Tungsten silicide and tungsten polycide anisotropic dry etch process for highly controlled dimensions and profiles

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I. INTRODUCTION

Highly anisotropic dry etching of tungsten silicide and tungsten polycides is required for the realization of submicron low resistance gates and interconnects for use in high performance complementary metal–oxide–semiconductor (CMOS) and BiCMOS technologies.[1] The current etch chemistries are not anisotropic, i.e., lateral etching of the tungsten silicide takes place which results in undesirable CD loss. In many applications a spacer needs to be formed on the polycide sidewall (Fig. 1). Undesirable undercutting can result in nonideal spacer formation for further device fabrication.

Tungsten silicide etching has been described in literature using mixtures of SF_6, Cl_2, or CF_4.[2–4] However, all these chemistries have excessive undercutting, no end point detection, and poor control of sidewall profile. It is the purpose of this brief to describe an etch chemistry using C_2F_6, Cl_2, and O_2 which forms polymer on the sidewall of the tungsten silicide during the etch in order to avoid undercutting.[5] In addition, the etch chemistry allows increase of the critical dimension by controlling the polymer deposition on the sidewall.

II. EXPERIMENTS

All etch experiments were performed in a LAM 384T Triode etcher. Power was applied to the lower electrode (RIE mode). The temperature of the electrodes was held between 15 and 30° C. Chamber pressure was maintained at 150 mT and the He backside cooling pressure was 8 T for all experiments. The C_2F_6, Cl_2, and O_2 system was explored under two different plasma power conditions. Detailed experiments were performed to determine the etch rates of WSi_x, polysilicon, and oxide under various gas plasmas and rf power.

WSi_x was deposited in a varian 3190 sputtering system from a composite target. Poly-silicon was deposited at 625 °C using low pressure chemical vapor deposition (LPCVD). The first step in the etch is an oxide etch which is to be used only if there is an insulator on top of the WSi_x. The end point can be detected when the silicide is exposed at the change in the CO emission at 450±25 nm when using a $CHF_3:C_2F_6$ chemistry. The second step is main WSi_x etch, the characterization of which is described in detailed next. An end point can be detected at the change in the emission at 289±25 nm. The third step is the poly-silicon etch which results in an endpoint at changes in emission at 289±25 nm. Resist loss for OCG 825 in a typical process is about 5000 Å.

III. RESULTS AND DISCUSSION

A mixture of C_2F_6 and Cl_2 was first tried for the WSi_x etch. It was discovered that the etch builds up polymer on the WSi_x sidewall, which is bombarded and removed during the etch. Since the bombardment is anisotropic, the polymer on the sidewall is not removed and a ''foot'' of WSi_x will be produced after resist is stripped. As the C_2F_6/Cl_2 ratio is increased, the selectivity between the WSi_x and poly etch rates is increased but more polymers are formed on the sidewall, resulting in a tapered profile. When the C_2F_6/Cl_2 ratio is decreased, the polymer formation is also decreased but the WSi_x and poly etch rates increase at a very rapid rate due to increased chlorine radicals in the ambient. High $\%Cl_2$ mixtures are thus not desirable since a decrease in poly-silicon etch rate is needed once the WSi_x is removed. Figure 2 shows the cross sections of the stack with two different C_2F_6/Cl_2 ratios. The corresponding etch rates are depicted in Fig. 3.

Addition of O_2 in the C_2F_6/Cl_2 mixture, however, results in a decrease of the polymer buildup and a highly anisotropic, straight sidewall. The polymer can be postulated to be a tungsten-carbon based compound that reacts with oxygen to form volatile compounds. SF_6 or CF_4 based chemistries described in prior arts do not provide enough carbon to form polymers on the sidewall and hence have resulted in undercut of the silicide. Figure 4 shows the etch rate variation with change in $\%Cl_2$ in the $C_2F_6/Cl_2/O_2$ system. It is interesting to note that in our study, the over all etch rates of oxide, silicide and poly-silicon does not change much within the variation of O_2 studied as shown in Fig. 5. Excessive O_2, however, can result in excessive side etching of the resist, unwanted increase of CD, and undercutting of WSi_x. The final mixture results in an optical end point at poly-Si inter-

