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Silicon and SiGe alloys wet etching using TMAH chemistry

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Wet anisotropic etching has been extensively used as a micromachining technology for the fabrication of low cost MEMS components such as cantilever beams, mirrors and several types of other structures in single crystal silicon wafers. In this field, even if the issue of its toxicity classification is currently under discussion, the interest in the Tetra-Methyl Ammonium Hydroxide (TMAH) solution has significantly increased as this anisotropic silicon etchant presents a good compatibility with CMOS processing, anisotropy and interesting selectivity, comparing with the more used KOH and EDP etchants [1, 2]. More recently, silicon anisotropic etching has already been considered to face new CMOS technology challenges: diamond shape recess etching into the PMOS S/D area for mobility gain into the channel [3], fabrication of Germanium nanowires by using a Germanium on nothing technology [4], Poly-silicon wet removal for Replacement Gate Integration [5].

In this study, following the evolution of the silicon wet etching needs, we first compared the traditional TMAH immersion mode (in manual wet benches) with the spin-on one (in a fully automated single wafer Raider SP tool). The impact of the chemistry injection mode as well as the TMAH solution dilution on the Si etch rate will be discussed (Figure 1). The compatibility of TMAH solutions has already been checked by measuring etch rates on various dielectrics (thermal oxide, TEOS, LPCVD and PECVD nitrides, HfSiON, SiON…) demonstrating the very good selectivity of TMAH silicon etching towards materials typically embedded in CMOS structures. The impact of TMAH exposure on Si surface has already been investigated showing that TMAH dilution highly impacts the exposed silicon morphology (Figure 2). Firstly, the more the TMAH solution is diluted, the higher the density of pyramidal structures (aligned on 111 plans) is. Secondly, even if no "texturation" effect can be detected using 25% TMAH, the AFM scans of Si exposed surfaces clearly reveal the surface damage resulting in the increase of the microroughness (RMS values going up to 0.6 nm).

Considering the growing interest of the CMOS technology to $Si_{1-x}Ge_x$ alloys (Raised Source and Drain, strained channels …), we focused the second part of this paper to the study of their compatibility towards TMAH chemistry. $Si_{1-x}Ge_x$ (x: 0.2, 0.3, 0.5 and 1) strained layers were epitaxially grown on 300mm SOI wafers and successively etched in 5% and 25% TMAH solutions, varying the temperature from 50°C up to 75°C (Figure 3). Increasing the Ge content in the $Si_{1-x}Ge_x$ alloys lead to a strong decrease of the etch rate (at 60°C, factors of 20, 45 and 110 respectively for 20%, 30% and 50% Ge alloys compared to Si etch rate) whereas full Ge layers do not etch at all whatever the TMAH concentration and temperature.

In conclusion, thanks to its high selectivity towards many materials (dielectrics, Ge) and its easy implementation on a spin–on full-automated tool, TMAH chemistry appears as a very interesting way to monitor Si and SiGe alloys wet etching in challenging CMOS technological steps.

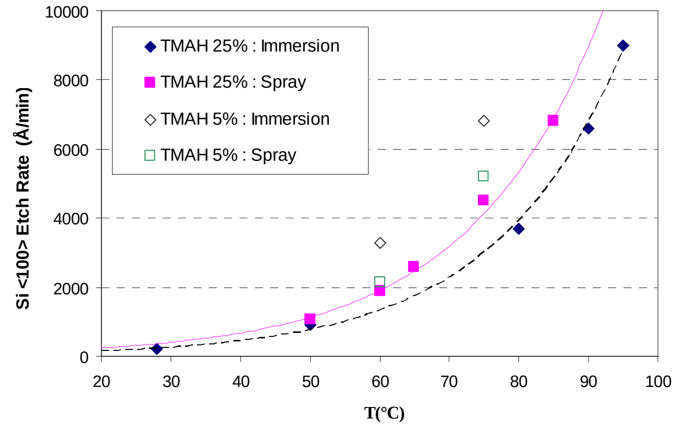

Fig.1. Influence of both chemistry dispense mode (immersion or spin-on) and TMAH dilution on the kinetic of silicon wet etching.

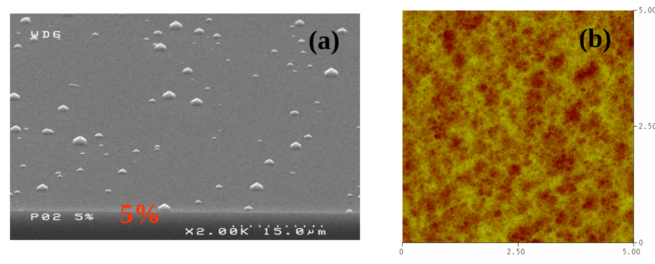

Fig.2. (a) SEM image of a textured silicon surface after immersion in a 5% diluted TMAH solution. (b) AFM 5µm^2 scan of a non textured silicon surface after 25% TMAH exposure.

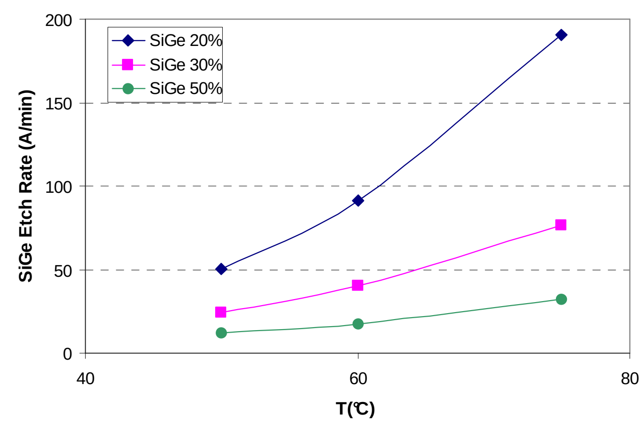

Fig.3. Evolution of the $Si_{1-x}Ge_x$ (x: 0.2, 0.3 and 0.5) etch rates as a function of the temperature using a 25% TMAH spin-on dispensed chemistry.

References

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