

RELATIONSHIP BETWEEN CRACK DISAPPEARANCE AND MECHANICAL RECOVERY ON NANO-NI DISPERSED AL₂O₃ HYBRID MATERIALS

Daisuke Maruoka¹ and Makoto Nanko²

¹Nagaoka University of Technology, Graduate School of Engineering, Kamitomioka, Nagaoka, Niigata, 940-2188, Japan
Email: daisuke@stn.nagaokaut.ac.jp

²Nagaoka University of Technology, Department of Mechanical Engineering, Kamitomioka, Nagaoka, Niigata, 940-2188, Japan
Email: nanko@mech.nagaokaut.ac.jp

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ABSTRACT

Self crack-healing of ceramic composite materials was discovered by Ando and his co-workers [1]. Some oxide composites dispersed with SiC shows the recovery of mechanical strength by high-temperature oxidation of the dispersoids. Surface cracks are filled by the formation of oxidation product, SiO₂ or mullite.

Al₂O₃ hybrid materials dispersed with 5 vol % nano-Ni particles (nano-Ni/Al₂O₃) is one of the nanocomposite materials which ceramic materials including some nano-size particles with excellent mechanical strength and improved fracture toughness [2]. Our group has discovered that nano-Ni/Al₂O₃ have crack-healing function by the formation of NiAl₂O₄ to fill cracks with air oxidation process at high temperatures [3]. Although filling of NiAl₂O₄ in the crack causes recover of mechanical strength, relationship between crack disappearance and mechanical recovery is not clear. In this study, microstructure and recovery of mechanical strength on nano-Ni/Al₂O₃ were investigated in various heat treatment conditions.

Densified 5 vol% nano-Ni/Al₂O₃ was fabricated by a commercial Al₂O₃ powder with nano-Ni particles with the pulsed electric current sintering at die temperature of 1400°C under 40 MPa pressure for 5 min in holding time in vacuum. After cutting samples into 3×4×26 mm, three Vickers indentations were introduced into the tensile stress side surface of the bending test specimens loading at 49 N for 10 s. Samples introduced cracks were heat treated at 1200°C for 1 to 6 h in air. Each crack length was measured before and after oxidation using scanning electron microscope (SEM) to determine percentage of crack disappearance. Three-point bending test (16 mm of span length) was conducted with cross-head speed of 0.5 mm/min at room temperature.

Figure 1 shows surface views of nano-Ni/Al₂O₃ after heat treatment at 1200°C for 1 h and 6 h in air. White dash lines show the edges of the Vickers indentation. Cracks were almost disappeared at 1200°C for 1 h. Complete disappearance of cracks was observed after heat treatment of 6 h.

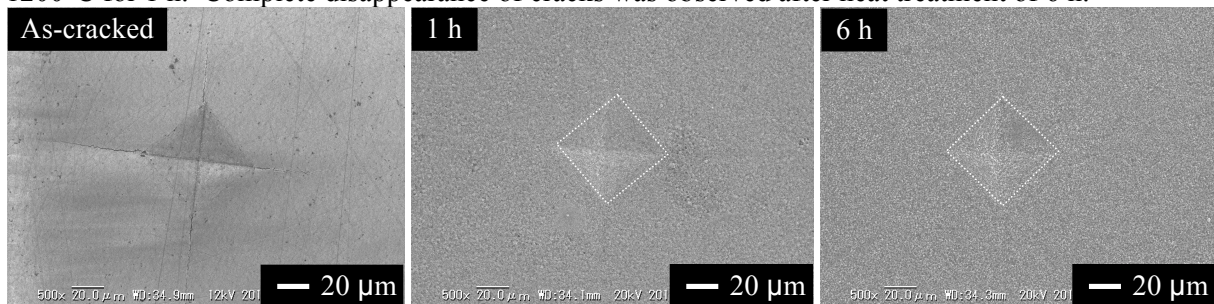


Figure 1: sample surface views of as-cracked and heat treated at 1200°C in air.

Figure 2 shows bending strength of nano-Ni/Al₂O₃ as function of heat treatment time. Percentage of crack disappearance was increased with increasing temperature. Although as-sintered samples shows 490 MPa in bending strength, the value of bending strength were decreased to 180 MPa on as-cracked samples. After heat treatment, bending strength is increased up to 570 MPa, similarly with as-sintered ones. Mechanical recovery was obtained for 1 h, even cracks was not disappeared completely. It is implied that crack healing would be occurred by relaxation of stress concentration at the crack tip. Figure 3 shows a speculative illustration of crack healing mechanism in cross-sectional nano-Ni/Al₂O₃. Although crack was remained after heat treatment for 1 h, the inside of crack would be filled partially with the oxidation product which recovered its bending strength. As a result, strength recovery is independent of percentage of crack disappearance.

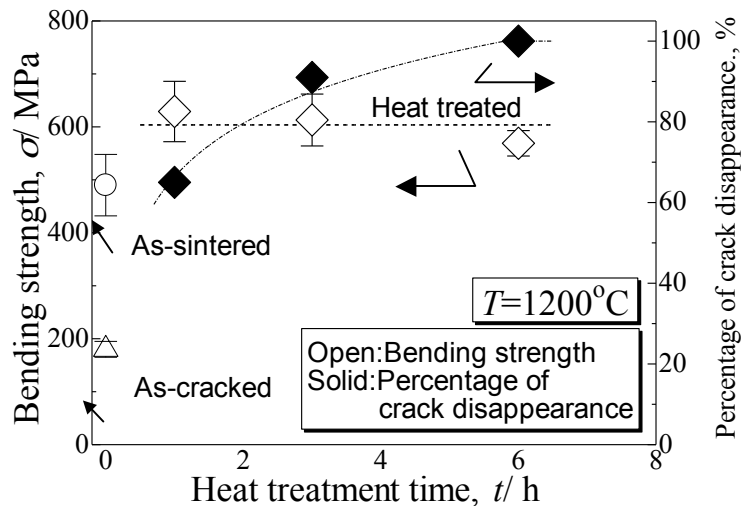


Figure 2: Bending strength of heat treated samples as function of heat treatment time.

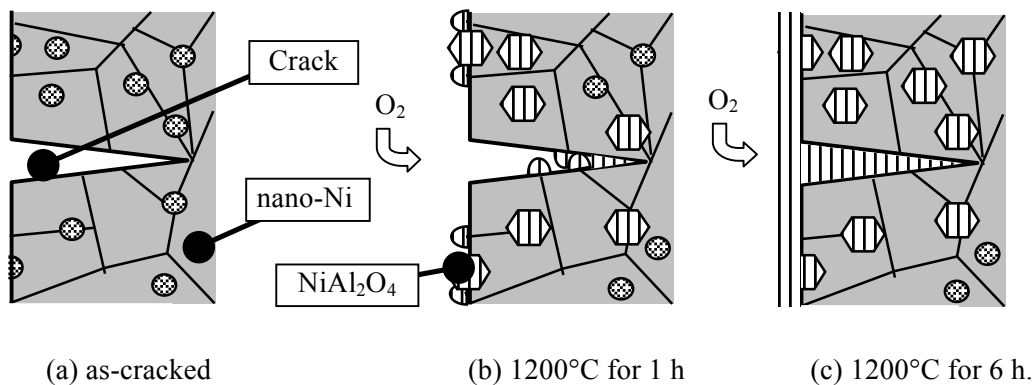


Figure 3: A speculative illustrations of crack healing mechanism in cross-sectional nano-Ni/Al₂O₃.

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