Study on the Degradation Behavior of Mechanical Performance of Tungsten, the Wall Material for Controlled Nuclear Fusion Devices, Under Helium Plasma Irradiation

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Tokamak devices are an important technological approach to achieve controlled nuclear fusion. Plasma species like hydrogen and helium can affect the grain size, hardness, strength, and overall performance of tungsten, the wall material of the Tokamak device. This article focuses on the influence of helium, generated during the nuclear fusion process inside the Tokamak device, on the recrystallization behavior of tungsten wall material. Tungsten samples were subjected to helium plasma irradiation with varying doses in a laboratory plasma irradiation setup using warm-rolled tungsten. After annealing treatment, the samples were analyzed using Electron Back Scattered Diffraction (EBSD) to measure the average grain size and recrystallization ratio. It was found that helium plasma significantly inhibits the recrystallization behavior. This is because helium plasma, during the tungsten material infusion process, forms helium bubbles or clusters that restrict grain boundary mobility and prevent grain boundary migration, thereby suppressing recrystallization. However, when the helium plasma concentration exceeds a certain threshold, it increases the internal stress within helium bubbles, resulting in partial rupture and weakening of the inhibiting effect.

Keywords: Helium, Tungsten, Recrystallization Behavior, Controlled Nuclear Fusion