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Effect of HIP and Mixture of Rare Earth Elements on the Microstructure and Mechanical Performance of Aged Nanostructured Inconel 718

H. M. Medrano-Prieto[1,*], A. Santos-Beltran[1], V. Gallegos-Orozco[1], M. Santos-Beltran[1], C.G. Garay-Reyes[3], G. Rodríguez-Cabriales[3], I. Estrada-Guel[3], J.S. Castro-Carmona[2], H. Camacho-Montes[2], and R. Martínez-Sánchez[3]

[1]*Departamento de Nanotecnología, Universidad Tecnológica de Chihuahua Sur, Aldama, Chihuahua, México*
[2]*Universidad Autónoma de Ciudad Juárez (UACJ), Ciudad Juárez, Chih., México*
[3]*Centro de Investigación en Materiales Avanzados (CIMAV), Laboratorio Nacional de Nanotecnología, Chihuahua, Chih., México*

*Corresponding author: hmedrano@utchsur.edu.mx

The Ni-based superalloys Inconel 718 (IN718) are principally used in high-temperature processes owing to their excellent oxidation resistance and high mechanical properties. They are widely employed in aeronautics, aerospace engines and other uses like power generation and chemical industries [1-2]. Research carried out in recent years on the effects of rare earth elements (REE) in superalloys has shown a significant impact on the solid solution hardening mechanism, lattice mismatch and modifications of eutectic phases and carbides, which enhance the mechanical and microstructural properties of the superalloys. Thus, the utilization of elements such as rhenium, hafnium, tantalum, niobium, and ruthenium has been growing to produce new alloys with superior properties to current ones. Additionally, the yttrium and samarium has been employed in others research areas such as chemistry and surface engineering [3]. Sintering processes like hot isostatic pressure (HIP) have been reported to generate a fine microstructure with high mechanical properties [2]. However, the use mixture of REE like cerium, lanthanum, neodymium and praseodymium in IN718 in conjunction with HIP has not been deeply studied; owing to that, this research work is focused on studying the effect of these elements, which possess high potential to generate modifications and the HIP influence to improve the microstructural and mechanical performance in the IN718.

The IN718 was modified with REE additions and fabricated by mechanical alloying (MA). The raw materials were an Inconel 718 commercial superalloy and REE Mischmetal with a purity of 99 % and content of Ce:La:Nd:Pr: 50-55:30-35:5-10:5-10: wt. %. The IN718 was modified with 0.1, 0.2 and 0.3 wt. % of REE. The MA was carried out in a high-energy Mill Spex 8000 with 5 h of milling time. N-heptane as a control agent and Ar as an inert atmosphere was used in the milling process. The compaction of powders was performed in a hydraulic press machine with a compaction pressure of 1.56 GPa for 5 min. The powders were consolidated in a HIP 1200 °C for 4 h at 120 MPa in an Ar atmosphere. The heat treatment of the samples was the standard temper: Solution treatment at 980 °C for 1 h, quenched in water at room temperature, two-step aging treatment at 720 °C for 8 h, cooling up to 620°C with a cooling ramp of 55°C and holding at 620 °C for 8 h before air-cooling to room temperature. The samples were characterized by a Panalytical X'Pert PRO x-ray diffractometer, TEM HITACHI 7700 and LM300 AT Vickers microhardness tester.

Fig. 1 shows TEM-BF micrographs (a, b) and SAED pattern (c) of the IN718 modified with 0.3 wt. % REE in aging condition. Fig. 1a shows a grain-refined microstructure with an average grain size of 240 nm. The REE additions generate smaller grain sizes since REEs act as new nucleation sites and create more grain boundaries [4]. In addition, Fig. 1b shows the presence of the γ' Ni_3(Ti, Al) and γ'' (Ni_3Nb) precipitates homogeneously distributed in the γ matrix. Fig. 1c corresponds to a SAED pattern obtained along [001] zone axis from Fig. 1b, which shows principal spots corresponding to the γ matrix and the minor intensity spots corresponding to γ' and γ'' precipitates phases. In the Vickers microhardness graph (Fig. 2), the higher hardness values correspond to the alloys with REE additions for all conditions. However, the highest hardness value is observed in the alloy modified with 0.3 wt. % REE in the aging condition. This behavior could be attributed to the finer microstructure obtained owing to REE additions, precipitation of γ' and γ'' precipitate phases, and the major densification caused by the HIP.

