Why joint of aluminum and steel?
- low density and high thermal conductivity of Al
- high strength and creep resistance of steel
- high corrosion resistance
- low costs

Applications?
- structural elements in car bodies and chases
- aircraft constructions
- shipbuilding
- heat exchangers, smelting production of Al
- household applications

Crucial parameter of overall composite’s mechanical properties?
- intermetallic layer (IMC) at the Al-steel interface
- study of diffusion kinetics required!

### Aims

- determination of effective interdiffusivity
- simulation of diffusion based on Fick’s second law
- in-situ observations

### Numerical analysis

**Boltzmann-Matano method (B-M method)**
- determination of concentration dependent interdiffusion coefficient \( D(c) \) from experimental concentration profile
- based on inversion of Fick’s second law of diffusion → explicit relation for \( D(c) \), [H. Mehrer, Diffusion in Solids]

\[
D(c^*) = -\frac{1}{2t} \int_{x_M}^{x^*} \frac{c(x) - x_M}{dx} c(x) dx
\]

\( x_M \) position of Matano plane

**Finite element method (FEM)**
- solution of 1D-diffusion equation

\[
\frac{\partial c}{\partial t} = \frac{D(c)}{\partial x} \left( \frac{\partial c}{\partial x} \right) ; \quad \frac{\partial c}{\partial t} \bigg|_{n} = 0 \quad \text{c}(x, t = 0) = (c_L - c) \mathcal{H}(x)
\]

### Results

**Computational test**
- analysis of the error-function profile
- limited precision of B-M method near \( c = 1 \) and 0
- \( D(c) \); near 0 and 1 is not taken into an account, piecewise fit is used

**Analysis of experimental concentration profiles**
1. EDX line analysis through Al-steel interface
2. simplification to a binary system – introducing „steel atoms”
3. smoothing of the concentration profile (Savitsky-Golay filter)
4. determination of effective diffusion coefficient using B-M method and inserting of its piecewise fit to diffusion equation → solution by FEM

**FEM analysis**
- plotting of initial condition – original interface position
- intermetallic layer grow rather towards Al
- Fe diffuses faster than Al
- satisfactory agreement between analytical and simulated profile

### Summary

Results of in-situ annealing are in contradiction to the simulation of diffusion according to Fick’s second law and published values of diffusion coefficients. Therefore, Fick’s laws and the related diffusion coefficient are rather disputable for interpretation of experimental results in case of Al-steel diffusion couple, which is often used in present studies dealing with the Al-steel cladding. Gradient of chemical potential as a driving force of diffusion should be used instead of gradient of concentration.

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