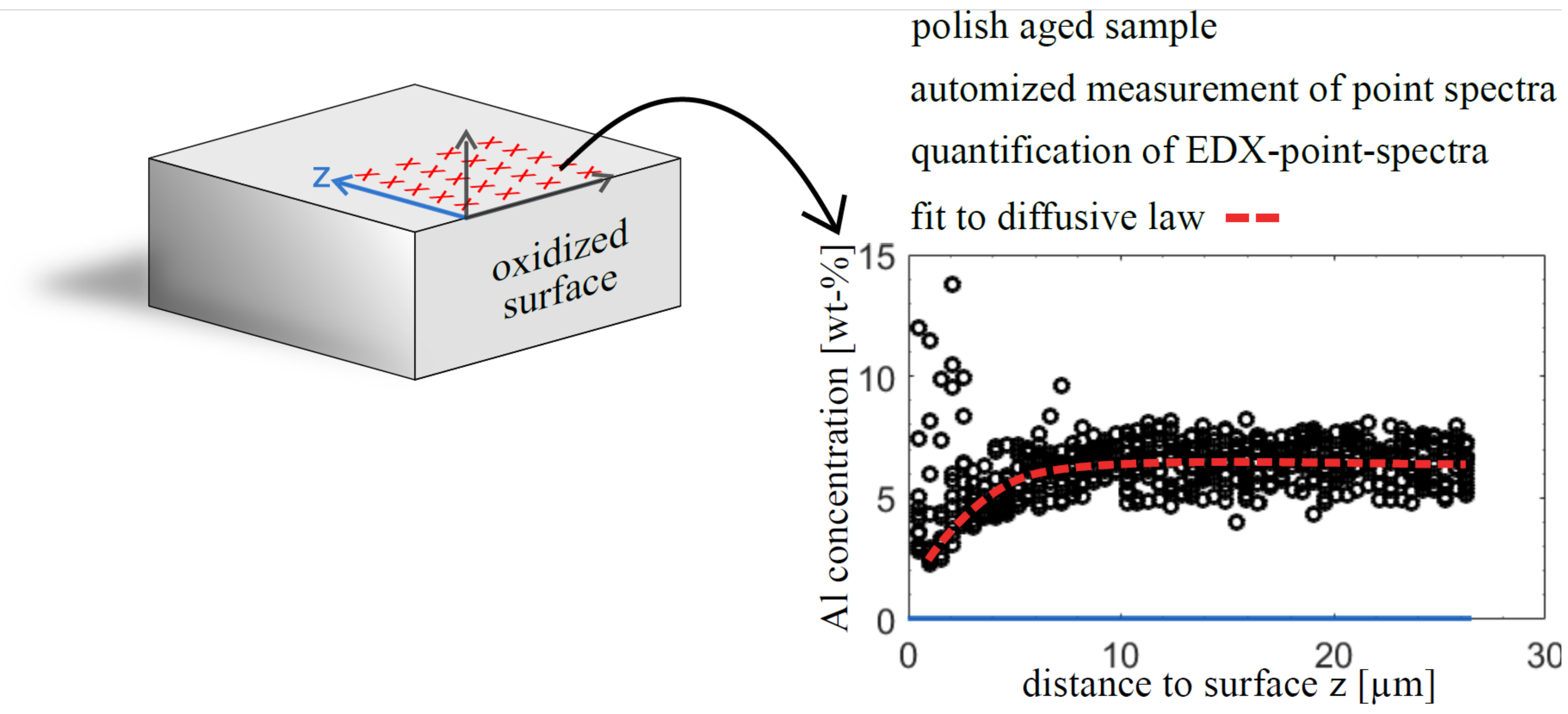
On the Investigation of Diffusive Aging Mechanisms in Ni-based Superalloys

A. Brueckner-Foit, J. Steger, A. Rienäcker, M. Senge,

Introduction

Resistance of nickel base super alloys against damage processes at high temperatures is achieved by second phase hardening. The cuboidal $L1_2$ ordered γ′ precipitates with chemical composition Ni3(Al, Ti, Ta) have sizes in the range of 0.3-0.5 µm, and represent up to 65% of the volume of the alloy. It is well established that γ′-precipitates age under the influence of high temperature either by coarsening or by dissolution caused by migration of the second phase forming elements Al, Ti and Ta to a free surface, where they form stable oxides. Detailed knowledge of this diffusive process is vital for assessing the thermal stability of superalloys and the expected lifetime of high temperature components in gas turbines.

