Proximal probe thermal desorption mass spectrometry: a method for measuring lateral distribution of hydrogen isotopes retention in tungsten

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In fusion devices, the plasma-facing components experience harsh hydrogen isotopes (HI) plasma irradiations. These irradiation conditions are highly heterogeneous, necessitating characterization of the spatially varying HI retention distribution on the plasma-facing components. To resolve this limitation, we developed Proximal probe thermal Desorption Mass Spectrometry (PD-MS). This technique employs pulsed heating using a probe in contact with the surface to induce localized deuterium desorption from subsurface regions in a sample, with desorbed species detected by a quadrupole mass spectrometer.

PD-MS analysis of a D plasma-irradiated sample revealed D retention distributions matching plasma beam density profiles during irradiation, with a detection sensitivity of ~ 10^{-4} D/W atomic ratio achieved. Spatial resolution better than 500 μm was confirmed by the dimensional temperature distribution measured by IR camera and deuterium distribution measured by time-of-flight secondary ion mass spectrometry. Temperature regulation via probe power control achieved a maximum temperature of 2200 K with fluctuations below ±30 K. A relative standard deviation (<5%) in the surface deuterium distribution of uniformly-coated magnetron-sputtered sample confirms the stability of the PD-MS characterization. A measured 20% difference in deuterium desorption between PD-MS and thermal desorption spectroscopy validates PD-MS's quantitative retention analysis capability.

PD-MS provides a promising method for measuring lateral HI retention distribution with a high spatial resolution in nuclear fusion devices. The technique has already demonstrated the capability for real-time in-situ monitoring in linear plasma devices, while exhibiting potential for further optimization of spatial resolution in the future. Ultimately, it aims to achieve in-situ measurement of deuterium concentration distribution with 100-micron spatial resolution.

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