

SELF-HEALING OF NANO-METAL/OXIDE HYBRIDIZED MATERIALS VIA THERMAL OXIDATION

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ABSTRACT

Metal/oxide hybridized materials are expected for structural applications at high temperatures as well as room temperature. In particular, nano-composites consisting of oxide matrix with nano-metallic particles have been known as having high mechanical strength and improved fracture toughness [1,2]. Some of metal/oxide hybrid materials have any other useful functions, which can be adapted in structural components. Our research group has discovered the self crack-healing function in Al_2O_3 hybrid materials dispersed with 5 vol% Ni nano-particles (referred to as nano-Ni/ Al_2O_3) via thermal oxidation treatment [3].

NiO- Al_2O_3 powder mixture was prepared by drying Al_2O_3 slurry with $\text{Ni}(\text{NO}_3)_2$ aqueous solution and followed by reducing with a stream of Ar- H_2 gas mixture at 600°C to obtain powder mixture consisting of nano-Ni and Al_2O_3 . Fully densified nano-Ni/ Al_2O_3 was fabricated by pulsed electric current sintering technique with the powder mixture of nano-Ni and Al_2O_3 at 1400°C for 5 min under 40 MPa in vacuum. Figure 1 shows microstructure of nano-Ni/ Al_2O_3 . Ni particle size was approximately 300 nm. Cracks introduced with the Vickers indentation with 49 N disappeared by thermal oxidation at 1200°C for 6 h in air.

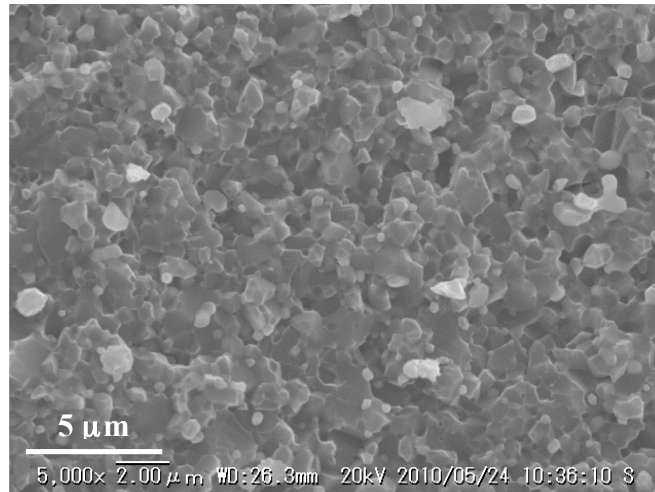


Figure 1: Microstructure of nano-Ni/ Al_2O_3

Figure 2 shows surface photos of nano-Ni/ Al_2O_3 with cracks by the Vickers indentation before and after thermal oxidation treatment. Surface cracks disappear by high-temperature oxidation. During thermal oxidation process, outward diffusion of cations occurs at the grain boundaries of the Al_2O_3 matrix, resulting in the formation of NiAl_2O_4 on the surface, as well as in surface cracks. Figure 3 shows an illustration of crack-healing mechanism of the nano-Ni/ Al_2O_3 via thermal oxidation treatment. Because NiAl_2O_4 filled up surface cracks can reduce the stress concentration at the surface crack, fracture strength is recovered up to the intrinsic strength without surface crack.

