Quantitative considerations in medium energy ion scattering analysis of nanolayers

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Functional components in today's microelectronic devices can hardly be characterized comprehensively in situ. Increasingly, device performance prediction is based on a combination of simulations with measurements on model structures. In this context, medium energy ion scattering (MEIS) in conjunction with spectrum simulation is increasingly coming into its own, due to its unique capability of providing near quantitative compositional and layer structure information during depth profiling analysis, in favourable cases, with sub-nanometre resolution.

The attainable accuracy in MEIS depth profiling is assessed using a simple, analytical calculation on a model target system (Si with dilute impurities) and this offers an insight in what can achieved. Considering the energy difference between scattering off a surface atom and one at greater depth, a linear relationship between depth of scattering and detected energy is obtained. Although for compound materials and multilayers complications arise, a similar relationship can be shown to apply, but iterative calculations using computer simulations are then required for its demonstration. Issues associated with straggling and discrete energy losses are briefly discussed.

An analysis is then given of the yield ratio of atoms scattered off the surface and those at greater depth, concluding that this ratio follows the Rutherford inverse energy squared prediction, modified with the inverse ratio of the energies at the detector to a power ~1/2. The dependence on the energy of energy width of the detector channel or bin is determined. The effects of screening due to the non-coulombic interaction potential on the backscattering yield in MEIS which mainly affects the scattering off heavy ions, is evaluated for different energies for both H and He ions using the Andersen correction. The effect of neutralisation which is most severe for light target atoms can be less accurately predicted but a pragmatic approach employing a data set of surviving ion fractions for both H and He on various surfaces, allows its parameterization and hence the description of the convolution of these two effects. This provides the dependence both on the projectile energy and the mass of the scattering atom. Although, absolute quantification, especially when using He ions, may not always be always be achievable, relative quantification in which the sum of all species in a layer add up to 100%, generally is. This conclusion is supported by the provision of some of examples of MEIS spectra derived depth profiles of nanolayers. Relative benefits of either using H or He ions are considered.