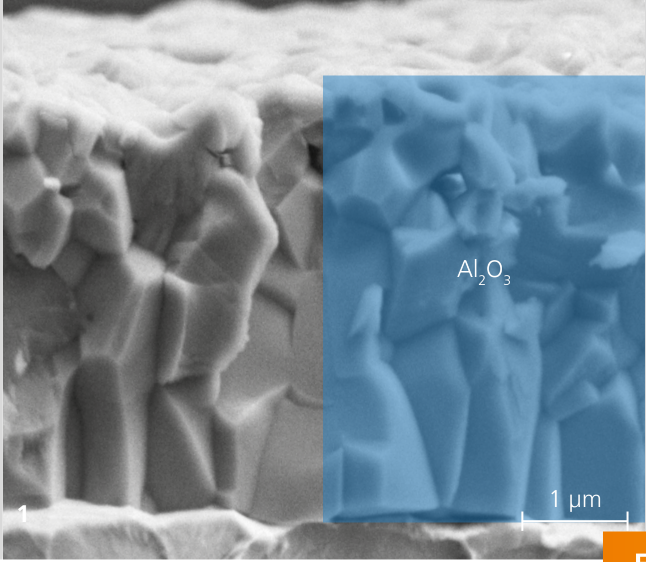

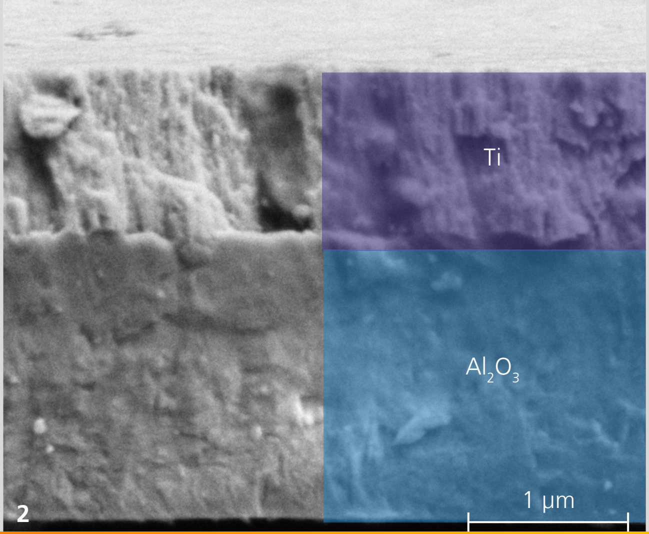

Extract from the annual report 2018
To the website: www.ist.fraunhofer.de/en.html

OXIDE LAYERS FOR HIGH TEMPERATURES

In high-temperature combustion processes such as gas-fired or aircraft engines, metal surfaces are subjected to extreme temperatures. Oxide layers produced and tested at the Fraunhofer IST can effectively protect metal materials against destruction through hot gas corrosion. In the combustion chambers of e. g. gas turbines these significantly determine the service life of the components. Furthermore, oxide based electrical insulation layers enable the utilization of sensorial functional layers on components. Particularly in high temperature environments (>1000 °C), the task of oxide layers is especially demanding.

Oxide layers for high and highest temperatures

Metal materials which, due to their application, are exposed to very high temperatures require a protective surface layer. Generally, chromium or aluminum is used for this. The layers of pure chromium oxide (Cr_2O_3) or pure aluminum oxide (Al_2O_3) formed at high temperatures must adhere well, be dense and free of cracks, grow sufficiently slowly and not evaporate significantly. At temperatures above 1000 °C, practically solely the thermodynamically stable high-temperature phase of aluminum oxide (α-Al_2O_3, corundum) fulfils these conditions.

The stable phase of the aluminum oxide can be produced thermally from suitable oxide formers such as MCrAlY. The growth of aluminum oxide takes place from the outside to the inside through the diffusion of oxygen ions to the interface with the metal. The addition of alloying elements, such as yttrium, to the oxide formers improves the adhesion and the service life of such protective coatings. Figure 1 shows a thermally grown aluminum oxide which has formed on an FeCrAl alloy at 1050 °C.