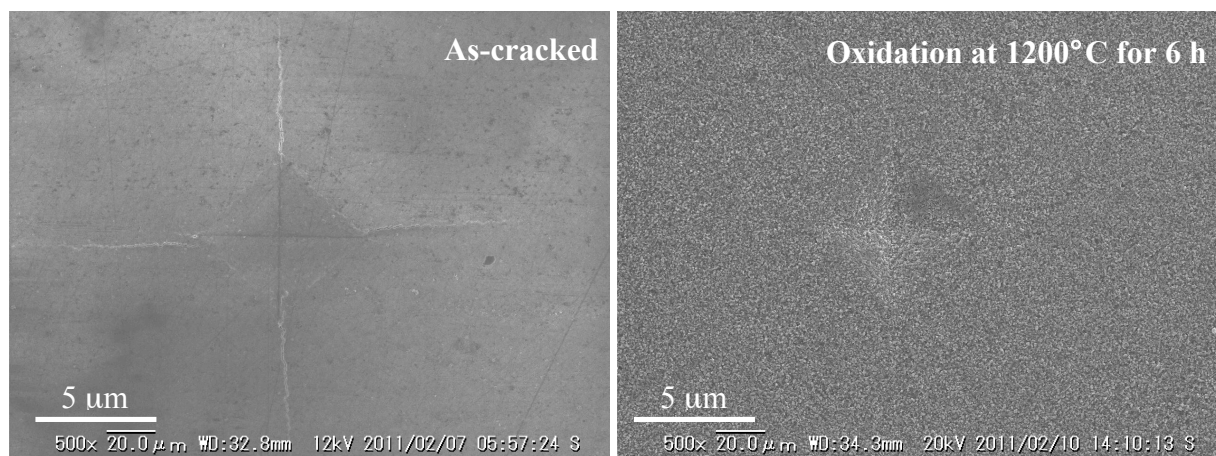


Figure 2: Surface photos of nano-Ni/Al₂O₃ with cracks by the Vickers indentation before and after thermal oxidation treatment.

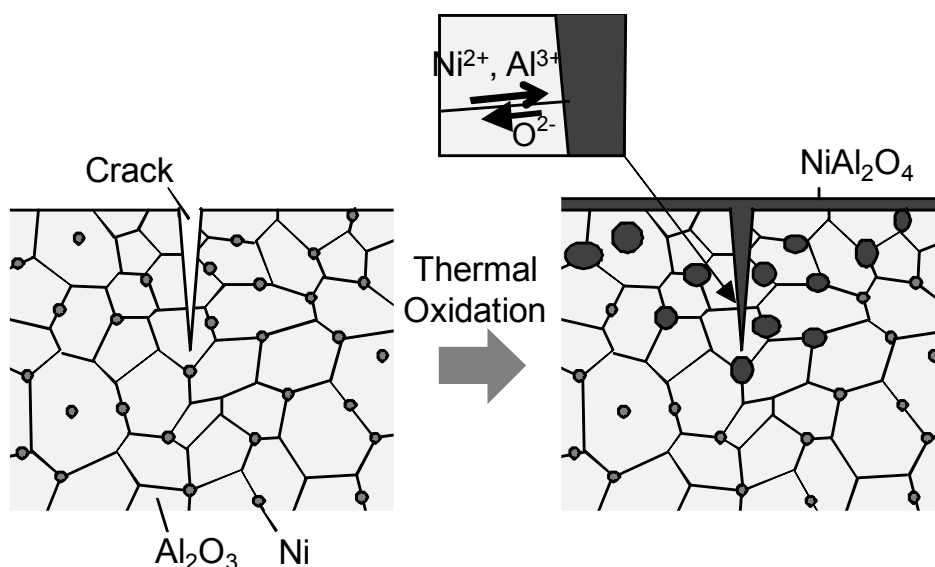


Figure 3: An illustration of crack-healing mechanism of the nano-Ni/Al₂O₃ via thermal oxidation treatment

Crack disappearance via thermal oxidation is discovered on Mo/Al₂O₃ hybrid materials via thermal oxidation at 700°C in air. Al₂O₃ composites dispersed with 5 vol% Mo were produced by pulsed electric current sintering with the powder mixture of Al₂O₃ and Mo. After thermal oxidation at 700 - 800°C, Al₂(MoO₄)₃ was filled into the cracks introduced by the Vickers indentation. The oxidation product was observed after high-temperature oxidation at temperature ranging from 700 to 800°C in air. Crack-disappearance of Mo/Al₂O₃ occurs at lower temperatures than that of nano-Ni/Al₂O₃.

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