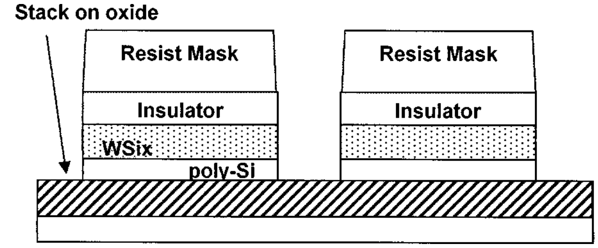

FIG. 1. Cross section of the polycide stack.

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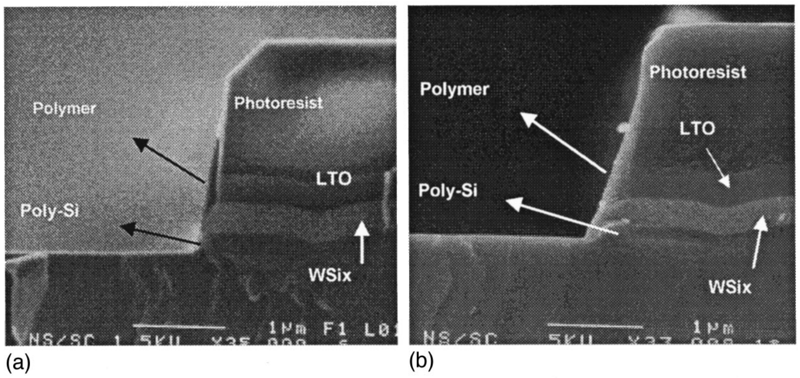

FIG. 2. (a) Stack cross section with WSi_x etch using $C_2F_6:Cl_2=85:50$, rf=400 W. (b) Stack cross section with WSi_x etch using $C_2F_6:Cl_2=100:35$, rf=400 W.

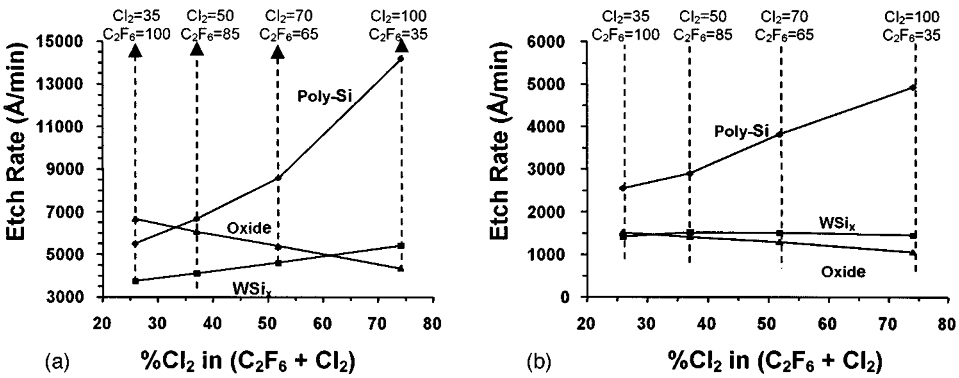

FIG. 3. (a) Etch rate variation in $C_2F_6:Cl_2$, rf=400 W. (b) Etch rate variation in $C_2F_6:Cl_2$, rf=100 W.

