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High temperature thermal barrier coatings from recycled fly ash cenospheres

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HIGHLIGHTS

- New FAC thermal barriers with potentiality for high temperature applications (HTA).
- A thermal conductivity value as low as 0.17 W/m K for FAC was found at 1200 K.
- Low thermal expansion coefficient of 5.96×10^{-6} for FAC was found. This avoids microcracking at HTA.
- HT values of α and e guarantee a good performance during unsteady state operation.

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ABSTRACT

The high temperature behavior of electrophoretically deposited thermal barrier coatings based on recycled fly ash cenospheres is presented. Thermal properties such as thermal expansion coefficient, specific heat, thermal conductivity, thermal diffusivity and thermal effusivity of fly ash (FA) and fly-ash cenospheres (FAC) were measured in the temperature range of 373 K–1173 K. Thermal conductivity values as low as 0.17 W/m K and 0.32 W/m K for FAC and FA respectively at 1200 K were found. These results confirm their potentiality as ultra-low thermal conductivity thermal insulators for high temperature applications.

1. Introduction

Coal power plants produce 41% of global electricity. Nevertheless, in addition to electricity these plants also produce a waste material because of the non-combustible mineral portion of coal. That material is compose of microscopic flakes and hollow spheres of mullite ($3Al_2O_32SiO_2$) which are called fly ash cenospheres and fly ash cenospheres respectively. Mullite is a promising material as a coating because of its excellent corrosion resistance, high thermal stability, its permanence in severe chemical environments and its low thermal conductivity. Moreover, when compared to currently thermal protective coatings which are based on yttrium stabilized zircon (YSZ) it has a coefficient of thermal expansion much lower [1,2].

Globally, coal-fired power plants produce 500 million tons of fly ash each year [3]. The recoverability of fly ash depends significantly on the manner in which it is disposed, in addition there are regulations related with the areas can be used to place such wastes. Fly ash disposed of in a monofill or holding pond likely would be suitable for beneficial use because it has generally not been commingled with other materials [4]. Unfortunately, the American Coal Ash Association (ACAA) is unaware of data indicating how much of the 100–500 million tons of stockpiled fly ash is deposited in monofills or holding ponds [5]. In 2007, only the United States produced 131 million tons of coal combustion products. While 43 percent were used beneficially, nearly 75 million tons were disposed of [6]. It is clear that by using ashes instead of disposing of it in landfills are avoiding the environmental degradation and energy costs associated with mining virgin materials [4].

Unlike the earlier work where the thermal properties of the heat barriers were analyzed in the temperature range from 100 K to 500 K [7], here we deal with an extensive study of thermophysical properties of thermal barrier coatings (TBCs) based on recycled fly ash cenospheres and their thermal behavior beyond room temperature (from 300 K to 1173 K). In addition to the aim of this research, here we are extending the applications of recycled fly ash cenospheres in areas other than filler material or in the concrete industry, in order to reduce the environmental problems related with its disposal.

The thermophysical properties governing the thermal energy propagation in solids are the thermal conductivity (k), thermal diffusivity (α) and thermal effusivity (e). However, while the role of k is well known, the role played by α and e is usually undervalued and misunderstood mainly because they describe the unsteady thermal state of the system. Thermal diffusivity is the quantity associated with the speed of propagation of thermal energy in

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