AN 402

Strained Si - Surface Morphology Measured by AFM

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Discussion

Enhanced channel mobility of CMOS devices has become a key technology goal to continue Moore's Law. One promising technical approach is to use a strained Si channel created by epitaxially depositing a thin (~ 10 nm) silicon layer on top of a strain-relaxed $Si_{1-x}Ge_x$ buffer layer film which has been grown on top of a silicon substrate. The difference in lattice constant between the two films results in a tensile strain in the top thin silicon layer.

However, the growth of the strain-relaxed $Si_{1-x}Ge_x$ layer on top of the silicon substrate also results in the creation of many dislocations which then create defects in the thin silicon channel layer. Usually, two types of dislocations, misfit and threading, are observed in the strain-relaxed $Si_{1-x}Ge_x$ layer.

Because the presence of threading dislocations can seriously degrade the device performance, graded $Si_{1-x}Ge_x$ layers are grown to minimize the density of threading dislocations. Furthermore, the misfit dislocations will lead to crosshatch patterns on the top surface of $Si_{1-x}Ge_x$ layer. When the thin tensile-strained Si layer is epitaxially grown on this strain-relaxed $Si_{1-x}Ge_x$ surface, the cross-hatch patterns are conformal.

Surface height variations of the crosshatch patterns can be significantly large as compared to the thickness of the tensile-strained Si layer. It is therefore important to minimize the surface variation (crosshatch patterns) of the tensile-strained Si surface.

For this purpose, AFM can provide quantitative surface roughness measurements and mapping of the crosshatch dimensions to assist in the process development and monitoring. Figures 1 and 2 show AFM images of two different tensile-strained Si surfaces. Sample 2 is smoother than sample 1 (0.6 nm compared to 1.7 nm), and the crosshatch dimensions (spatial frequencies) are very different (Neither sample received a CMP step to smooth the surface.)

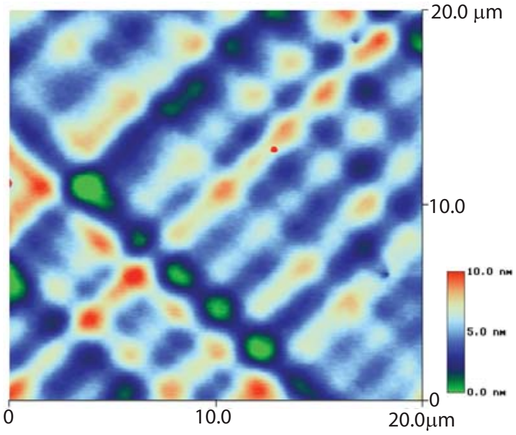

Figure 1. Tensile-strained Si surface of sample 1 Rrms: 1.7nm

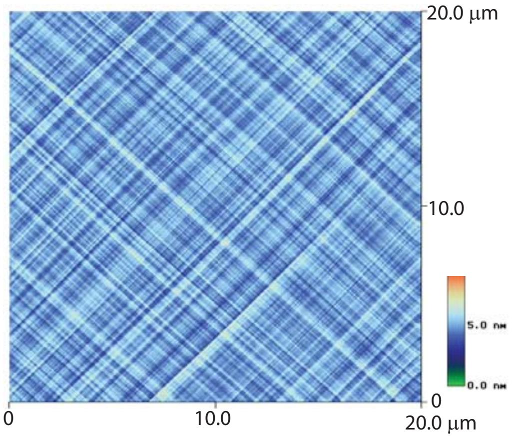

Figure 2. Tensile-strained Si surface of sample 2 Rrms: 0.6nm

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