Sputtered aluminum oxide layers

Well-adhering protective layers of pure aluminum oxide can also be applied to heated metallic components by means of thin film techniques, e. g. reactive gas flow sputtering (see Figures 2 and 3). The decisive factor hereby is that, if possible, the α-phase is already present in the layer prior to the first application at high temperatures. A heating of the low temperature phase (γ-Al_2O_3) above the threshold of 1000 °C would lead to a strong alteration in volume due to the phase transformation and therefore to the failure of the layer compound. Furthermore, pores can form within the layer which then impair the application. Tests at the Fraunhofer IST have shown that by means of ion assistance or suitable template layers, the formation of the α-phase is already promoted at deposition temperatures of approx. 830 °C. By means of X-ray diffractograms of reactive sputtered aluminum oxide layers, Figure 3 shows that a chromium template layer encourages the development of the rhombohedral corundum phase.

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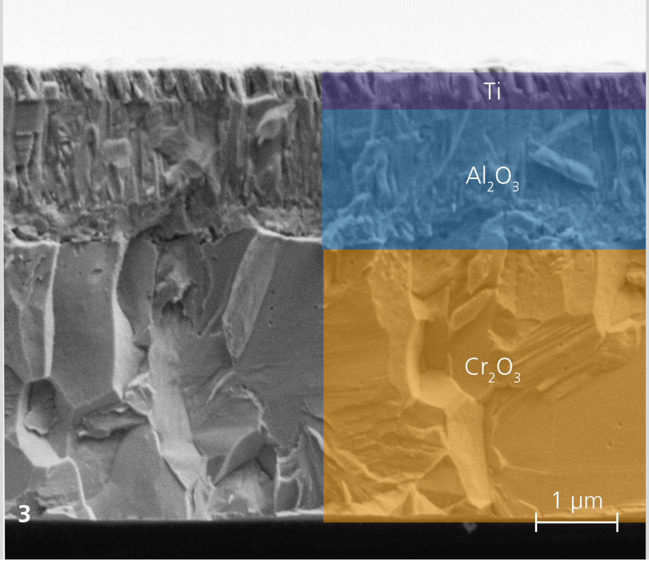
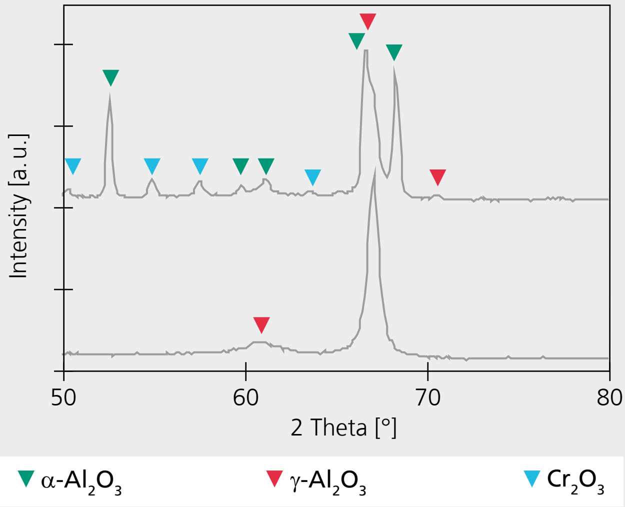


1 *Fracture edge of a thermally grown aluminum oxide layer on a high-temperature alloy.*

2 *Sputtered aluminum oxide layer directly on a high-temperature alloy. A titanium electrode was additionally applied (at the top).*

3 *Sputtered aluminum oxide layer on a chromium oxide template layer. Here also with titanium electrode at the top.*



X-ray diffractograms of sputtered Al_2O_3 layers. Above: with chromium oxide template layer; below: without chromium oxide. Deposited in each case under comparable conditions.

Outlook: oxide layers for high-temperature sensor technology

Crack-free and dense barrier layers of aluminum oxide are also an important component for the integration of additional electrical functions on components in a high-temperature environment. Sensors, actuators and electrical information transfer only become possible through high-quality, temperature- and cycle-resistant insulation layers. Good insulation properties are achieved with layer thicknesses of several micrometers. By means of conventional magnetron sputtering, good and adherent layers can be applied. The relatively low deposition rates and the complex process control are, however, disadvantageous. In this respect, reactive gas-flow sputtering offers the possibility of achieving high rates with simple process management. Parallel to the development of the insulation layers, the Fraunhofer IST is also investigating high-temperature sensor layers, e. g. for strain measurement.

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