Microstructure characterisation of double glass-ceramic coatings on TIMETAL 834

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TIMETAL 834, a near-α titanium alloy, offers increased tensile strength and creep resistance up to 600°C together with improved fatigue strength [1]. This alloy is applied for fabrication of last stages compressor parts in modern gas turbines [2]. One of the major limitations of TIMETAL 834 alloy restricting its use at high temperatures is a poor oxidation resistance at temperature above 600ºC. To improve it, a surface treatment is frequently applied. Glass-ceramic based coatings are very promising materials for protection of titanium alloys against oxidation at high temperature [3]. Their processing by a simple and low cost slurry method is an excellent method to manufacture reproducibly protective coatings with complex and homogenous chemical composition, uniform morphology and coating thickness [3,4].

The aim of the present work was to characterise a microstructure and phase composition of the double glass-ceramic coating produced on TIMETAL 834 alloy by slurry technique. The coating was characterised by SEM and TEM (SAED, EDS, STEM-EDS). TEM investigations were performed using JEM-2010 ARP on cross-section thin foils prepared by PIPS. The SAED patterns were interpreted with the JEMS software [5].

The coating consists of two layers with a different microstructure and phase composition: outer SiO_2-P_2O_5-B_2O_3-CaO-K_2O-Na_2O layer (about 140 µm thick) and intermediate $Si0_2$-Al_2O_3-CaO-Na_2O one (about 215 µm thick) (Figs 1a,b). Several crystalline phases were found in the outer layer: mainly SiO_2 (tetragonal primitive), $Na_2Ca_3Si_6O_{16}$ (triclinic primitive) and $CaSiO_3$ (triclinic primitive). Additionally an amorphous phase, containing mainly Si and O as well as some Ca and K, was identified. The fine particles (50-100 nm in size) of the $Ca_5P_2Si_1O_{12}$ (orthorhombic primitive) in SiO_2 grains were observed. Also some amorphous particles containing mainly Si and O (up to 100 nm) in amorphous phase were found. The $CaSiO_3$ grains in amorphous matrix are shown on Fig. 2a. The intermediate layer is composed of the crystalline phases: $CaSiO_3$ (monoclinic primitive), $NaAlSiO_4$ (hexagonal close-packed, hcp), Na_2CaSiO_4 (cubic primitive), $Na_2Ca_3Si_6O_{16}$ (sporadically) and amorphous phase (containing mainly O, Si, Al and some Ca). The $NaAlSiO_4$ grains in amorphous matrix are shown on Fig. 2b. The microstructure of the as-received alloy consists mainly of the α phase (hcp), a small amount of the β one (body-centred cubic, bcc) and precipitates of the Zr_5Si_4 phase (tetragonal primitive) [6].

The applied coating has a good adhesion to the substrate and significantly improves the oxidation resistance of the TIMETAL 834 alloy at 800°C. No weight change of the coated alloy was observed after oxidation during 200 hours at 800°C, in contrary to a significant weight change for the uncoated specimens.

