FIG. 1. Cross section of the polycide stack.

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

R. Bashir, A. E. Kabir, F. Hebert, and C. Bracken
National Semiconductors, Santa Clara, California 95051
(Received 31 December 1997; accepted 22 May 1998)

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. 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 SF₆, Cl₂, or CF₄. 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 C₂F₆, Cl₂, and O₂ which forms polymer on the sidewall of the tungsten silicide during the etch in order to avoid undercutting. 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 mTorr and the He backside cooling pressure was 8 T for all experiments. The C₂F₆, Cl₂, and O₂ system was explored under two different plasma power conditions. Detailed experiments were performed to determine the etch rates of WSiₓ, poly-silicon, and oxide under various gas plasmas and rf power.

WSiₓ 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 WSiₓ. 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 CHF₃:C₂F₆ chemistry. The second step is main WSiₓ 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 C₂F₆ and Cl₂ was first tried for the WSiₓ etch. It was discovered that the etch builds up polymer on the WSiₓ 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 WSiₓ will be produced after resist is stripped. As the C₂F₆/Cl₂ ratio is increased, the selectivity between the WSiₓ and poly etch rates is increased but more polymers are formed on the sidewall, resulting in a tapered profile. When the C₂F₆/Cl₂ ratio is decreased, the polymer formation is also decreased but the WSiₓ and poly etch rates increase at a very rapid rate due to increased chlorine radicals in the ambient. High %Cl₂ mixtures are thus not desirable since a decrease in poly-silicon etch rate is needed once the WSiₓ is removed. Figure 2 shows the cross sections of the stack with two different C₂F₆/Cl₂ ratios. The corresponding etch rates are depicted in Fig. 3.

Addition of O₂ in the C₂F₆/Cl₂ 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. SF₆ or CF₄ 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 %Cl₂ in the C₂F₆/Cl₂/O₂ 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 O₂ studied as shown in Fig. 5. Excessive O₂, however, can result in excessive side etching of the resist, unwanted increase of CD, and undercutting of WSiₓ. The final mixture results in an optical end point at poly-Si inter-
Fig. 2. (a) Stack cross section with WSi$_x$ etch using C$_2$F$_6$:Cl$_2$=85:50, rf=400 W. (b) Stack cross section with WSi$_x$ etch using C$_2$F$_6$:Cl$_2$=100:35, rf=400 W.

Fig. 3. (a) Etch rate variation in C$_2$F$_6$:Cl$_2$, rf=400 W. (b) Etch rate variation in C$_2$F$_6$: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.
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 WSi₇ etch process with a gas mixture of C₂F₆:Cl₂:O₂ = 100:35:20 at 400 W, 150 mT, and poly-Si etch using C₂F₆:Cl₂ = 85:50 at 100 W, 120 mT.

The polymer-forming recipe can also be used to make self-aligned butted contact structures. 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 C₂F₆/Cl₂/O₂ mixture in a LAM 384T system. The O₂ 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.