In future Laser Inertial Fusion Energy (IFE) power plants, MeV-ions will impinge on the chamber wall at high fluence (up to 20 J/cm²) and at rates up to 10 Hz. The effect on materials subjected to such fluences is being investigated on the 800 kV RHEPP-1 facility at Sandia National Laboratories. Beams of helium or nitrogen are directed onto samples of tungsten, tungsten alloy, and graphite, either at room temperature or 600°C. Fluences per pulse range from below melt to beyond ablation thresholds.

Polycrystalline tungsten surfaces exposed to hundreds of ion pulses appear to suffer fatigue-related stress fracturing, and formation of severe surface relief. This roughening corresponds to a peak surface temperature (from heat-flow modeling) of 2,000 - 2,500K, depending upon whether the sample is heated or not. Use of finer-grain tungsten, or orientation of the grains perpendicular to the surface can significantly reduce the roughening. Alloying with rhenium also reduces but does not eliminate these effects. Fracture modeling predicts a per-pulse surface stress intensity below the single event crack threshold for tungsten, which may explain the slow morphology evolution. The cracks must be initiated by cyclic loading before they are able to grow to detectable lengths.

The same model predicts a much higher surface stress intensity factor for tungsten exposed to energy deposition expected in ITER Edge-Localized Modes (ELMs), e.g. 0.7 MJ/m² deposited over 500 µsec. The surface temperature reaches approximately the same value as indicated above for IFE pulses, but stresses and temperature gradients extend much deeper below the surface. This has implications for plasma-facing components exposed to MFE discharges. Graphite can survive lower ion fluences well, but erodes at fluences well below the sublimation point of carbon. The implications for both inertial and magnetic fusion energy reactors will be discussed.

Measurements of surface roughening and removal, and SEM and TEM analysis will be presented, and compared to materials response predictions from simulation codes.

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