

On the low temperature mixing processes in metal/ceramic interfaces

R. Nagel and A.G. Balogh

Institute for Materials Science, Darmstadt University of Technology, Petersenstrasse 43, 63741 Darmstadt

Heavy ions in materials science can be used for many applications concerning changes in composition, structure and physical properties. The modification of interfaces in bi-layer samples is frequently performed by ion beam mixing experiments [1-4]. However, the mixing behaviour of the components is much more complicated than in the earlier studied metal/metal systems, because of the more complex structure of the ceramic materials.

Samples with different composition (Fe, Cu, Ni, Pt, Zr, Ti and TiO₂ on Al₂O₃, SiO₂, MgO and SiC-substrates) were prepared by molecular-beam-epitaxy. The samples were irradiated at the GSI 300kV implantation facility with 150 keV Ar⁺ ions at different temperatures. Rutherford backscattering spectroscopy (RBS) was used to obtain the element depth profiles. The surface topography and the surface roughness was studied with a high resolution scanning electron microscope (Philips XL 30 FEG) and with atomic force microscopy (AFM).

The RBS spectra were converted to depth profiles by using the computer code *ndf* [5]. The width (σ_I) and the position of the interface was calculated using an error function. The measured and calculated mixing rates are shown in figure 1. In many systems (Cu/Al₂O₃, Cu/SiC, Fe/Al₂O₃, Fe/SiO₂, Fe/SiC,

Ni/Al₂O₃, Ni/SiO₂, Ni/MgO, Ni/SiC, Pt/Al₂O₃, Pt/SiC, Zr/Al₂O₃, Zr/SiO₂, Ti/SiO₂ and TiO₂/SiO₂) the low temperature data can be interpreted using the binary collision model (BCS) [6] alone (fitted line in the upper part of fig.1). For the systems Cu/Al₂O₃, Fe/MgO, Cu/SiO₂, Ni/SiO₂, Pt/SiO₂ and Cu/MgO the measured values exceed the predictions of the BCS model. Therefore the model was expanded following the approach of Refs. [7-8]. The ion beam mixing rates will be enhanced in this compound model by a factor, which is the ratio between the atomic densities of the mixing species. Using the expanded c-BCS model all data points could be fitted correctly as it is shown at the lower part of fig.1. However, the difference between the predictions of the BCS model and the measured values can be also explained assuming the formation of local thermal spikes. After Cheng [9] the space filling character of the collision cascade, as primary condition for the formation of thermal spikes, is only possible, if the energy transferred to the recoils (E_R) is lower than the spike initiation threshold energy $E_{TS}=0.039eV*Z^{2.23}$, but higher than the displacement energy (E_d). Taking the Ni/Al₂O₃ system as an example, this means, that the formation of local thermal spikes will be allowed, if the recoil energy falls between 16 and 28 eV.

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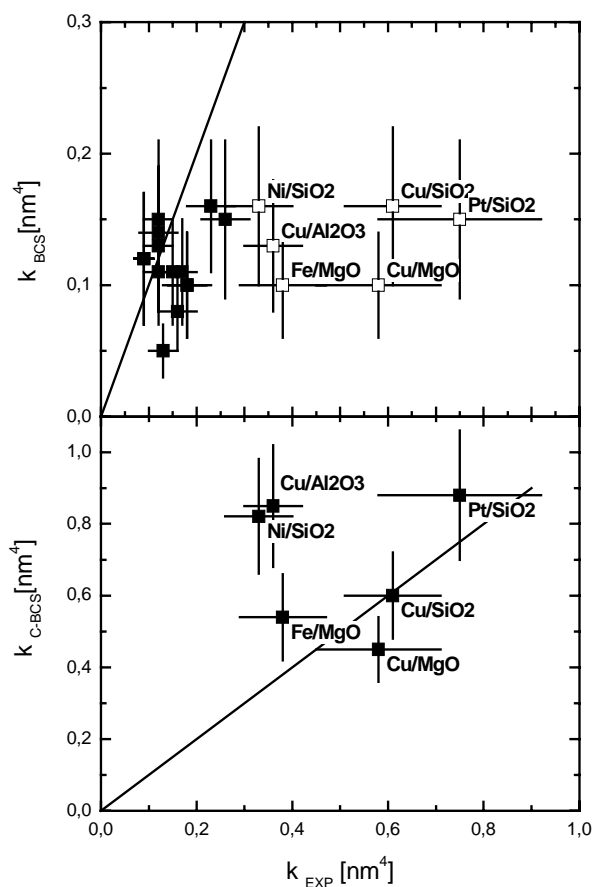


Fig. 1.: Measured and calculated mixing rates for different systems. At the top: fitted by the BCS model, at the bottom: fitted by the compound-BCS model.