Materials and experiments



Alloy PWA1484 in heat treated condition were studied. Slices of 3 mm x 8 mm x 8 mm were cut by electric discharge machining (EDM) from single crystal rods and then polished with SiC Paper to P1000 in order to remove the rough surface caused by EDM and to generate comparable surface roughness values for all samples. γ′ depleted zones were obtained by ageing these samples in 12 hour intervals for up to 96 hours at constant temperature levels of 750 °C – 1050°C. The cross section was prepared for microscopic analysis. EDX measurements were performed in a high vacuum SEM. Serial fitting was used for the deconvolution of the EDX spectra. Measurement and shaping time for an EDX spectrum was 20 seconds for each point. Thus, each measurement point consisted of a minimum of 340.000 counts. For automation of the numerous EDX measurements Quantax Scripting was used.

Results and Conclusion

Depletion of Al-concentration correlates well with the detectable γ′ coarsening and depletion in backscattered SEM images. A simultaneous increase of the relative tantalum concentration in the γ′ precipitates is explained by the interchangeability of Ta and Al in the $L1_2$ crystal, thereby marking the γ′ stabilizing characteristics of tantalum. The sharp increase of Al at the samples surface coincides with the oxide scale. Al-Oxide and the peak in Ta-concentration are describing the upper and lower limit of the γ′-depleted area in the sample.

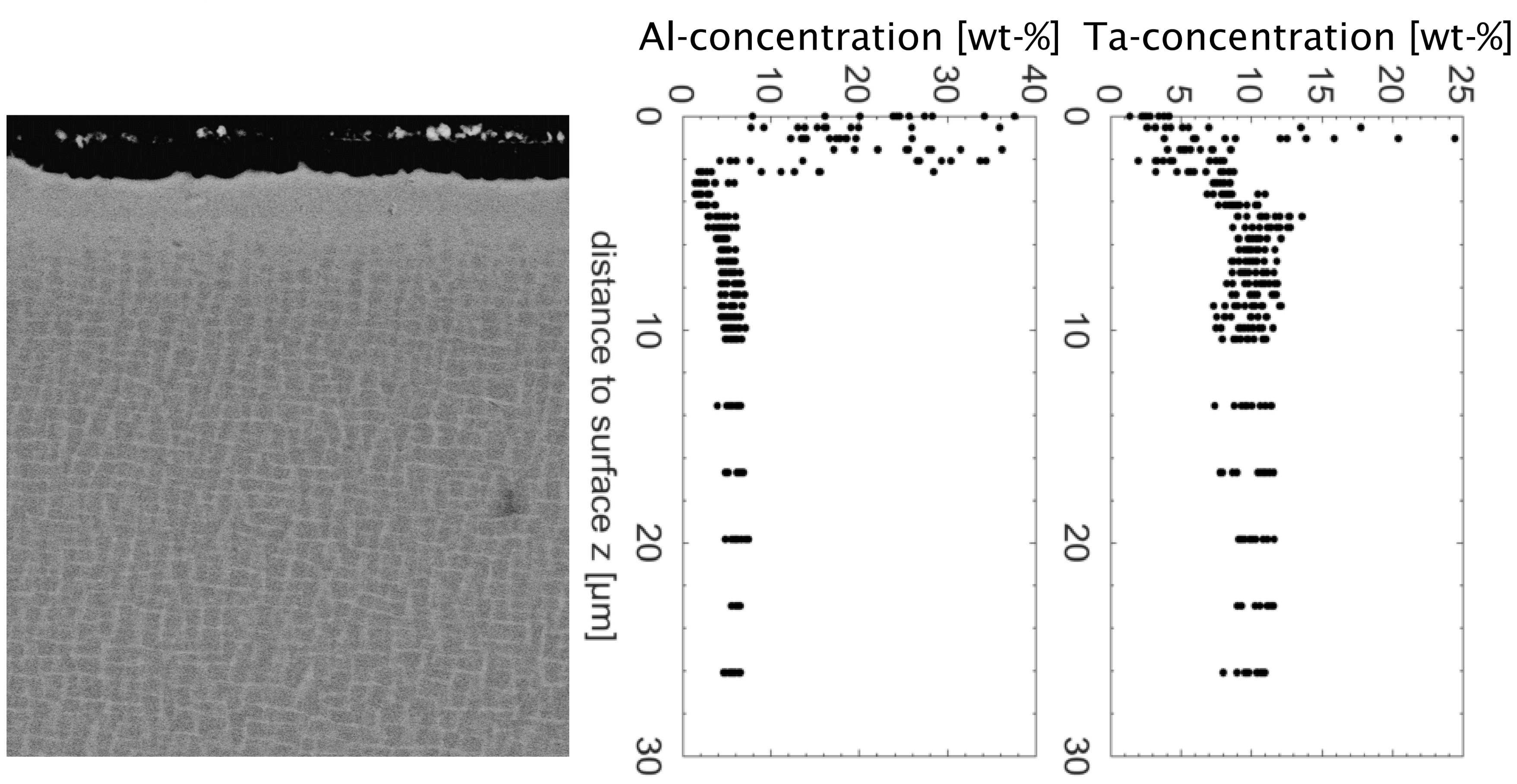


Fig. 1 Results of EDX surface scan for the 900 °C sample after 96 h

The dataset gathered by the experiments allowed fitting a diffusive law over time and temperature.

