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Direct observation of electrothermal instability structures on intensely Ohmically heated aluminum with current flowing in a surface skin layer

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Implosions on the Z Facility assemble high-energy-density plasmas for radiation effects and ICF experiments, but achievable stagnation pressures and temperatures are degraded by the Magneto-Rayleigh-Taylor (MRT) instability. While the beryllium liners (tubes) used in Magnetized Liner Inertial Fusion (MagLIF) experiments are astonishingly smooth (10 to 50 nm RMS roughness), they also contain distributed micron-scale resistive inclusions, and large MRT amplitudes are observed. Early in the implosion, an electrothermal instability (ETI) may provide a perturbation which greatly exceeds the initial surface roughness of the liner. Resistive inhomogeneities drive nonuniform current density and Joule heating, resulting in locally higher temperature, and thus still higher resistivity. Such unstable temperature and pressure growth produce density perturbations which seed MRT. For MagLIF liners, ETI seeding of MRT has been inferred by evaluating late-time MRT, but a direct observation of ETI is not made. ETI is directly observed on the surface of 1.0-mm-diameter solid Al rods pulsed to 1 MA in 100 ns via high resolution gated optical imaging (2 ns temporal and 3 micron spatial resolution). Aluminum 6061 alloy rods, with micron-scale resistive inclusions, consistently first demonstrate overheating from distinct, 10-micron-scale, sub-eV spots, which 5-10 ns later merge into azimuthally stretched elliptical spots and discrete strata (40-100 microns wide by 10 microns tall). Axial plasma filaments form shortly thereafter. Surface plasma can be suppressed for rods coated with dielectric, enabling extended study of the evolution of stratified ETI structures, and experimental inference of ETI growth rates. This fundamentally new and highly 3-dimensional dataset informs ETI physics, including when the ETI seed of MRT may be initiated.