УДК 621.74

Thermal properties of thermal barrier coatings (TBC)

Master gr. 101M-17, Bektemirov B.Sh.
Scientific supervisor prof. Saydakhmedov R.X.
Tashkent State Technical University after named Islam Karimov

That high thermal property of ceramic coating controls the durability and effectiveness of a thermal barrier coating will be covered in this paper. A good thermal stability, a low thermal conductivity, a high coefficient of thermal expansion (CTE) in combination with a high fracture toughness are the main required properties for the ceramic top coat on top of metallic components.

Thermal conductivity. In TBCs the thermal conductivity of the system can be seen as a combination of two main controlling factors; the radiation component due to photons and the lattice wave component based on phonons. The lattice waves can be seen as vibration waves that propagate through the lattice due to a displacement from the equilibrium position of atoms. The energy of these waves in an ideal solid without any type of defect would remain constant and hence due to non-thermal equilibrium of the waves, a high thermal conductivity would be achieved. In reality, these ideal solids never exist and due to lattice defects and grain boundaries, lattice waves are scattered upon interaction resulting in thermal equilibrium limiting the thermal conductivity through the material. The radiation component that is generated due to photons is a large contributing factor in the thermal conductivity at high temperatures. Literature has shown that dense materials act as black bodies, absorbing much of the radiated heat. If the amount of defects in the material is increased, the radiation component decreases due to reflection of the photons [1]. In Fig. 1, the coefficient of thermal conductivity at room temperature for some common TBCs is presented. [2].

The thermal conductivity can be understood using two simple equations, one that depends on the transportation of heat by phonon transfer through the solid, Eq. 1[3].

$$K = \frac{1}{3} C_v * v * l$$

Where *C*v is the specific heat of the solid, ν is the speed of sound through the solid and *l* is the mean free path.

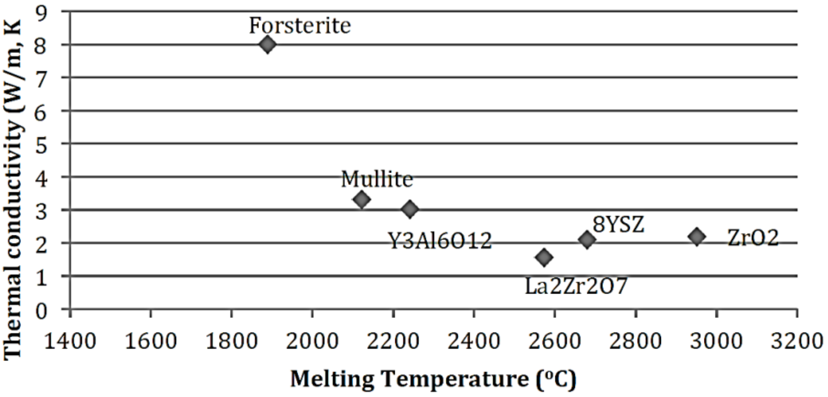

Figure 1 - Thermal conductivity at room temperature of selected TBC material [2].

The mean free path in this equation can be altered to lower the thermalconductivity by introducing lattice defects or porosities into the system that scatter the phonons. The influence of the porosity on the thermal conductivity can be seen by reviewing equation 2 [3].

$$K = \alpha * C_p * \rho$$

Where instead of the mean free path used in Eq. 1,the density ρ, is used together with thethermal diffusivity, α, and specific heat Cp. When reviewing the specific heat of a solid, Cv and Cp can be assumed the same. As Eq. 2 shows, an increase in density, as indensification during sintering increases the thermal conductivity of the solid, resulting in anon-thermally stable TBC that loses its shielding properties at higher temperatures.The material parameter specific heat, defined as the amount of thermal energy the material can absorb (J/K,mol), plays a large role in the thermal conductivity of the material. The behavior of the specific heat can be divided into two stages where in the initial stage thespecific heat increases with increase temperature. In this stage the specific heat increasesdue the vibrations of the individual unit cell, vibrations that increases with temperature. At a certain temperature the wavelength of the phonons exceeds that of the unit cell, calledthe Debye temperature. Rendering the specific heat to be independent of the individual vibrations and the specific heat stabilizes [3].

Thermal expansion coefficient. One of the key aspects when designing and choosing a TBC system, in terms of topcoat and bondcoat is the thermal expansion of the individual components. To generate a durableand effective TBC, the thermal expansions of the components should match each other,reducing the thermal stresses induced during the cycling. If the difference in thermalexpansion between the topcoat and the underlying material is large enough the generatedmismatch stresses will results in failure of the TBC system. The thermal expansion/contraction depends on the coefficient of thermal expansion and the difference in temperatureaffecting the different layers in the system [2] Fig.12. Shows the linear CTE of some commontopcoat materials together with the common substrates for exhaust components and theNiCrAlYbondcoat [2].

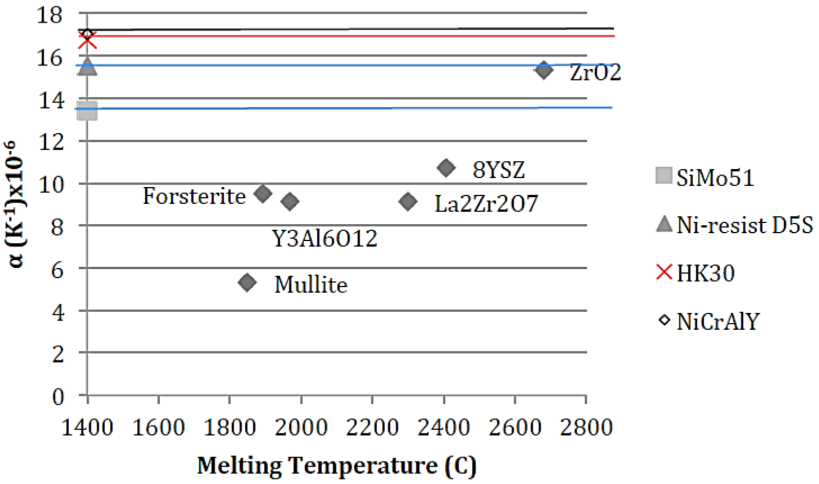

Figure 2 - Linear CTE of selected TBC materials [2]

Literature

1. Klemens PG, Gell M. Thermal conductivity of thermal barrier coatings. Materials Science and Engineering: A 1998;245(2):143-149 p.
2. Huibin X, Hongbo G. Thermal barrier coatings. 1st ed. Cambridge: Woodhead Publishing Limited; 2011.
3. Gaskell DR. Introduction to the thermodynamics of Materials, Fifth edition. 5 eth ed. New York: Taylor and Francis group, LLC; 2008.