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Composition Measurements on the Atomic Scale: Complex Oxide Interfaces

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Abstract – Modern, aberration corrected electron microscopy in conjunction with electron energy loss spectrosopy has become an indispensable tool to access structure and composition on the atomic scale. Here composition measurements accross the polar interface between $DyScO_3$ and $SrTiO_3$ are exemplified to demonstrate the significance of modern electron microscopy for materials science.

It is well known, that the polar discontinuity at the $LaAlO_3/SrTiO_3$ interface is accommodated by a charge transfer. In consequence, a two dimensional electron gas is established, which makes the interface between the two insulating materials conductive. In a similar way a conducting interface is expected for the $DyScO_3/SrTiO_3$ interface, since $LaAlO_3$ and $DyScO_3$ comprise the same polarity and are band insulators holding similar dielectric constants and energy gaps. However, our electrical measurements on $DyScO_3/SrTiO_3$ multilayers reveal insulating behavior.

High-resolution Z-contrast microscopy and electron energy loss spectroscopy are employed to measure the composition of individual atomic layers across the interfaces in a $DyScO_3/SrTiO_3$ multilayer system. An ordered interface structure is observed, which is identified by the alternating contrast along rows 4 and 14 in the Z-contrast image shown in Figure 1. An intermixing extending over two monolayers at the interfaces is established for both, the Dy-Sr sublattice and the Sc-Ti sublattice (see Fig.2). Employing the ionic model the composition of the individual atomic layers can be translated into charges. Considering compensation between adjacent layers each of the layers is found to be neutral. Hence, the interfaces are expected to be insulating, which is confirmed by electric measurements [1]. From this result it is concluded that in addition to charge accumulations, intermixing of cations can contribute to counteract the interface dipoles associated with the polar discontinuity.

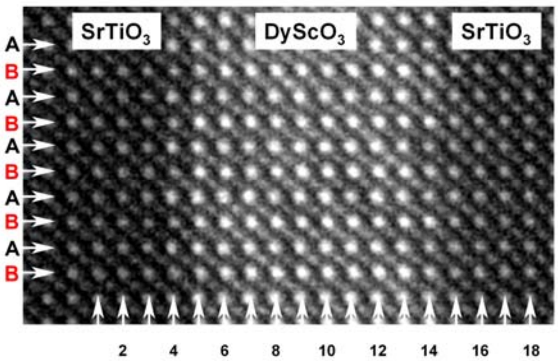

Figure 1: Z-contrast image of $SrTiO_3/DyScO_3$ multilayers. For each Dy layer (numbered 1 through 18) the concentrations of positions A and B are deduced and plotted as red triangles in Fig. 2. The interface layers, rows 4 and 14, show a distinct difference in contrast between the neighbouring positions A and B. Hence, an ordered interface structure is formed.

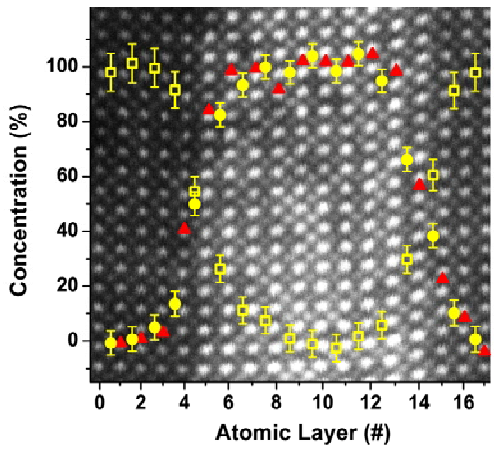

Figure 2. Simultaneously with the Z-contrast image shown (acquisition time 100 s) EELS spectra have been recorded for each atomic layer. Quantitative evaluation of the EELS spectra yields the Sc (yellow circles) and Ti (yellow open squares) concentrations. In addition the Dy concentration obtained from FIG 1 is plotted versus the atomic layer number.

References

[1] M. Luysberg, M. Heidelmann, L. Houben, M. Boese, T. Heeg, M. Roeckerath, and J. Schubert, Acta Mat. 57, (2009) 3192.