Figure 4(b) shows the T-gate aligned onto the HSQ gap; the gap on the substrate has further being recessed for device applications. Device performance and advantages of this technique will be presented.

[1] Kwang-Seok Seo, Dae-Hyun Kim, Proceedings of International Conference on Indium Phosphide and Related Materials, pp: 30 – 35, May 2006

[2] Y. Yamashita, et al., IEEE-EDL, vol 23, pp 573-575, 2002

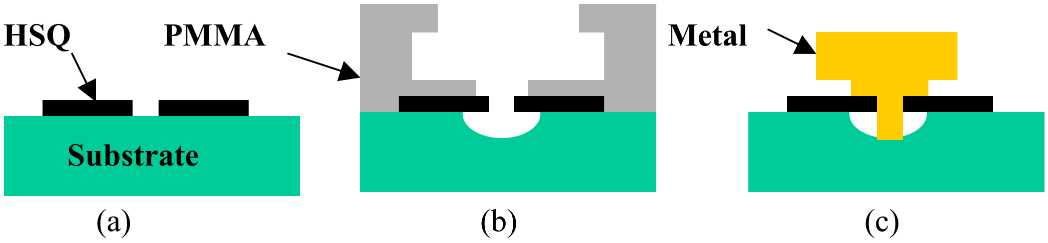

FIG. 1. T-gate fabrication process on InGaAs/InAlAs/InP substrate using HSQ.

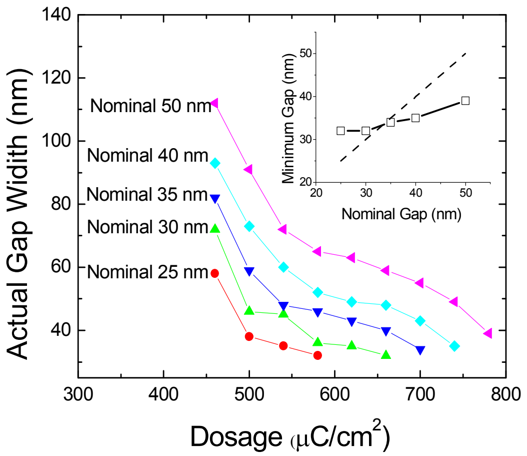

FIG. 2. Actual HSQ gap width as a function of dose and nominal gap width.

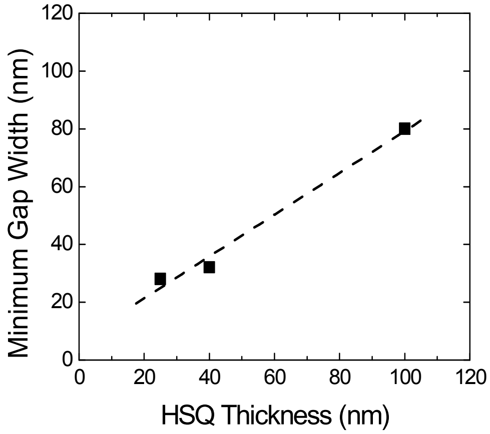

Fig. 3. Minimum HSQ gap width as a function of HSQ thin film thickness.

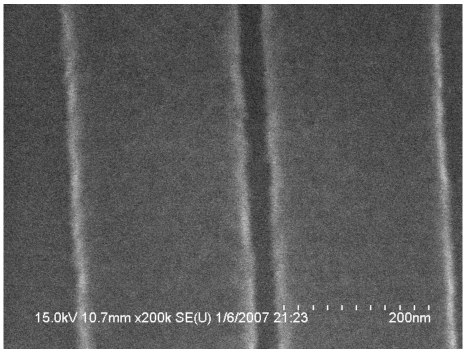

Fig. 4 (a). ~32 nm wide gap in a 40 nm-thick HSQ film.

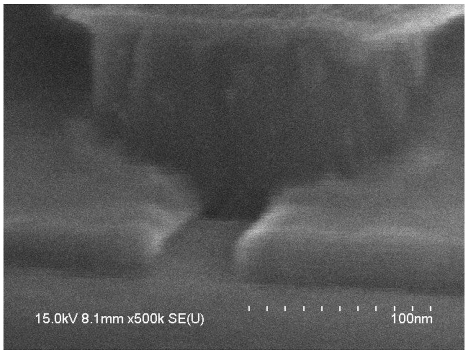

Fig. 4 (b). T-gate structure with footprint defined by the HSQ gap.