Fabrication of Nanotiles for thermal/electrical insulation coatings

Yu Lei
Nanomaterials for Advanced Catalysis and Seperations
Department of Chemical Engineering
Northeastern University
Boston, Massachusetts 02115

Thermal barrier coatings (TBCs) are advanced heat management systems usually applied to metallic surfaces, such as gas turbines or aero-engine parts operating at elevated temperatures, as a thermal insulation/protection layer. Currently, Yttria Stabilization Zirconia (YSZ) is the material that has been dominantly used for TBCs due to its high coefficient of thermal expansion and low thermal conductivity. However, there has been limited success in reducing the thickness of YSZ protective layers below several hundred micrometers. If we could reduce the quantity of material used for TBCs, we could reduce the extra weight imparted by the coating materials and thereby reduce the overall materials cost and energy.

Nanotiles, single layers of silicates from nanosheet precursors such as MCM-22 (P) and AMH-3, show promises to make thinner, lighter, and highly efficient thermal protection coatings for thermal protection. The coating of nanotiles can lower the thickness of TBCs significantly due to the high aspect ratio of nanotile layers as well as their layer thickness of ~ 1nm. Silicate is known to show low thermal conductivity compared to YSZ due to its long phonon mean free path. Furthermore, the periodic void structures within silicate nanotiles may cause the scattering of phonons at the pore boundaries, which will facilitate further reduction of thermal conductivity compared to bulk crystals.

The synthesis of individual nanotiles begins with the swelling of a nanosheet precursor. We are developing nanosheet precursors containing silicate layers around ~ 1 nm thickness, which are swollen by organic molecules such as cetyltrimethylammonium bromide (CTAB). Small monomer molecules such as aziridine (C_2H_5N) are then diffused in this interlayer space and catalyzed for ring-opening reactions, yielding hyperbranched polymers that can shove the nanosheet layers apart into individual nanotiles. Dispersion of nanotiles will be prepared by dissolution of the interlayer polymer fillers with organic solvents followed by a solvent exchange, which can be coated onto the surface of various metal supports by spray coating or dip coating. The proposed synthesis schematics will provide a non-destructive, one-pot-synthesis route for morphology-preserved nanotiles on a large scale, which will lead to the possibility of using these nanotiles as thermal protection coating (TBC) platforms for ultra-high temperature applications. The technology developed in this work also can find other engineering applications, such as insulating layers for electronics.