TEM and SEM studies of rafting in 4th generation Ni-base superalloy

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Nickel-base single crystal (SC) superalloys, are mainly applied as a turbine blades and vanes in aero-engines and industrial gas turbines. The superior mechanical properties of SC alloys at temperatures up to 0.85 T_m (T_m, melting point) are achieved due to the optimization of their chemical composition and microstructure.

The 4th generation, SC Ni-base superalloy, PWA1497 was developed for a turbine airfoils with long-term durability for use in the aircrafts. In order to achieve adequate long time strength improvements at moderate temperature and retain good microstructure stability, it was necessary to make significant composition changes from 2nd and 3rd generation single crystal superalloys, namely lower chromium levels, higher cobalt and rhenium levels and add a new alloying element, ruthenium. The evolution of microstructure-property relationship of the 1st-4th generation SC superalloys is presented.

The microstructure stability of the PWA1497 superalloy during creep deformation at high temperature (above 950˚C) was studied by quantitative SEM and TEM.
The microstructure of the as-received alloy was consisting of the γ matrix strengthened by γ' particles. During primary creep, γ' precipitates started to coalescence early. They continued to develop rafted structure in steady-state creep by their increased lateral extension. During the last stage, the γ' rafts become more wavy. At the final step of the process, the γ' phase become topologically a matrix, surrounding the γ phase.

The development of γ' rafting process described above was studied by quantitative SEM and TEM metallography and was characterized by four parameters: L – mean length of γ' particles, T – mean thickness of γ' particles, S – mean spacing of γ channels, R – rafting parameter as a function of creep duration.
Rafting of the γ' precipitates, which is essential factor determining creep strength of SC superalloys and significantly contribute to their degradation, is discussed in detail.

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