WET AND DRY EX-SITU/IN-SITU CLEANING FOR CONTROL OF INTERFACE IMPURITIES AND MICROSTRUCTURE OF LOW TEMPERATURE SILICON DEPOSITION

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The purpose of this work was to develop production worthy ex-situ and in-situ low temperature cleaning procedures for the removal of native oxide and other silicon surface impurities (carbon, florine, metallics and particles) prior to low temperature (600°C to 850°C) silicon deposition. By selectively using different wet and dry HF ex-situ cleaning techniques in conjunction with in-situ low temperature hydrogen bake/anneal, we have been able to remove native oxide and other impurities from the silicon surface prior to silicon deposition. More importantly, we have also been able to control the interface impurity levels of oxygen, carbon and florine. The levels of these interfacial impurities determine the microstructure and properties of the as deposited film and the subsequently annealed film. Therefore, we report for the first time a unique way to control the microstructure of silicon by controlling the interfacial impurity levels and using florine to prevent epitaxial alignment of silicon. This resulted in either poly or epitaxial silicon deposition at 645°C.

Four ex-situ cleaning procedures were compared during this study, two wet and two dry techniques. The wet HF clean leaves less than a monolayer of native oxide ($<1E15/cm^2$), carbon at $2E13/cm^2$, florine at $2E12/cm^2$ on the silicon surface, and removes metallic surface impurities. Combined with a megasonic clean, a 9Å chemical oxide on the surface was achieved as well as surface particle reduction. The dry HF vapor clean also leaves less than a monolayer of native oxide ($<1E15/cm^2$), carbon at $4E13/cm^2$, however, residual florine on the surface is now an order of magnitude higher at $3E13/cm^2$ and metallic surface impurities and particles are not removed. Used with an ozone clean results in 8Å oxide on the surface with no reduction in carbon nor florine surface impurity levels. Once cleaned a wafer can be stored for days with minimal native oxide regrowth as shown in Fig.1.

Results from in-situ low temperature hydrogen bakes on interfacial oxygen, carbon and florine impurity levels are shown in Figs.2,3&4. Lower bake pressures also leads to improved native oxide removal (Fig.5). The impact of interface impurity level on as deposited silicon microstructure are shown in Figs.6,7&8 for no clean, wet HF and vapor HF ex-situ cleans while Fig.9 is for wet HF+RTP bake ex-situ/in-situ clean. With just ex-situ cleaning, a wet HF clean results in an interfacial oxygen level of $9E14/cm^2$ with a discontinuous interface and single crystal epitaxial deposition as seen in the X-TEM of Fig.7, while a vapor HF clean results in the same interfacial oxygen level but with a continuous interface due to the much higher level of residual florine at the interface and poly deposition. The continuous interface prevents epitaxial alignment of silicon adatoms during deposition. Using the combined ex-situ and in-situ cleans results in a very clean interface, no measureable carbon nor florine, oxygen at $7E13/cm^2$ and epitaxial deposition at 645°C (Fig.9). Use of the ex-situ/in-situ clean in selective poly bipolar emitter technology is shown in Fig.10 for a 775°C bake resulting in an interfacial oxide of $1.9E15/cm^2$, carbon of $3E13/cm^2$ and florine of $1.5E11/cm^2$.

