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Magnetic field threshold for thermal plasma formation from an aluminum surface pulsed to multi-megagauss magnetic field[1]

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The first measurement of the thermal ionization threshold of a thick-metal surface by pulsed multi-megagauss magnetic field is reported. Whether plasma should form from intensely ohmically heated thick metal has been of interest since at least 1959, when Fowler *et al.* first reported producing fields above 10 MG. Plasma formation from thick metal is uncertain, even for megagauss field, because fresh, cold, high conductivity metal persists within, reducing the electric field, current density, and ohmic heating at the surface. The phase-state of thick metal subjected to ultra-high field has been examined by pulsing Al rods of initial diameter 0.50-2.00 mm to 1.0 MA peak current in 100 ns. Experiments accessed the surface-heating regime, where the magnetic penetration depth is less than the conductor radius, and current flows in a skin layer. Shot hardware with novel electrical contacts mitigated or eliminated the non-thermal precursor plasma produced by electric-field-driven electron avalanche and arcing electrical contacts in earlier experiments. Rod surfaces were examined with time-resolved imaging, visible and EUV radiometry and spectroscopy, and laser shadowgraphy. For magnetic field rise rates from 30-80 MG/μs, thermal plasma forms from 6061-alloy Al when the surface field reaches the threshold level of 2.2 MG, in qualitative agreement with simulation results by Garanin *et al.* [J. Appl. Mech. Tech. Phys. 46, 153 (2005)] which suggest that a thick Cu surface will ionize when the imposed magnetic field reaches 1.5-3 MG. Measurements of the time-evolution of the surface temperature, Al expansion rate, and ionization state, as functions of applied field, significantly constrain the choice of models used in rad-MHD simulations.

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