Process development for polysilicon patterning

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Polysilicon thin films serve as robust hard masks for deep etching of silicon dioxide and fused silica, offering advantages over metal masks by avoiding re-sputtering issues. This makes polysilicon especially suitable for applications demanding smooth etching profiles with well-defined sidewalls and bottoms. In this study, we present a comparative analysis of methods to achieve smooth, straight photoresist sidewalls on polysilicon layers. Three surface preparation techniques were investigated: untreated polysilicon, anti-reflection-coated polysilicon, and polished polysilicon. Our results indicate that polished polysilicon yields the best results, producing straight, well-defined photoresist sidewalls, while untreated and anti-reflection-coated polysilicon exhibited waviness.

Introduction

Deep reactive ion etching (DRIE) of silicon dioxide is integral in application spanning microfluidic[1], MEMS and integrated photonic. Various mask materials, such as SU-8[2], Nickel[3] amorphous silicon[4] and silicon wafer[5], were used for silicon DRIE. However, each presents challenges: SU-8 requires thick layers, nickel risks contamination, and silicon wafers need additional bonding steps. We explore low-pressure chemical vapor deposition (LPCVD) polysilicon as an effective hard mask for high-quality DRIE of silicon dioxide, addressing these challenges. In this paper, we especially investigate 3 methods of forming photoresist mask on top of the polysilicon surface

Experimental methods

Figure 1 illustrates the process flow for each of the three methods. A 2 µm thick polysilicon layer was deposited on 4-inch silicon wafers with 8 µm thermal oxide layers. The wafers were then divided into 3 groups. In group 1, we directly spin HMDS and 1.7 µm Olin OIR 907-17 photoresist. In group 2, we firstly spin a layer of anti-reflective coating and than spin olin oir 907-17 above the anti-reflective coating. In group 3, the wafers were firstly planarized by chemical mechanical polishing (CMP) and then HMDS and olin oir 907-17 was spined onto the wafer. After exposure using an EVG 6200 NT mask aligner, all samples were developed and characterized by scanning electron microscopy (SEM).

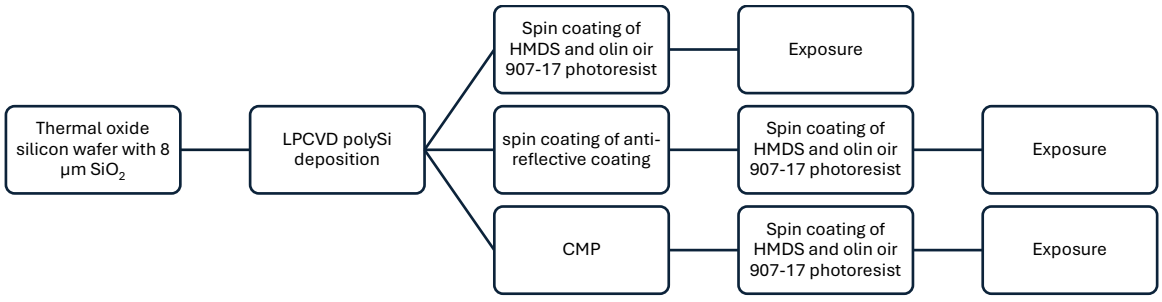
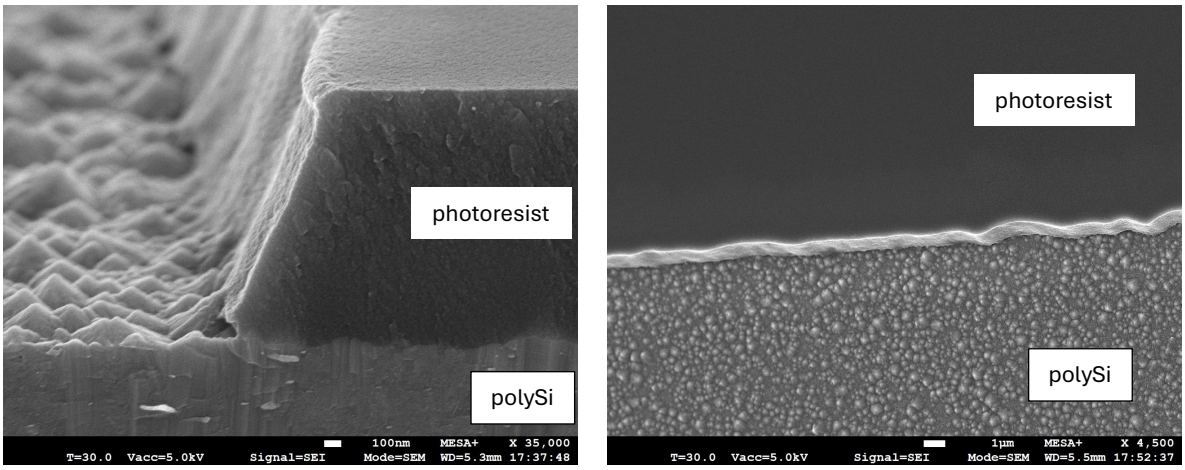


