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Development of ultra-fine-grain 316L steel with 1.0-2.0 wt% TiC for nuclear reactor materials

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SUS316L austenitic stainless steel is normally employed as a corrosion resistant structural material for nuclear facilities. In order to safely apply the steel to more advanced nuclear energy systems, higher radiation-tolerant performances are essential because neutron irradiation causes significant degradation of macroscopic properties of SUS316L steel, such as irradiation hardening, loss of corrosion resistance, irradiation assisted stress corrosion cracking and void swelling. Such property degradation is due to the super-saturation of radiation-induced point defects (interstitial atoms and vacancies). Since grain boundaries (GBs) and the region around dispersoids effectively act as sinks for point defects, it is expected that higher radiation-tolerant performances can be achieved by microstructural modification of increasing the area of GBs and introduction of a high density of dispersoids in SUS316L. The authors fabricated Ultra-Fine-Grain (UFG) SUS316L steel containing 1.0-2.0 wt% TiC by powder metallurgical route (P/M) utilizing mechanical alloying (MA) and hot isostatic pressing (HIP). It is shown that the developed SUS316L-2%TiC exhibits ultra-fine grains with 90-270 nm sizes, accompanied by TiC precipitates with 20-50 nm in grain interior and 70-110 nm at grain boundaries. The developed materials have shown much less hardening in Vickers hardness due to neutron irradiation to 1 dpa (displacement per atom) at 290°C in JMTR (Japan Materials Testing Reactor). The void swelling data are lower than 0.01 % in the 1.0 MeV HVEM electron irradiation to 5 dpa at 400°C for both of the steels with 1% and 2%TiC addition, which is lower than 1/10 of standard SUS316L steel.

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