Spectral and Total Emittance of Oxide and Non-Oxide Ceramic Matrix Composites (CMCs) as a Function of the Temperature

Leire del Campo[1, S, C], Lionel Cosson[1], Gerard L. Vignoles[2], Alexander Konschak[3], Jens Schmidt[3], Liviu Dan Toma[4], Christian Eckardt[4], Andrea Lazzeri[5], Roberto d'Ambrosio[6], Giuseppe Annino[6] and Olivier Rozenbaum[1]

[1]*Conditions Extremes et Materiaux: Haute Temperature et Irradiation, CEMHTI, UPR 3079-CNRS Univ Orleans, Orleans, France*
[2]*Universite de Bordeaux, Pessac, France*
[3]*Fraunhofer ISC, Center for High Temperature Materials and Design HTL, Bayreuth, Germany*
[4]*Fraunhofer-Center for High Temperature Materials and Design, Bayreuth, Germany*
[5]*Department of Civil and Industrial Engineering, University of Pisa, Pisa, Italy*
[6]*Institute for chemical and physical processes, IPCF-CNR, Pisa, Italy*
leire.del-campo@cnrs-orleans.fr

CMCs represent one of the latest and most promising solutions for high temperature applications in strategic economic sectors, such as transport, energy and heavy industry. In particular, these CMCs are being considered to replace Inconel/stainless steel alloys in radiant tube furnaces in the steelmaking industry in view of the expected transition to renewable fuel mixtures, based on hydrogen/biogas, as well as their higher lifetime, thermal and chemical resistance. Therefore, in the framework of the EU CEM-WAVE project, the application of different CMCs, in different radiant tube sections, is being evaluated. As a result, a detailed knowledge of the thermal emissivity as a function of the temperature is crucial for both the fabrication process and the final application.

In this work, two CMCs are studied:

- An oxide-oxide CMC: Zirconia-based matrix reinforced with alumina fibers (Nextel^{TM} 610) coated with aluminum phosphate ($Al_2O_{3f}/AlPO_4/ZrO_2$)
- A non-oxide CMC: Silicon Carbide (SiC) matrix reinforced with Silicon Carbide fibers (High-Nicalon^{TM} type S) coated with a multiple Boron Nitride-SiC interphase layer ($SiC_f/(SiC/BN)_3/SiC$)

Emissivity at room temperature has been obtained indirectly (applying Kirchhoffs' laws) using an integration sphere coupled to a Fourier Transform InfraRed spectrometer (FT-IR) for reflectance and transmittance measurements. The direct radiative method is then used to measure the spectral emissivity of the sample for a spectral range going from 400 cm^{-1} to 11000 cm^{-1}, and between ~400 K and ~1400 K.

We have found that the spectral emittance of the non-oxide CMC is much higher than that of the oxide-oxide CMC. Using the spectral emittance obtained experimentally, the total emittance has been computed as a function of the temperature. We have found that the total emittance of the oxide-oxide CMC drastically decreases with temperature. The total emissivity of the non-oxide CMC is higher and positively less temperature-dependent than that of the oxide-oxide CMC.

We can conclude that, to enhance the radiant energy of radiant tubes, and, due to the higher thermal resistance, non-oxide SiC based CMCs are more suitable for application at higher temperature. Regarding to the oxide-oxide CMC, the total emissivity of this composite is rather low; the absorption should be enhanced in the 2500 cm^{-1} - 6000 cm^{-1} spectral band, either by adding an emissive coating, or adding an absorber in the bulk of the ceramic composite (such as oxides of iron or other transitional elements for example).

Acknowledgments

The authors acknowledge support from the European Commission through the funding of the Horizon 2020 project "CEM-WAVE" under grant agreement no. 958170.