Figure 1, schematic process flow of 3 wafer groups presented in this paper

Results and discussion

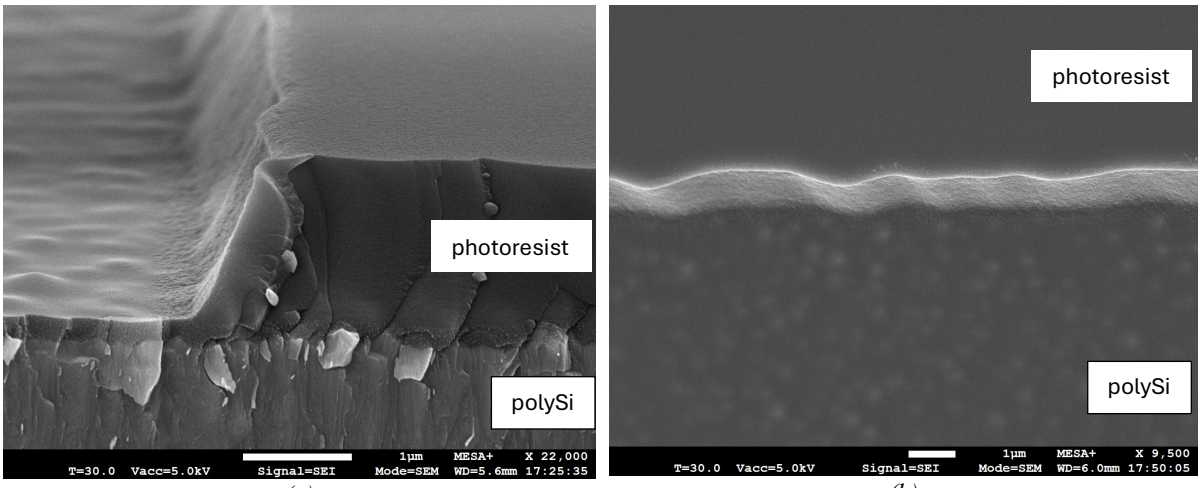
Figure 2 shows SEM images of photoresist from wafers in group 1. Figure 2(a) shows that the top surface of the polySi layer consists of randomly distributed pyramid structures. Figure 2(b) shows that the developed photoresist layer have a waving front. This is induced by the random reflection of the pyramid structure in the polysilicon layer



(a) *(b)*

Figure 2. SEM images of the cross section (a) and top view (b) of developed photoresist on top of rough polysilicon surface.

Figure 3 shows the shows SEM images of photoresist from wafers in group 2. Figure 3(a) shows that the anti-reflective coating is not removed after the photoresist development. Figure 3(b) shows that the photoresist still have a waving front. This is because the anti-reflective coating reduces the reflection partially by destructive interference, however, the anti-reflective coating on the rough polySi surface have non uniform thickness, the anti-reflective effect is not uniform on the surface.



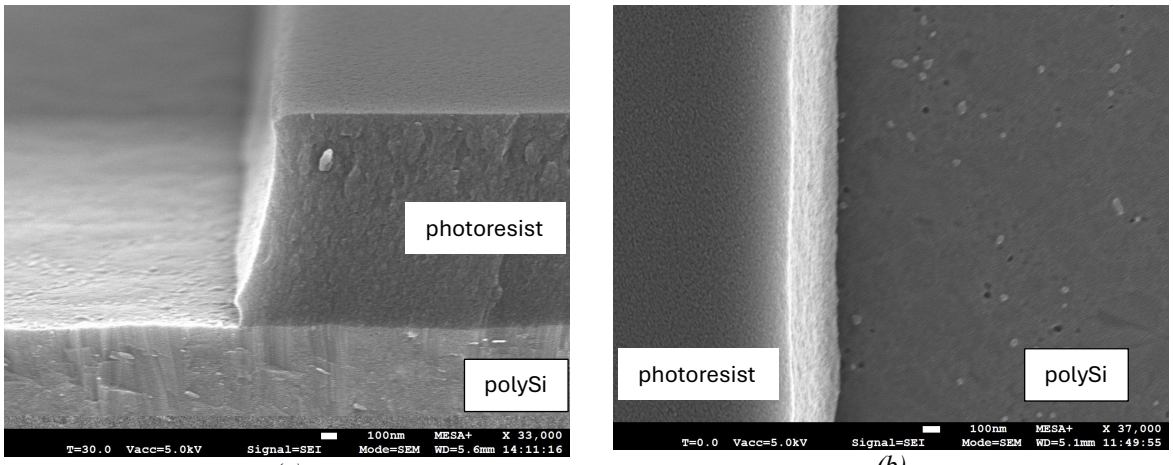
(a) *(b)*

Figure 4. SEM images of the cross section (a) and top view (b) of developed photoresist on top of rough anti-reflection coating.

Figure 4 shows the SEM images of photoresist from wafers in group 3. Figure 4(a) shows that CMP effectively planarized the top surface of the polySi layer. Figure 4(b) shows that the front of the photoresist is straight, thanks to the regular and vertical reflection of the polished polySi surface.

Conclusions

This study highlights three approaches to patterning photoresist on polysilicon. Untreated and anti-reflection-coated polysilicon resulted in wavy profiles, while polished polysilicon achieved the desired straight photoresist edges. CMP-based planarization is essential for applications requiring precise, high-quality patterning on polysilicon.



(a) *(b)*

Figure 4. SEM images of the cross section (a) and top view (b) of developed photoresist on top of polished polysilicon surface.

Reference

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