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Bimodal microstructure and fatigue properties of nanocrystalline and ultrafine grained nickel

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The nanocrystalline (NC) and ultrafine grained (UFG) materials show very high strength but low ductility. In this work bimodal microstructures are developed by introducing larger grains into the finer grained matrix, to combine high strength and considerably high ductility at the same time.
Different bimodal microstructures are developed by heat treatment of the PED NC nickel and the ECAP UFG nickel. The grain growth kinetics is quantitatively analyzed using the JMAK model and the Burke and Turnbull model for the PED nickel. However, the annealing phenomena for the ECAP UFG nickel are difficult to be described quantitatively due to the initial severe plastic deformed state and are only qualitatively analyzed.
Microhardness measurement and tensile tests show that the finer grains provide the strength and the coarser grains ensure the ductility in the bimodal microstructures. The fatigue behavior and crack growth resistance is systematically investigated for the different microstructures. The microcracks introduced by focus ion beam propagate during the fatigue experiments and induce the ultimate fracture for the PED NC, NC/UFG and UFG nickel. Among them the bimodal NC/UFG nickel shows the best fatigue performance. However, the ECAP nickel is not sensitive to the microcracks, and therefore the macro-notches are introduced to investigate the crack growth behavior. Dynamic recrystallization is found to be the main mechanism for the plastic deformation in the ECAP nickel.