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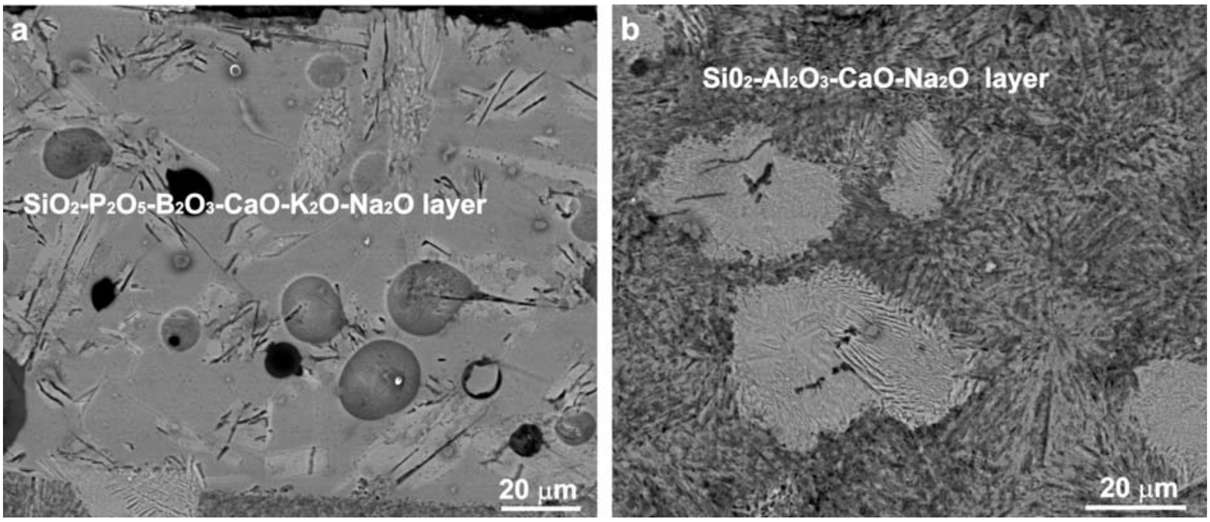

Figure 1. Cross-section of an outer (a) and an intermediate (b) layer of double glass-ceramic coating on TIMETAL 834 substrate, SEM electron back scattered images.

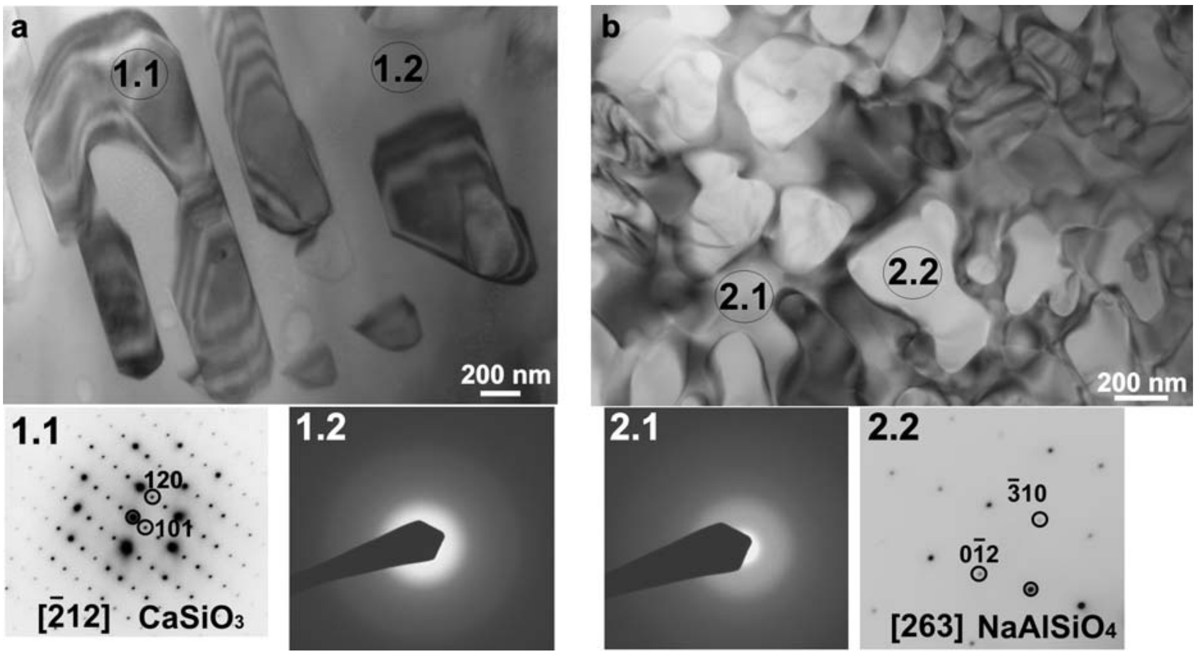

Figure 2. Microstructure of the outer (a) and intermediate layer (b) of the double glass-ceramic coating on TIMETAL 834 as well as SAED patterns and their identification, TEM, cross-section thin foil.