NANOSCALE REINFORCED, POLYMER DERIVED CERAMIC MATRIX COATINGS

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I. Objectives

The goal of this project is to explore and develop a novel class of nanoscale reinforced ceramic coatings for high temperature (600-1000 ^{0}C) corrosion protection of metallic components in a coal-fired environment. It is focused on developing coatings that are easy to process and low cost. The approach is to use high-yield preceramic polymers loaded with nano-size fillers. The complex interplay of the particles in the polymer, their role in controlling shrinkage and phase evolution during thermal treatment, resulting densification and microstructural evolution, mechanical properties and effectiveness as corrosion protection coatings will be investigated.

II. Accomplishments to Date

During the first six months of the project (last year's reporting period), a comprehensive literature analysis of polymer-derived ceramics and also of corrosion protection coatings in coal-fired environments was completed. Based on this, two polymeric systems and a variety of potential fillers were identified. A new dip coating system using a universal mechanical testing machine was installed and used to make preliminary coatings.

The main accomplishments this year have been:

- A systematic study of the thermal conversion characteristics of a range of potential nanoscale reinforcements leading to the selection of the most attractive fillers for the coating
- A scientific investigation on the effect of processing parameters on the coating leading to development of optimized coating parameters.

A detailed investigation of the thermal properties of both active and inert fillers has been completed. Research emphasis was placed on active fillers due to their relatively complex oxidation behaviors. We have investigated twelve fillers in detail. In particular we looked at their thermal stability and also the thermal conversion rates (for active fillers) as a function of process parameters (temperature, heating rate and particle size). Based on this systematic study, a list of six active fillers has been selected. These readily oxidize under the processing conditions and lead to significant volume increase which is needed to compensate for the shrinkage of the polymer. The fillers are in two groups, disilicides ($TiSi_2$, $CrSi_2$ and $ZrSi_2$) and aluminides ($TiAl_3$, TiAl and Ti_3Al). For each one of these fillers, the volume fraction needed to give close to zero shrinkage of the composite coatings has been calculated.

We have also identified the two representative alloy substrates that will be used in this investigation. These are representative of the materials being considered for next generation coal fired plants. One is a stainless steel (SS 304) and the other is a nickel-based superalloy (Inconel 617).

Using a systematic approach starting from the theoretical treatment of the effect of processing parameters on the thickness of the coating, we are investigating the effect of processing parameters (e.g. slurry viscosity, withdrawal speed during dip coating) on the green and fired films characteristics. This study will be used to develop a set of optimized processing parameters for the nancoscale composite ceramic coatings.

III. Future Work

We have completed the selection of the material systems (Task I in the proposed research) and made significant progress on Task II (Processing of coatings including optimization of slurry rheology). In the coming year, work will focus on completion of Task II and significant progress on Task III (characterization of the coatings).

IV. Publications, Patents and Presentations

Kaishi Wang, Rajendra K. Bordia**, "Nanoscale Reinforced Polymer Derived Ceramic Matrix Coatings",** Presented at 31st International Cocoa Beach Conference & Exposition on Advanced Ceramics and Composites, Symposium on Advanced Ceramic Coatings for Structural, Environmental and Functional Applications, January 21-26, 2007, Daytona Beach, Florida

V. Student Supported Under this Grant

Mr. Kaishi Wang is a second year Ph.D. student in the Department of Materials Science and Engineering at the University of Washington. He is being supported on this project since December 15, 2005. He will work on this project for its entire duration as a part of his Ph.D. dissertation.