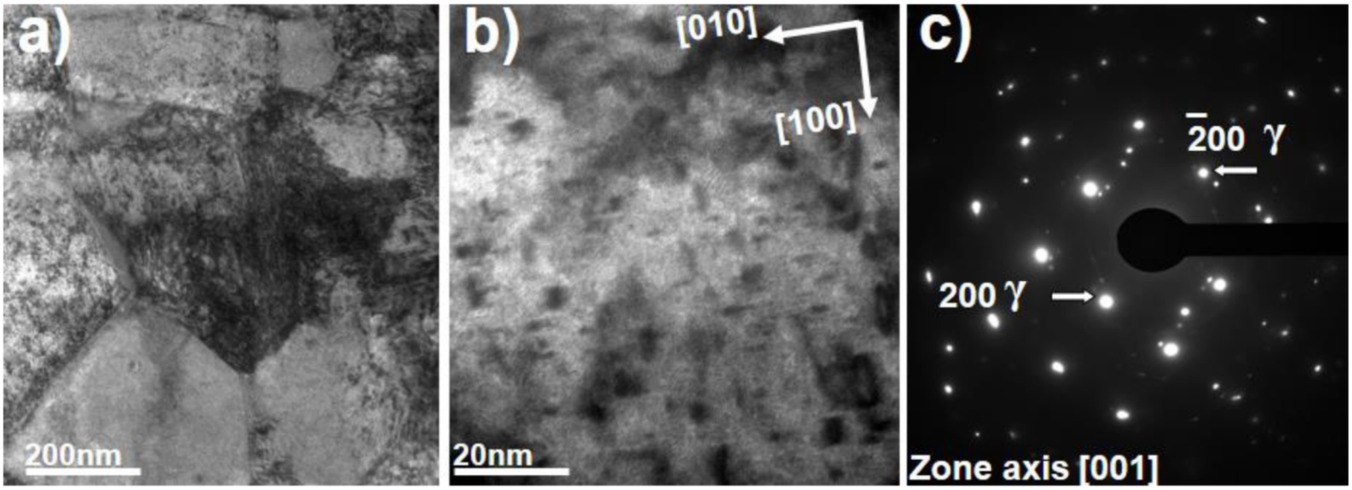

Fig. 1. a-b) TEM-BF micrographs of IN718 alloy modified with 0.3 wt. % REE and aged, c) SAED pattern taken from b).

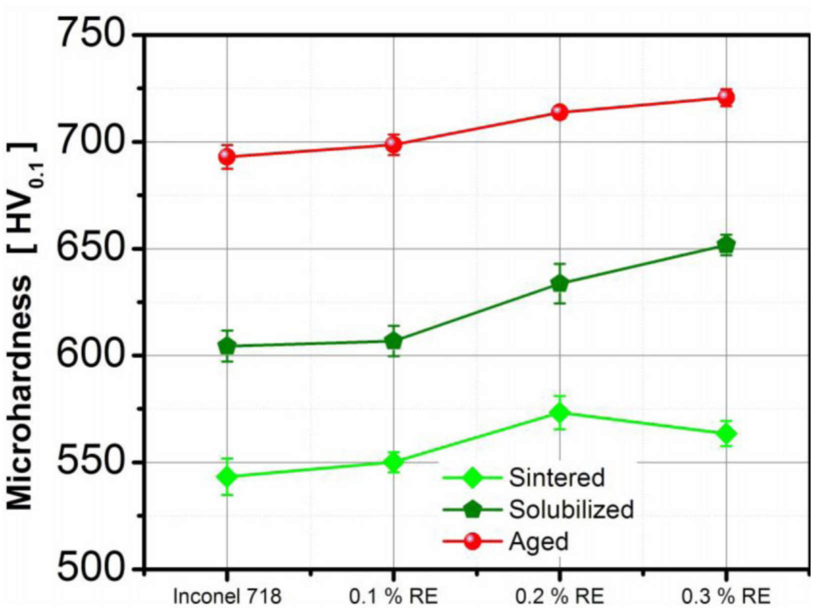

Fig. 2. Vickers microhardness values of IN718 alloy and those modified with REE additions in sintered, solubilized and aged conditions.

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