

The limitations of SIMS in nanoscale technologies : quantitative near-surface and interfacial analysis of complex systems.

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The use of Secondary Ion Mass Spectrometry (SIMS) has grown consistently over many years primarily for its extreme sensitivity combined with high depth resolution and quantification properties. In particular in the semiconductor area, this have become eminent and SIMS is one of the main characterization methods to study dopant and impurity incorporation and diffusion enabling the development of devices with ever decreasing dimensions. With the advent of sub-45 nm technologies, the semiconductor industry is moving towards the use of extremely shallow (< 10-20 nm) dopant profiles. Dopant diffusion and activation is no longer pursued by long, high temperature anneal processes causing excessive diffusion but rather by ultra short anneal cycles (RTA, laser anneal, solid phase epitaxial regrowth,..) such that metastable concentrations can be achieved (exceeding solid solubility limits) and (the very limited) outdiffusion becomes entirely dominated by transient (enhanced) diffusion. Subtle changes in profile shapes need to be monitored as these contain all the relevant physics and thus dopant profiling with a depth resolution better than 1 nm becomes a prerequisite. At the same time many new materials are being introduced such as high k and low k dielectrics, (workfunction engineered) metal gates, strained Si-layers and even new substrate materials such as Ge instead of Si. Their introduction puts serious challenges on SIMS as the problem of depth resolution now becomes coupled with additional matrix effects and ionization yield variations at the various interfaces.

In this paper we discuss some of the fundamental aspects of SIMS depth profiling (sputter yield variations, ionization yield variations, differential shift, escape depths) in relation to a series of challenging examples highlighting the increasing difficulty of SIMS to meet those targets as well as potential alternatives (H-RBS, H-ERDA, LEAP) which may aid SIMS to solve the se problems. Examples discussed are :

1. quantitative near-surface and interfacial profiling : the role of outdiffusing oxygen on profile distortions and optimized (?) profiling conditions, transients with Cs,
2. limitations of the dilute limit in high dose implants
3. complex high k layers : composition, underlayer interdiffusion, impact on dopant profiles,
4. dopant distribution in workfunction engineered silicides used as gate material
5. dopant profiles in Ge : roughness, dilute limit,..
6. Ge-migration in monolayers of Si
7. localized impurities in metallization systems such as Cu