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1475 N. Scottsdale Road, Suite 200
Scottsdale, AZ 85287-3538
Phone: 480 884 1996 Fax: 480 884 1984

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Manufacturing and Healing of Ceramic Metal Composites by Electrodeposition

Inventors

Majid Minary Jolandan
Mohammadreza Mahmoudi

Contact

Physical Sciences Team

Background

Ceramics are well-known for their high-strength, high-temperature resistance, and excellent chemical stability, but their strong covalent bonds prevent them from ductile behavior. Surface or internal defects such as cracks can nucleate in service life of the ceramic components, and can considerably deteriorate the fracture strength of the materials. Incorporating a metallic phase into the ceramic components can further improve their properties by increasing the toughness of the ceramic components and introducing the self-healing property to the material.

Self-healing materials were inspired by polymers, and generally a curing agent, catalyst, or monomer is embedded inside the main polymer matrix. Once the crack is initiated and propagated the embedded healing material flows inside the crack and reacts with the base polymer to solidify and heal the crack. Although self-healing mechanisms such as chain re-entanglement, noncovalent bonding, reversible chemical reactions have demonstrated effective healing, they lack full strength recovery, which requires strong bonding between fractured surfaces.

Metal matrix composites (MMC) require high energy input to melt lower melting temperature metal to active the intrinsic healing mechanism. This stops the MMC component from operation since it requires disassembly and post processing.

Invention Description

Researchers at Arizona State University have developed a novel process for healing of metal matrix composites (MMCs) at room temperature. This process uses freeze casting to fabricate large porous ceramic scaffolds, and then electrodeposition to fill up the porous ceramic with metal to fabricate the ceramic metal composite (CMC). Damages or cracks in the CMCs can be sensed by measuring the electrical conductivity. This process is capable of fabrication of large ceramic scaffolds rapidly.

Initial results showed that the energy required to fill up the ceramic scaffold was at least two orders of magnitude lower than the traditional metal matrix fabrication techniques. Results also showed that the energy input to heal a crack per unit length of a crack was three orders of magnitude lower than that of a similar approach for metallic foams.

Potential Applications

- Biomedical and electronic devices
- Aerospace (jet engines)

- Industrial (power turbines, heat exchangers, energy-based manufacturing etc.)
- Automotive (electric vehicles)

Benefits & Advantages

- Low-cost process
- Operates at room temperature & does not require high energy input to melt metal
- Does not require sensor for damage evolution (detection based on change in electrical resistance of the MMMC)
- Able to locally heal damage in materials

Related Publication: “Low-cost manufacturing of metal-ceramic composites through electrodeposition of metal into ceramic scaffold” | ACS Applied Materials & Interfaces 11, No. 4 (2019)