Long Narrow Gaps for III-V Transistors Fabricated by Electron Beam Lithography

S. Thoms and D.S. Macintyre
James Watt Nanofabrication Centre, School of Engineering, University of Glasgow, Glasgow, G12 8QQ, UK

Both High Electron Mobility Transistors (HEMTs) and MOSFETS on III-V substrates often require source-drain contacts with dimensions around 100 µm and separations of 1 – 2 µm. The materials involved are typically gold containing alloys which cannot be easily dry etched, and so lift-off is the preferred fabrication method. Smaller gaps are often desirable, but have proved difficult to fabricate when using electron beam lithography. This is unexpected since there are numerous papers demonstrating high resolution electron beam lithography down to 10 nm and beyond.

Part of the issue lies in the nature of poly methylmethacrylate (PMMA), the resist typically used for this application. The contrast of PMMA is fairly low – typically around 3.5 (when using natural logarithms), which results in about 20 % resist loss in the region between two adjacent pads. This cannot be eliminated by using proximity correction since negative doses would then be required. This leads to rounding of the resist profile in the gaps, making it unsuitable for lift-off. Secondly, adhesion becomes an important issue, since the ideal profile shown in Figure 1 has a small contact area with the substrate and is prone to delamination or collapse. A third issue is the nature of the III-V substrates, which are relatively delicate, and precludes, for instance, the use of HF-induced lift-off with HSQ as the resist, a technique successfully used to form narrow gaps on silicon substrates.

In this paper we investigate a number of techniques to fabricate long narrow gaps between large metal contacts. These include the use of a hydrogen silsesquioxane (HSQ) / PMMA bilayer[1] and we have used this approach to obtain the gap shown in Figure 2. To ensure the adhesion of the HSQ for the long, narrow lines required, we found that an adhesion promoter was necessary between the PMMA and the HSQ. We also consider the use of high contrast resists. The difficulty here is controlling the undercut by wet processing since too great an undercut results in loss of adhesion, and consistent results are difficult to obtain using this method. Finally we investigate the use of multi-layer lithography. Figure 3 shows the left and right hand pads can be written using separate lithography steps This shows a 65 nm gap over 100 µm, but at the cost of an extra lithography step.

[1] H. Yang, A. Jin, Q. Luo, J. Li, C. Gu and Z. Cui, Microelectronic Engineering 85, 814 (2008)

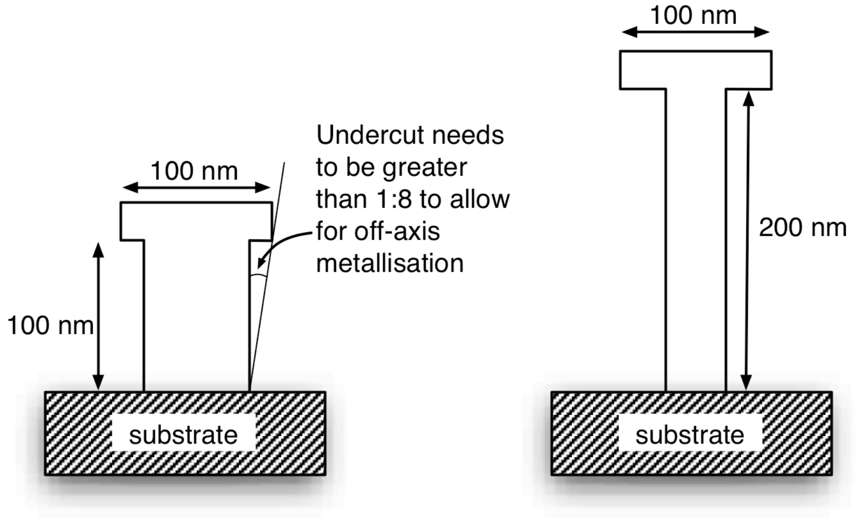

Figure 1: Required resist profile: This needs to extend for a length of around 100 µm. The dimesions shown are typical, with narrower and taller lines sometimes required. The adhesion between the resist and the substrate becomes critical as the width shrinks much below 100 nm, or if much thicker resist is required for, say, 200 nm thick metallisations as shown on the right.

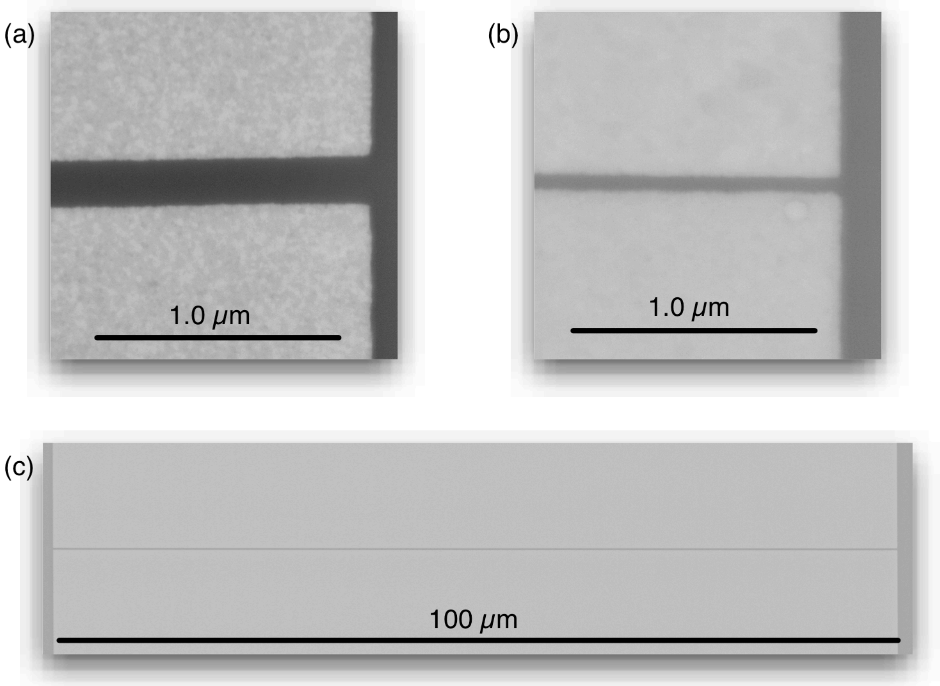

Figure 2: 100 µm Long Fabricated Gaps: (a) 200 nm gap was fabricated using an HSQ / PMMA bilayer; (b) 65 nm gap fabricated using two lithography layers and alignment; (c) shows the entire length of the 200 nm gap.