LA-ICP-MS STUDIES IN NICRALY-BASED COATINGS ON HIGH-TEMPERATURE ALLOYS

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A microlocal analytical technique using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) was developed for investigations of elemental diffusion at the interface of NiCrAlY-based coatings on high-temperature alloys. The surface of the cross section of alloyed sample was scanned with a focused laser beam (diameter of laser crater – 25 µm, wavelength - 213 nm, laser power density – 1010 W/cm^2), and the laser ablation system was coupled to a double-focusing sector field ICP-MS. The capabilities of LA-ICP-MS using “line scan” and “single point” mode at laser energy of 2 and 4 mJ were compared. Alloy certified reference material (CRM) BAM-328-1 (BAM - Bundesanstalt für Materialprüfung, Berlin, Germany) with a similar matrix composition in comparison to the samples investigated was employed to determine the relative sensitivity coefficients (RSCs) of chemical elements to quantify the analytical data. The RSCs of analytes measured by LA-ICP-MS in alloy CRM vary between 0.2 and 2. In addition, other calibration procedures via calibration curves and solution-based calibration were discussed briefly.
LA-ICP-MS was used to study the lateral element distribution on NiCrAlY-based alloy and coating after oxidation in air (300, 1000, 5000, 15000 hours) at a temperature of 980 ˚C, whereby an increasing aluminum loss due to diffusion from coating into the high-temperature base alloy was observed. Furthermore, the diffusion of several substrate alloying elements (e.g., Co, Ta, Mo, W) into the coating after annealing was found, which could be the reason for the alteration of mechanical properties (high-temperature stability) and/or oxidation performance.

In many technical applications metallic, alloyed or ceramic construction materials are subject to corrosive, in particular to oxidized, environments at high temperatures, which results in a deterioration of physical, especially of mechanical, properties. To reduce the corrosion effects on materials the surface is covered with temperature-resistant coatings, which are protective layers several hundred µm thick. The most commonly used system for high-temperature Ni-based alloys are overlay coatings of the MCrAlY type (with M = Ni or Co). The base materials are characterized by relatively low chromium content, and the substantial addition of titanium, tantalum, tungsten, etc., frequently results in poor oxidation resistance of the materials [1]. Development and application of coating systems which guarantee reliable component protection during long-term service is a crucial requirement for this type of materials in industrial gas turbines. Interdiffusion between coating and substrate (base material) after oxidation in air at a temperature of 980 ˚C for several thousand hours affects the coating life and causes the formation of new, frequently brittle phase at and close to the coating and substrate interface. Several effects, especially the interdiffusion of matrix elements at high temperature, could result in an alteration of the mechanical properties and/or oxidation performance. Therefore, lateral element distribution and diffusion profiles between coating and substrate material are of special interest as a function of oxidation time in air at a temperature of 980 ˚C.

Different analytical techniques such as secondary ion mass spectrometry (SIMS) and sputtered neutral mass spectrometry (SNMS) [2-3] are available for the determination of lateral element distribution on cross section surfaces in order to investigate diffusion effects at the interface. However, a major problem in analysis by SIMS is the strong matrix-dependence of the ion yield, which makes SIMS profiles difficult to quantify [4]. SNMS overcomes some inherent limitations of SIMS by detecting sputtered and ionized neutrals. Glow discharge mass spectrometry

(GDMS) and glow discharge optical emission spectroscopy (GD-OES) can also be used for the direct surface analysis of solid samples and depth profiling [5-6].

Laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) has been established in the last few years as a powerful tool for the direct bulk analysis of elements in any solid samples for the determination of trace and ultratrace impurities down to the sub ng g-1 concentration level and isotope ratio measurements in quite different fields of science and technology [7-11]. Furthermore, LA-ICP-MS is a microlocal analytical technique applied in materials research and for geological, biological, medical and environmental materials [7,12-15]. The application of LA-ICP-MS as a surface analytical technique for the determination of lateral element distribution has also been described for ceramic layers [16], and for profiling of patterned metal layers [17].

For the quantification of measured data in LA-ICP-MS mostly suitable standard reference materials were used. For quantification purposes in trace analysis on zeolites Pickhardt et al. [18] proposed the use of geological reference materials with a composition similar to samples whereby from both zeolites and reference materials fused lithium borate targets were prepared in order to improve matrix matching NIST glass standard reference materials are often applied as external calibration standards for the analysis of glasses and geological samples, e.g. basalt glasses [19]. Jochum et al. [11] created new reference materials (geological glasses) for microlocal analysis. However, the quantification of analytical results could be a serious problem in LA-ICP-MS especially if no suitable certified reference material (CRM) is available. If no matrix-matched CRMs are available, synthetic laboratory standards were prepared, as demonstrated for the quantitative analysis of trace impurities in ceramic layers of solid oxide fuel cells. [16]. Furthermore, CRM-free quantification strategies using solution-based calibration have been developed for the determination of impurities in geological samples [20], in silicates [21] and platinum nanoclusters [22].

Certified reference materials of similar matrix composition for the quantification of analytical data are available to determine element concentrations in NiCrAlY-based coatings and high-temperature alloys .

The aim of this work is to develop an analytical technique for the characterization of NiCrAlY-based coatings on high-temperature alloys to study element interdiffusion at interfaces.

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