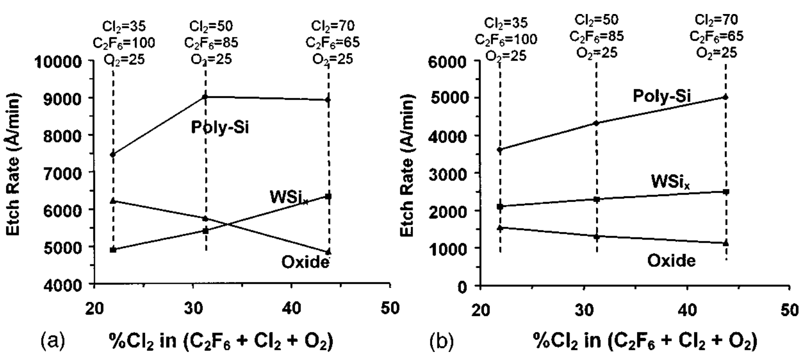

FIG. 4. (a) Etch rates for variation in %Cl at rf=400 W. (b) Etch rates for variation in %Cl at rf=100 W.

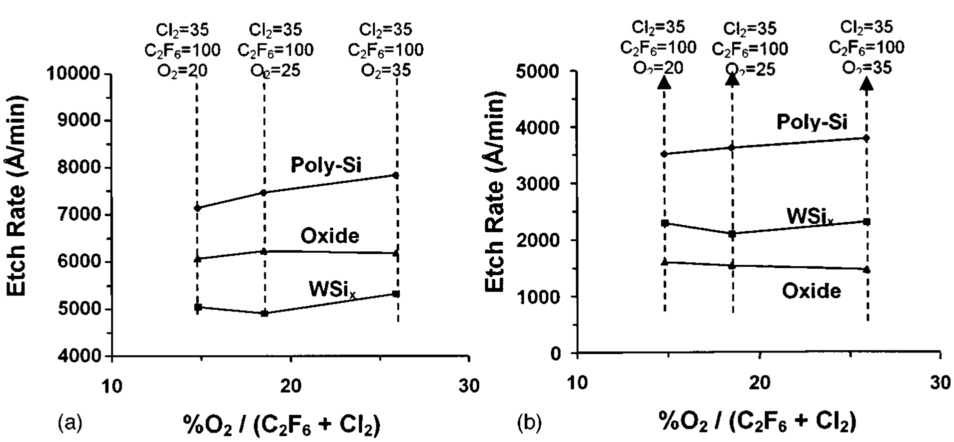

FIG. 5. (a) Etch rates for variation in $\%O_2$ at rf=400 W. (b) Etch rates for variation in $\%O_2$ at rf=100 W.

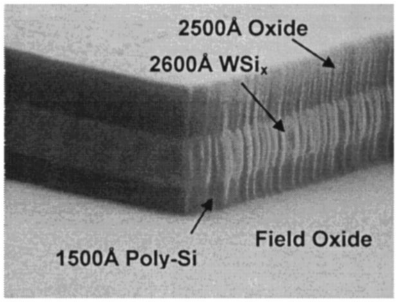

FIG. 6. Angled SEM of the stack with WSi_x etched with the final process. (WSi_x etch using $C_2F_6:Cl_2:O_2=100:35:20$ at 400 W, 150 mT, and poly-Si etch using $C_2F_6:Cl_2=85:50$ at 100 W, 120 mT.)

face. The end point is detected by a change in the emission at wavelengths of 289 ± 25 nm. There is no known reference of such an optical end point. Figure 6 shows an angled high magnification scanning electron microscopy (SEM) showing the anisotropic profile of the stack etched using the optimized WSi_x etch process with a gas mixture of $C_2F_6:Cl_2:O_2=100:35:20$ at 400 W, 150 mT, and poly-Si etch using $C_2F_6:Cl_2=85:50$ at 100 W, 120 mT.

The polymer-forming recipe can also be used to make self-aligned butted contact structures.[6] For example, simultaneous contact to the buried poly or silicide film and underlying substrate can be formed without a mask.

IV. CONCLUSIONS

A new etch chemistry has been developed to etch tungsten silicide and tungsten polycide films with high control of the sidewall profile using a $C_2F_6/Cl_2/O_2$ mixture in a LAM 384T system. The O_2 in the ambient helps control the etching of sidewall polymer and hence provides an additional degree of freedom in controlling the slope of the sidewall without significantly affecting the etch rates.

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