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Evolution of Ni on Si after thermal annealing observed with XRR

STEFAN ZOLLNER, D. JAWARANI, S. BOLTON, K. CHANG, R. NOBLE, M. JAHANBANI, M. ROSSOW, Freescale Semiconductor, Inc. — The self-aligned silicide module of a CMOS process requires cleaning the silicon surface, metal deposition, thermal annealing, and selective removal of the unreacted metal by wet-chemical etching, followed by a final thermal annealing step to reduce the electrical resistivity. We have followed the evolution of sputtered Ni films with 10 nm thickness on Si (100) through these process steps with x-ray reflectivity (XRR). Both HF wet clean and in situ plasma clean produce NiSi films with similar properties. We also did not find a significant impact of the anneal method. Films annealed at 360C for 5s or at 320C for 30s produced similar XRR spectra. However, Ni films deposited on Si after an in situ RF sputter etch with Ar ions have a low-density voided region below the surface, which cannot be removed by annealing. A similar intermediate layer is reported in the literature when annealing Pt on Si in an oxygen-containing ambient. Transistors produced with NiSi contacts have undesirable characteristics (leakage) if the substrate is cleaned by RF etch prior to Ni deposition. Most likely, the RF sputter edge encourages the formation of NiSi2 pyramids at very low temperatures ($< 400°C$) or the diffusion of Ni from the source-drain regions of the transistor into the channel.

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