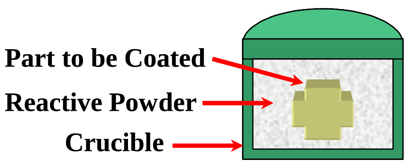
Materials

Environmental Barrier Coatings Formed by Low-Cost Pack Cementation Process

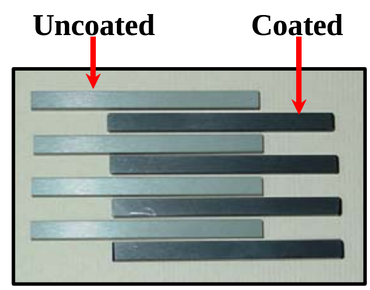
Allows Uniform Coating on Complex Shapes

Background

Monolithic silicon nitride (Si_3N_4) ceramics are currently the primary ceramic material being used in combustion engine environments and are under consideration as hot-section structural materials for microturbines and other advanced combustion systems. In oxidizing conditions, Si_3N_4 will typically form a surface oxidation layer (silicate). In a turbine engine environment, this silicate layer can undergo rapid degradation because of the corrosive and erosive effects of high temperature, high pressure, high gas velocity, and the presence of water vapor, thus severely limiting the useful life of the ceramic. The development of an environmental barrier coating (EBC) for the ceramic has become an essential goal for enabling the long-term utilization of these materials in advanced combustion engine applications.



Basic pack cementation configuration

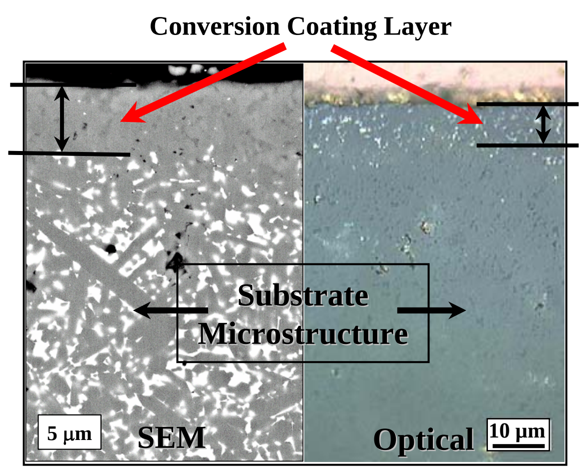


Coating of AS800 Si_3N_4 Bars
Pack: Al - NH_4Cl - Al_2O_3
Conditions: 1000°C, 5 hr., Ar

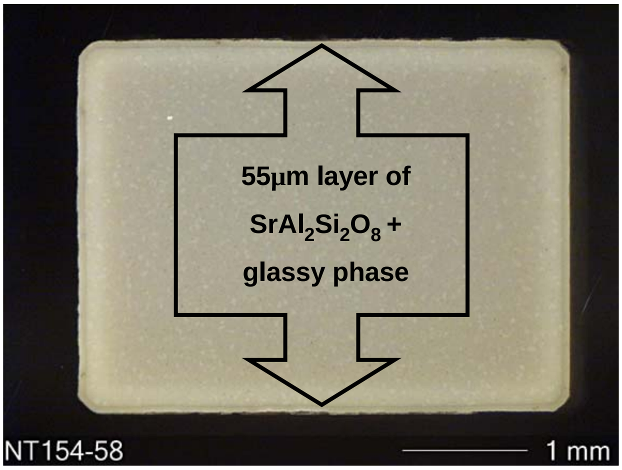
Example of coated parts

Technology

One approach that is being pursued to produce an EBC for Si_3N_4 is the formation of a surface conversion layer using the pack cementation process. Pack cementation has been used for many years to develop an oxidation protection coating on nickel-based superalloys that are used for hot-section components in gas turbine engines. The part is essentially heat treated in a reactive environment to chemically alter the composition of the surface region to form ceramic compounds that may provide enhanced corrosion and erosion resistance. Variables that affect the coating process include: substrate composition, powder bed composition, and heat treating conditions of temperature, time, and furnace atmosphere. In contrast to most other coating techniques, pack cementation is a non-line-of-sight process, which coats all surfaces of the part



Micrographs of polished cross-sections of coated bars shown above simultaneously and in a uniform manner. This provides a tremendous benefit for coating complex-shaped parts such as turbine blades and rotors. The pack composition can be varied to produce different coating phases. During FY04, coatings of $Y_2Si_2O_7$, $SrSiO_3$, Yb_2SiO_5, $SrAl_2Si_2O_8$, and $ZrSiO_4$ were produced on Si_3N_4 substrates having varying additive compositions. These include: Honeywell AS800, Saint-Gobain NT154, and Kyocera SN281. Analysis has shown that the coatings are typically multiphase, and efforts are now being focused on identifying the most protective composition and forming a single-phase coating. Industrial collaborators are providing substrate materials, as well as sharing ideas and suggestions for coating compositions. Collaborators include: Saint-Gobain Industrial Ceramics, Honeywell Ceramic Components, Kyocera Ceramics, Kennametal, United Technologies Research Center, and GE Aircraft Engines. Efforts are continuing to define the best pack cementation processing conditions and to identify promising coating compounds.



Optical micrograph of the cross-section of a coated bar shows the uniformity of the surface coating.

Coating compositions currently being investigated for environmental protection

$SrAl_2O_4$	$SrAl_2Si_2O_8$	Yb_2SiO_5	$Yb_2Si_2O_7$

Benefits

Pack cementation coating is a promising new method for producing coatings on high temperature ceramic materials for advanced gas turbine engines. It has an established and successful history for coating metal parts in the aircraft engine industry. Some advantages include:

- •Non-line-of-sight process for uniform coatings on complex shapes
- •Batch process which can coat hundreds of parts simultaneously
- •No unique equipment required to establish coating capability
- •Technology can be easily transitioned to industrial production

Future Work

The durability and uniformity of coatings on complex-shaped substrates exposed to a simulated gas turbine engine environment will continue to be assessed as the pack cementation process is further refined. There are also plans to evaluate new coating compositions and investigate substrate composition modifications for enhanced coating adhesion and protection.

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