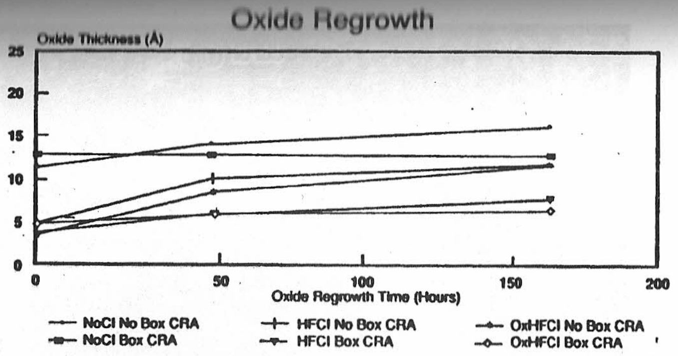


Fig.1

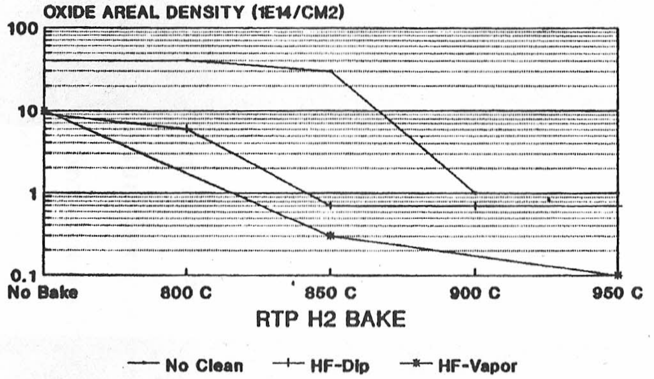


Fig.2

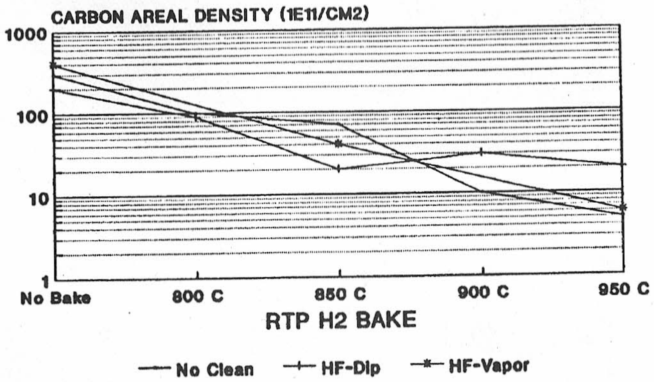


Fig.3

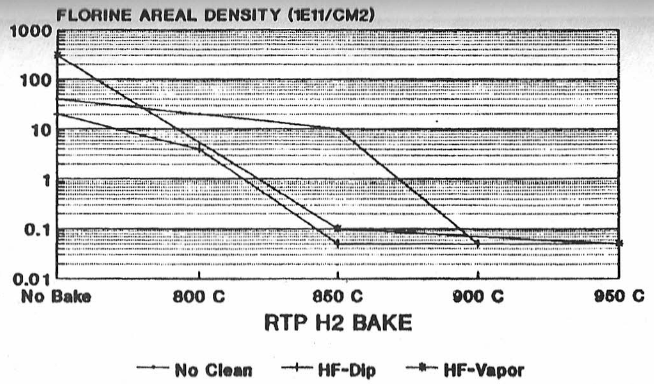
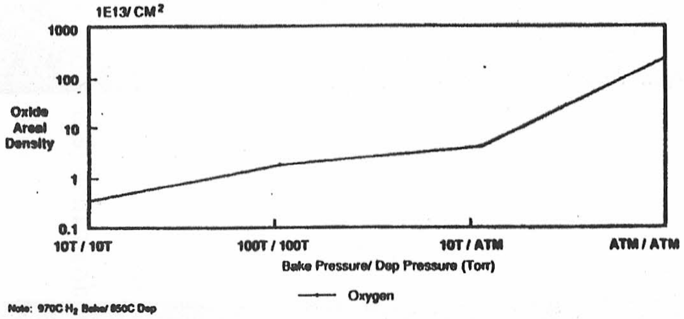


