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Exact Quantitative Analysis of Low-Dimensional Quantum Structures using Alkali-Metal based Molecular-ion SIMS: Perspectives and Challenges

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Continuous progress in the understanding of fundamental and instrumental aspects of Secondary Ion Mass Spectrometry (SIMS) has made this technique extremely powerful for the analysis of materials. Secondary ion-emission is a complex phenomenon and amongst various mechanisms, the 'electron-tunnelling model' based on the survival probability of an escaping ion above the surface is the widely accepted notion in the understanding of ionization probability for positive and negative ions. As the secondary-ion intensity of a particular element strongly depends on the ionization efficiency of a sputtered atom or molecule, instantaneous local chemistry of the sample surface plays a significant role in the secondary-ion emission. This is the so-called "Matrix Effect", which makes the SIMS technique challenging for quantification in spite of its highest detection sensitivity (<ppb) and exceptional depth-resolution (<1nm). Therefore, the compensation of "matrix effect" is required. If alkali-metals such as Li, Rb, K, Na, Cs, …etc. (referred to as 'A') are present in the neighbourhood of the probing element (M) on a sample-surface, a quasi-molecular $(MA)^+$ ion can be formed by the attachment of this alkali-ion with a sputtered atom (M^0) in the close proximity of sample surface. Such phenomenon can occur if an alkali-ion beam is chosen as the impinging ion-beam for sputtering. The $(MA)^+$ molecular-ions that are formed in the SIMS process have strong correlation with the atomic polarizability of the element M. As the emission process for M^0 is decoupled from the MA^+ ion formation process, the 'matrix effect' drastically decreases. This is
very similar to the ion formation in "secondary neutral mass spectrometry" (SNMS). Although the detection of $(MA)^+$ molecular ions has found its applicability in materials quantification without calibration standards, it generally suffers from a low useful yield. In such case, the detection of $(MA)_2^+$ molecular-ions offers a better sensitivity (by orders of magnitude), as the yields of $(MA)_2^+$ molecular-ions have been found to be much higher compared to that of $(MA)^+$ molecular-ions.

Monitoring of molecular-ions is often employed in standard SIMS experiments to improve the detection of sputtered ion-species which show poor dynamic ranges or are affected by mass interference. For example, while making SIMS analysis of GaAs, carbon as an impurity-element is detected by monitoring $(AsC)^+$ molecular-ions instead of C^- ions, because the latter has a high background arising from residual-gas species in the analysis chamber. Cs is highly preferred for MCs^+
or MCs_2^+ molecular-ions in SIMS because of the strongest reactivity and electropositive nature of caesium.

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N/A

Level for award;(Hons, MSc, PhD, N/A)?

N/A

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Yes, I ACCEPT

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