THERMAL ALUMINUM PLASMA FORMATION AND EVOLUTION BY PULSED MEGAGAUSS FIELD*

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When, where, and how plasma forms on metal surfaces driven by intense current are important questions for both basic science and applications. The thermal ionization of the surface of thick metal, in response to a pulsed multi-megagauss magnetic field, is being investigated with detailed experiments[1-3] and numerical modeling[4-8]. Aluminum 6061 rods with initial radii (R_0 from 0.25-1.00 mm) larger than the magnetic skin depth are pulsed with the 1.0-MA, 100-ns Zebra generator. The surface is examined with time-resolved imaging, radiometry, spectroscopy, and laser shadowgraphy. The surface magnetic field (B_s) rises at 30-80 MG/μs, with corresponding peak B_s of 1.5-4 MG. For these rise rates, thermal plasma is observed to form when B_s reaches 2.2 MG. Optical emission from the plasma surface is initially non-uniform, but becomes quite highly uniform as T_{BB} increases. While the current is rising linearly, the Al surfaces expand at 3-4 km/s, with no evidence, after surface plasma forms, of either re-pinching or outward acceleration. At peak current, T_{BB} is 20 eV for R_0 = 0.50 mm rods, but only 0.7 eV for R_0 = 1.00 mm rods. Strong plasma fluting develops in the first case, while extremely smooth expansion occurs in the second (indicating resistive vapor). Moreover, after peak current, plasma (if formed) accelerates (to 10 km/s), while resistive vapor continues expanding at constant speed. The well-characterized experiment is providing a benchmark for radiation-MHD modeling. VNIIEF-UP and UNR-MHRDR modeling have achieved results that agree well with observations. Plasma is formed in low density material resistive enough to expand across the magnetic field, yet conductive enough that ohmic heating exceeds expansion cooling as the expanding material undergoes the liquid-vapor transition. An analytic calculation indicates ohmic heating should produce plasma, consistent with numerical and experimental observations.

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