Synchronous growth of CNTs and PyC for fabricating nanocomposites to self-adapting ultra-high temperature ceramic coatings

Gang Kou[1], Ling-jun Guo[1 *], Ning-kun Liu[1], He-jun Li[1 *], Wei Li[1], He Shen[2 *], Li-jing Bai[3]

1. State Key Laboratory of Solidification Processing, Shaanxi Province Key Laboratory of Fiber Reinforced Light Composite Materials, Carbon/Carbon Composites Research Center, Northwestern Polytechnical University, Xi'an, China

2. Department of Mechanical Engineering, California State University, Los Angeles, USA

3. School of Material Science and Engineering, Xi'an University of Technology, Xi'an, China

*Corresponding authors: guolingjun@nwpu.edu.cn; lihejun@nwpu.edu.cn; he.shen@calstatela.edu.

In the field of carbon fibers reinforced pyrocarbon matrix (Cf/C) composites fabrication, normally the carbon fiber preform is densified with the pyrocarbon matrix (PyC) after it is produced and weaved. Such two-step method is due to the different structures and different fabrication conditions that matrixes and reinforcements require. Here, we achieve the synchronous growth of matrix (PyC) and reinforcement (carbon nanotubes, CNTs) in one step using a controlled thermal gradient chemical vapor deposition (TGCVD). This proposed one-step method can greatly simplify the fabrication process of traditional C/C composites. And the fabricated carbon nanotubes reinforced pyrocarbon matrix (Ct/C) nanocomposites achieve improved mechanical performance and show isotropy and super-elastic property. The Ct/C nanocomposites can be the substitution of traditional C/C composites and isotropic PyC materials. And such method can provide a new technical strategy for synthesizing multi-carbon structures and other nanocomposites.

On the other hand, mismatch of coefficients of thermal expansion (CTE) between the Cf/C composites ($<4.0\times10^{-6}$/°C) and thermal barrier coatings (TBCs) ($>4.0\times10^{-6}$/°C) has significantly restricted the service-life of Cf/C composites in high temperature environment. Because it's impossible to change the high CTE of TBCs, the designed high CTE substrate is meaningful to reduce the mismatch of CTEs. The Ct/C nanocomposites have high CTEs ($4.0\sim6.5\times10^{-6}$/°C) and it varies with the content of CNTs. Due to the decreased mismatch of CTEs between TBCs and substrate, no crack is found in the prepared TBCs on Ct/C composites. Moreover, after heat-treatment at 2100°C, the TBCs are intact without cracks on CtC composites, but more and larger cracks are found in the TBCs on

Cf/C composites. The variable CTE of Ct/C composites can self-adapt different TBCs which can protect the substrate of carbon composites from oxidation at high-temperature.