11th International Conference on Advanced Materials

ICAM 2009

Rio de Janeiro Brazil
September 20 - 25

Fabrication of Ceramic Composites by Rapid Prototyping Techniques

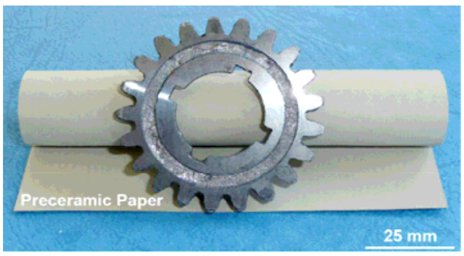
N. Travitzky

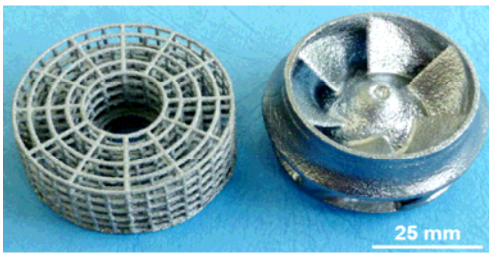
Department of Materials Science, Glass and Ceramics, University of Erlangen-Nuremberg, Martensstr. 5, 91058 Erlangen, Germany

Abstact - Dense ceramic/glass (e.g., alumina/glass), porous ceramics (e.g., alumina) and ceramic/metal (e.g., SiSiC, Fe-Si/Si, TiC/Ti-Cu, Al_2O_3/Cu, $Ti_3AlC_2/TiAl_3/Al/Al_2O_3$) composites with complex geometry have been fabricated via different RP processing routes, Fig.1. Microstructure and mechanical properties of the fabricated composites have been investigated.

Design and development of advanced materials for medical and high performance applications ranging from automotive to aerospace and bringing these materials into use is one of the most challenging tasks of modern materials engineering. Ceramic materials are natural candidates for these demanding applications due to their biocompatibility, exceptional mechanical properties, chemical stability and oxidation resistance from ambient to peek operation temperatures. Owing to the inability of current technology related methods to produce complex-shaped ceramic parts with the desired microstructures and properties, novel techniques, so-called Solid Free Form (SFF) or Rapid Prototyping (RP) (e.g., three-dimensional printing - 3DP^{TM}, laminated object manufacturing - LOM, selective laser sintering - SLS) are becoming increasingly important processing techniques.

The mechanical properties of the materials fabricated by RP techniques in many cases are similar to the corresponding properties for commercially available ceramic-based materials fabricated by other methods. For instance, bending strength of 315 MPa and the fracture toughness of 3.8 MPa $m^{1/2}$ were measured on the SiSiC materials fabricated by LOM technique using novel SiC - loaded preceramic paper as a starting material. RP technologies can create parts using advanced materials superior to traditional ones. For example, dense Ti - A - C - O composites were fabricated by 3D printing of a TiO_2/TiC powder mixture, followed by subsequent pressureless infiltration of Al. The reaction of Al with the preform phases finally resulted in a dense composite of Ti_3AlC_2 - $TiAl_3$ - Al_2O_3 - Al, which exhibits a pronounced R-curve behavior. Enhanced crack deflection associated with the lamellar structure of the nanolaminate phase Ti_3AlC_2 gives rise to a reduction of the crack tip stress field and an increase in crack surface, as well as crack bridging and friction between crack surfaces, resulting in increasing crack tip shielding with increasing crack extension.





Figre 1: SiSiC parts fabricated via LOM (left) and 3DP^{TM} (right) methods.

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