Effects of Cl_2 on In-Situ Boron Doped $Si_{1-x}Ge_x$ Source/Drain Junctions for CMOS Technology Nodes Beyond 30 nm

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Scaling of MOSFETs for technology nodes beyond 30 nm require novel junction and contact formation technologies to suppress short-channel effects and satisfy parasitic resistance specifications[1,2]. A new technology was recently proposed by this laboratory to meet the requirements of future technology nodes[3]. The technology relies on selective deposition of in-situ boron doped $Si_{1-x}Ge_x$ alloys in junction regions recessed to the desired junction depth. The films are epitaxially grown at temperatures at or below 550°C. These junctions satisfy the demands of future technology nodes including low sheet resistance, super-steep lateral junction-to-substrate abruptness, low contact resistivity and low processing temperature.

The success of the proposed junction technology has to be coupled with excellent deposition selectivity with respect to the sidewall spacer and the surrounding insulators. In our previous work, depositions relied on the inherent selectivity of the Si_2H_6 and GeH_4 chemistry. However, Si and $Si_{1-x}Ge_x$ depositions without Cl_2 or HCl typically lose selectivity beyond a critical thickness[4,5,6,7]. Furthermore, it was suggested that B_2H_6 could contribute to loss of selectivity[8].

In this work, we have investigated the consequences of adding Cl_2 to enhance the selectivity robustness. The films were analyzed by XRD, SIMS and four-point probe measurements. Loss of selectivity was monitored by Atomic Force Microscopy (AFM). Root Mean Square (RMS) surface roughness of the insulator surface was used to quantify the degree of selectivity.

Figure 1 shows the RMS value of the insulator surface roughness as a function of chlorine partial pressure for depositions within a temperature range of 450 – 550 °C. As shown, addition of Cl_2 enhanced selectivity even at very low deposition temperatures considered in this study.

Our results indicated that addition of Cl_2 resulted in reduced B incorporation (Figure 2). Nevertheless, extremely low film resistivities around $3x10^{-4}$ ohm-cm were still possible due to enhanced $Si_{1-x}Ge_x$ mobility at lower boron densities (Figure 3). This resistivity corresponds to sheet resistance values compatible with the needs of physical gate lengths down to 9 nm as reported in ITRS 2001[9].

The results of this study indicate that a chlorinated deposition chemistry can be used to improve selectivity at low deposition temperatures without sacrificing the low sheet resistance of the deposited films.

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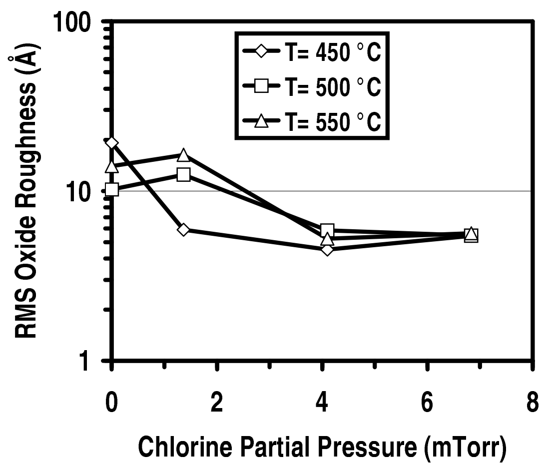

Figure 1: RMS oxide roughness as a function of temperature and Cl_2 partial pressure.

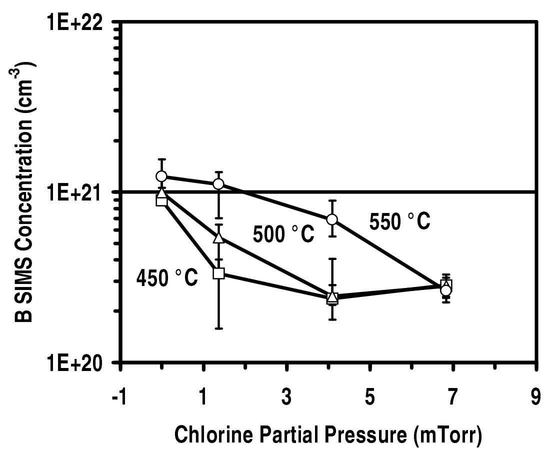

Figure 2: Incorporated B concentration as a function of temperature and Cl_2 partial pressure.

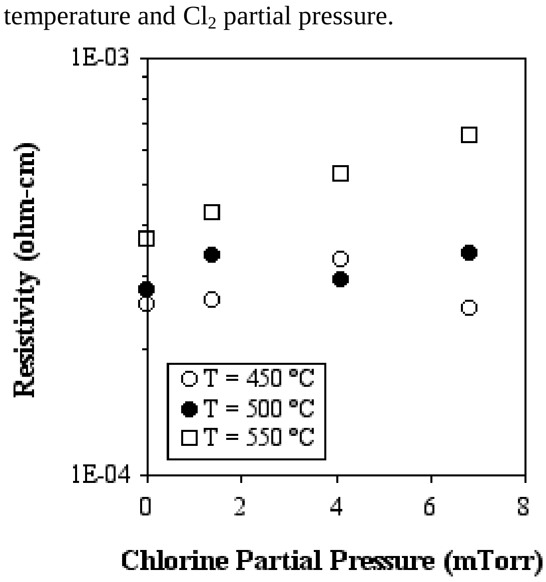

Figure 3: Resistivity as a function of temperature and Cl_2 partial pressure.