Patterning of Chromium Oxide as a Hard Mask by Plasma Etching

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It has been recently reported that chromium oxide (Cr_2O_3) is a more suitable hard mask material compared to chrome metal (Cr) for pattern transferring via plasma etching, and also that both materials have a similar etch resistance and selectivity over silicon in SF_6-based plasmas [1]. Since Cr_2O_3 contains oxygen, it is more readily etched in Cl_2/O_2 plasmas with less oxygen content than is required for Cr metal etching. It is therefore advantageous to transfer the pattern onto Cr_2O_3 rather than metallic Cr.

In this work, we present a systematic investigation of plasma etching of Cr_2O_3 films via an inductively coupled plasma-reactive ion etching (ICP-RIE) system in the nanoscale. The effects of plasma composition, rf chuck power and ICP source power on the etch rates, sidewall profile, surface roughness, selectivity and dc-bias have been systematically investigated.

As for a hard mask to pattern the 500nm-thick Cr_2O_3 film, approximately a 50nm-thick SiO_2 was used via an e-beam evaporator and lift-off technique. The effect of ICP source power on the etch rate, dc-bias, and undercut are shown in Fig. 1. It is observed that the etch rate linearly increased whereas dc-bias decreased. There is always an undercut at each ICP power, however a lower ICP power resulted in a smaller undercut.

Secondly, rf chuck power was investigated and the etch rate, dc bias, and undercut were illustrated in Fig. 2. The chuck power was increased from 10 to 100 W while the rest of the system parameters were set to 5 mTorr of chamber pressure, 600 W of ICP power with the same plasma chemistry.

Figure 3. represents correctional SEM images as a function of the oxygen content in the Cl_2/O_2 plasma at 5 mTorr of chamber pressure, 100 W of rf power and 600 W of ICP power. It was observed that by increasing the oxygen content to 20%, the etch profile changed from tapered to vertical geometry. Above this value, excess oxygen content resulted in an undercut below the hard mask.

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1 F. Aydinoglu, F Saffih, RK. Dey, and B. Cui, J. *Vac. Sci. Technol. B.* **35**, 06GB01, (2017)

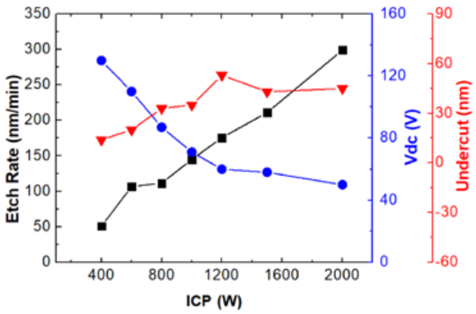

Figure 1: Etch parameters as a function of ICP power; the rest of the system parameters were set to 5 mTorr of chamber pressure, 20 W of rf power with a mixture of chlorine and oxygen gases mixed at a ratio of 40:10 in sccm at 40 ^{o}C.

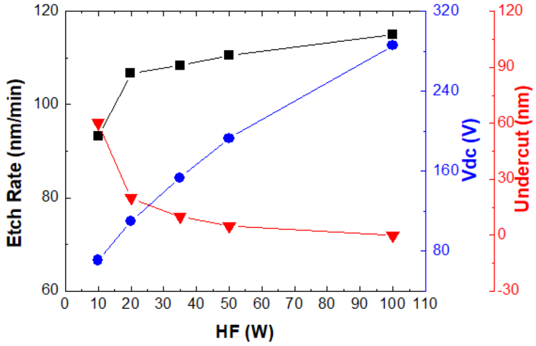

Figure 2: Etch parameters as a function of rf chuck power; the rest of the system parameters were set to 5 mTorr of chamber pressure, 600 W of ICP power with a mixture of chlorine and oxygen gases mixed at a ratio of 40:10 in sccm at 40 ^{o}C.

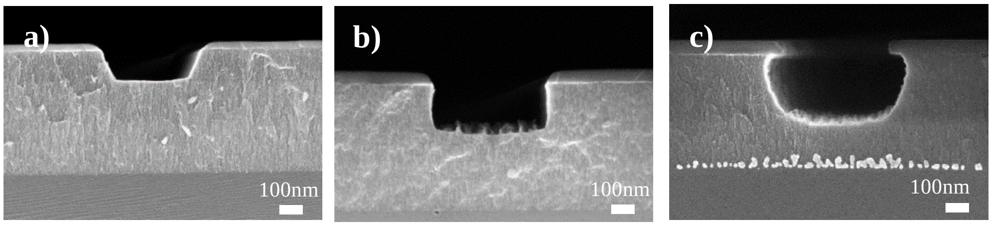

Figure 3: Etch profiles with respect to the oxygen content in the Cl_2/O_2 plasma. While increasing oxygen content in the plasma, rest of the parameters were kept constant at 5 mTorr of chamber pressure, 100 W of rf power and 600 W of ICP power. Low oxygen content resulted in a tapered profile (**a**) whereas excess oxygen content caused undercut (**c**). 20% of oxygen content led to vertical sidewalls (**b**).