Fig.4



Note: 970C H_2 Bake/ 850C Dep

Fig.5

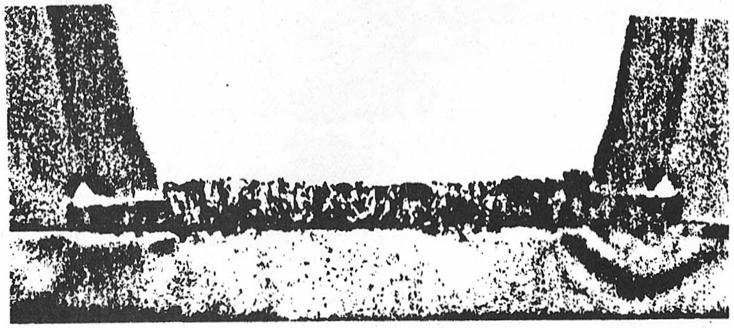


Fig.10

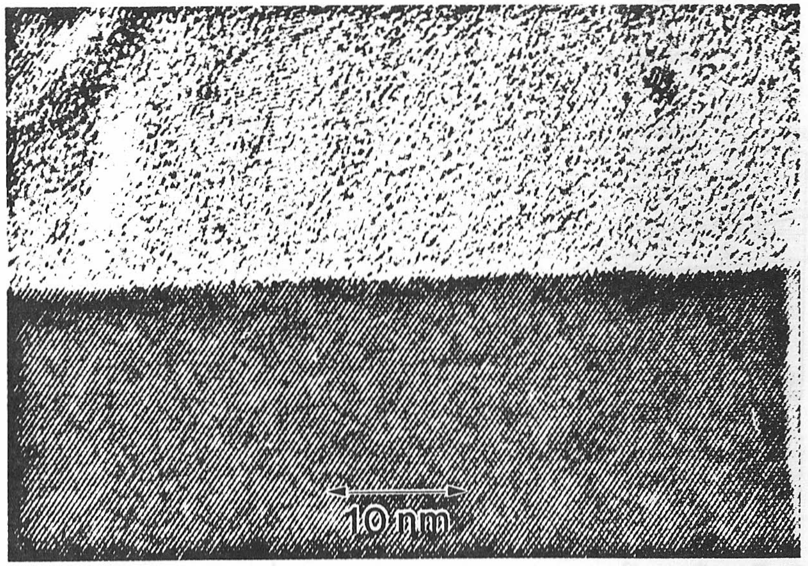


Fig.6

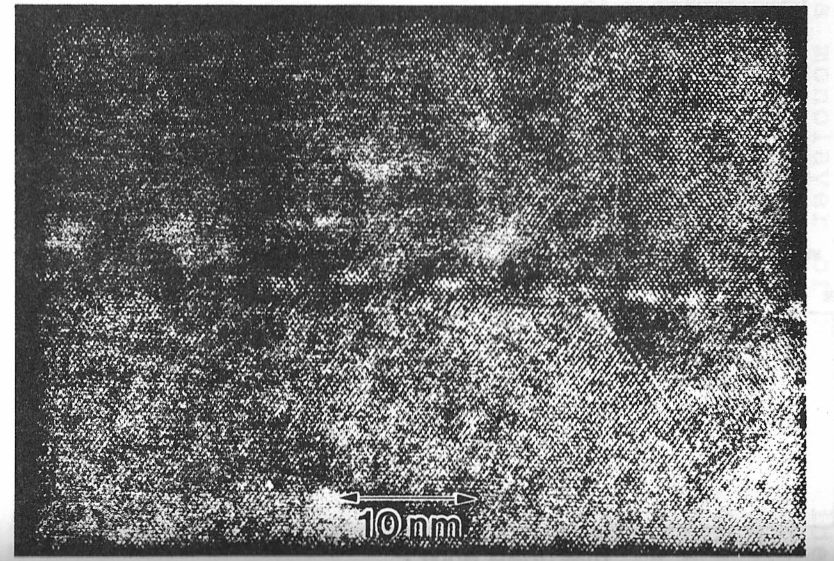


Fig.7

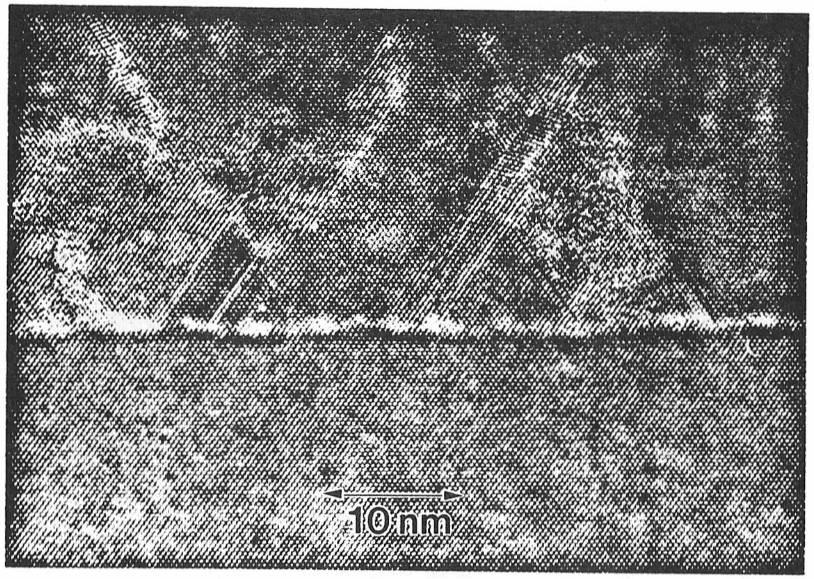


Fig.8

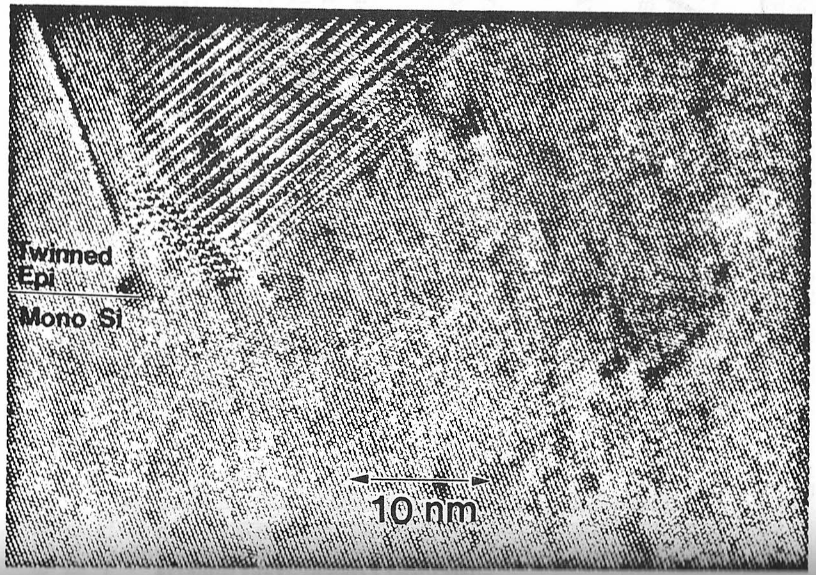


Fig.9