ON THE INITIAL OXIDE SCALES OF Ti_2AlC

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ABSTRACT

Ti_2AlC is a fascinating member of the family of layered ternary MAX phases [1,2]. It has attracted considerable attention due to its unusual combination of properties [1-4], making it an attractive choice for structural components for high-temperature applications, oxidation-resistant coatings on alloy surfaces, conducting ceramic in harsh environments. In all these applications, the oxidation resistance of Ti_2AlC is a critical property.

Microstructural analysis, especially the atomic scale of the oxidation process, is scantly available whilst research has been focused on its preparation and structural properties. Published research on high temperature oxidation has been focused on the macro-scale. Questions about the initial stage of the oxidation and possible crystallographic relationships between the oxide phase and the Ti_2AlC substrate were not addressed before.

In this contribution a detailed and systematic transmission electron microscopy (TEM) analysis is presented about the initial stage of the high temperature oxidation of Ti_2AlC at 1200 °C. In view of crack healing of Ti_2AlC by oxidation at higher temperature, presents here a detailed microstructural analyses of the crystallographic relationships between the α-Al_2O_3 oxide scale and Ti_2AlC parent material, the atomic diffusion and formation of oxide scale on Ti_2AlC at the initial oxidation stage at 1200 °C. It is shown that the α-Al_2O_3 oxide scale on the surface of Ti_2AlC can be either a continuous or discontinuous capping layer. An intermediate layer, which is Ti-rich and consists mostly of TiC, interrupts the continuity of the α-Al_2O_3 layer, as shown in Fig. 1. The channels for Ti, Al outward and O inward diffusion are along the grain boundaries of α-Al_2O_3 and through the Ti-rich intermediate layer. The outward diffusion of Al atoms is either parallel to (001) basal plane or parallel to prism planes of Ti_2AlC. Crystallographic orientation relationships between α-Al_2O_3 oxide scale and Ti_2AlC were observed, e.g. $[\bar{1}12]\alpha_{\text{-Al2O3}}$ // $[010]_{\text{Ti2AlC}}$, $(110)\alpha_{\text{-Al2O3}}$ // $(001)_{\text{Ti2AlC}}$ and $[001]\alpha_{\text{-Al2O3}}$ // $[331]_{\text{Ti2AlC}}$, $(110)\alpha_{\text{-Al2O3}}$ // $(1\bar{1}0)_{\text{Ti2AlC}}$. Fig. 2 shows the former relationships both with electron diffraction pattern and atomic structures clearly.

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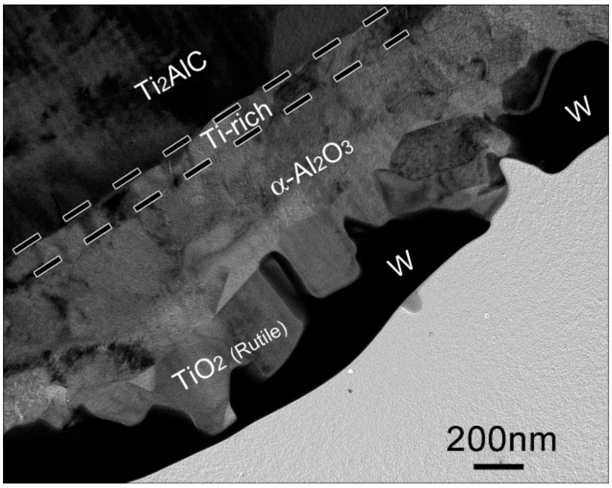

Figure 1. Bright field TEM micrograph showing a cross-section of oxidized Ti_2AlC at 1200 °C for 3 minutes. The oxide layers are TiO_2 (rutile) and α-Al_2O_3 from the outside to the inside, respectively. A discontinuous Ti-rich layer is observed between the α-Al_2O_3 layer and the Ti_2AlC matrix. The darkest outer layer is tungsten deposited to protect the oxidation surface before milling with FIB.

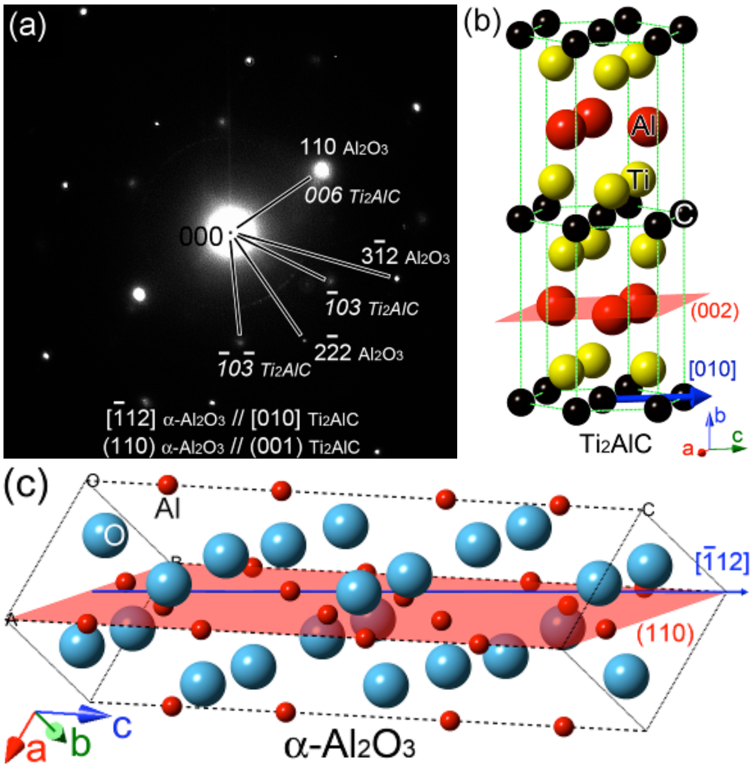

Figure 2. (a) SADP showing the crystallographic orientation relationship between the α-Al_2O_3 oxide and Ti_2AlC matrix, (b) and (c) schematic drawings of their unit cells according to the orientation relationship: $[\bar{1}12]_{\alpha\text{-}Al2O3}$ // $[010]_{Ti2AlC}$, $(110)_{\alpha\text{-}Al2O3}$ // $(001)_{Ti2AlC}$.