$$z_{av} = \sqrt{D_0 \cdot \exp\left(-\frac{Q}{RT}\right) \cdot t}$$

The fitted result of D_0 of 1.522e+05 [m/s²] and Q 2.115e+05 [J/mol] are in good agreement with results derived from tracer experiments for similar alloys.

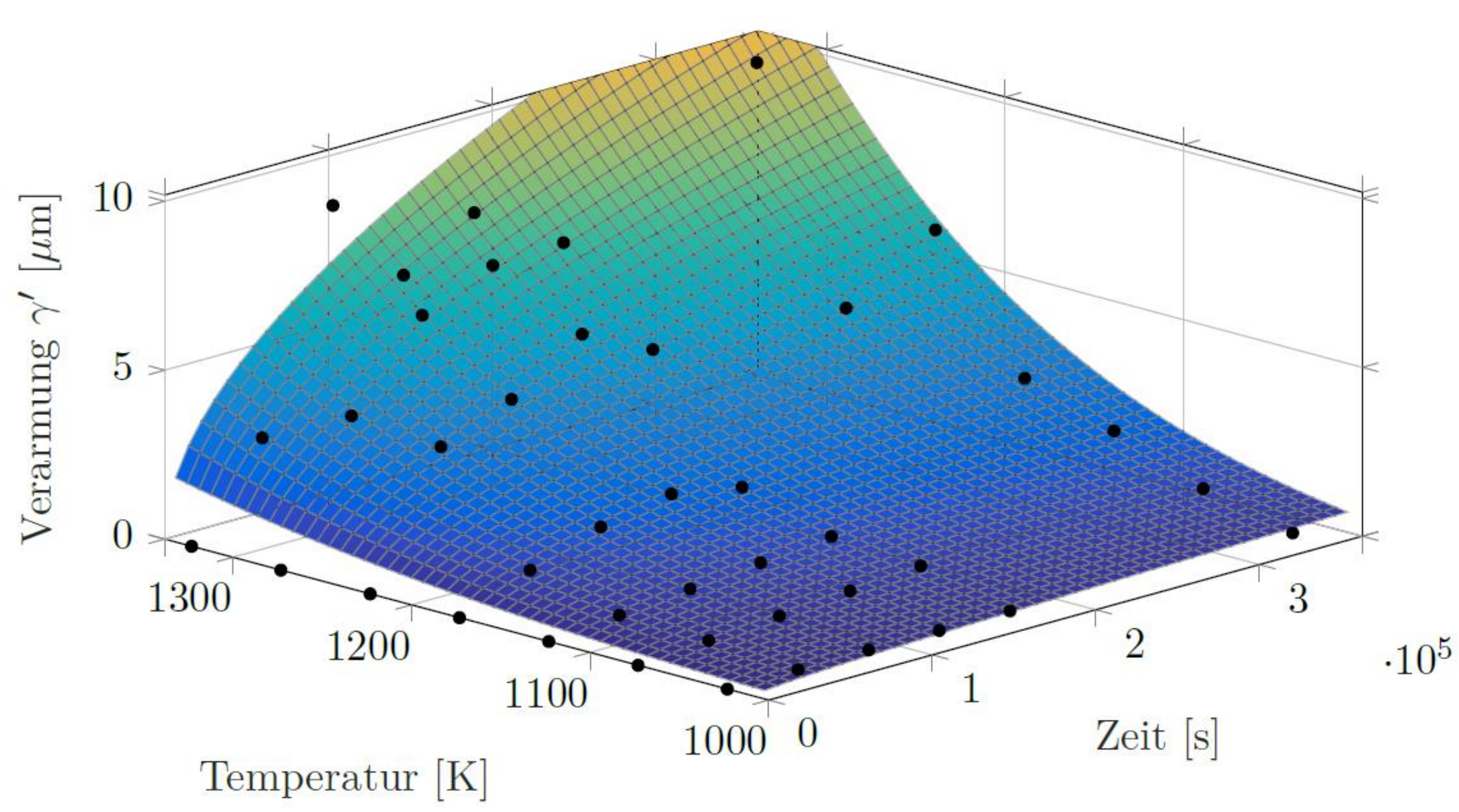


Fig. 2 Fitted Arrhenius relationship over time and temperature

UNIKASSEL
VERSITÄT