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Dynamics of Audio Square Wave Plasmas: Insights for Plasma Cleaning of Vacuum Diode Electrodes

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The Z machine is a high-current pulsed-power generator located at Sandia National Laboratories capable of delivering 100-ns, 30-MA current pulses to a variety of targets. Under certain conditions, however, a significant fraction of the current does not reach the load but is shunted across the inter-electrode vacuum gap that leads to the load. That undesirable current loss is believed to be due to neutral desorption from the heated electrodes that are then ionized, forming an electrode plasma that flows into the vacuum gap. Much past work on vacuum diodes have shown positive effects of various in-situ conditioning techniques in improving diode performance, including cryogenically-cooled electrodes, surface coatings, discharge cleaning, and electrode heating.

Due to the operation and scale of Z, an in-situ discharge cleaning approach was chosen for electrode conditioning. Implementation focuses on cleaning the convolute and final feed regions where majority of current loss is observed to occur. A novel approach of generating the cleaning plasma using a bipolar audio square wave (ASW) was developed and compares favorably with the conventional method of radio-frequency (rf) generation. Optical emission spectroscopy of the two plasmas reveals higher-intensity emission in the UV/visible range for the ASW plasma comparing to the rf plasma at comparable powers. Data suggest that the electron energy is higher for the ASW plasma leading to higher ionization, resulting in increased ion density and ion flux to surfaces. Laser absorption and laser-induced fluorescence (LIF) measurements reveal intriguing dynamics for the ASW plasma and provide insights for further optimization. Preliminary modeling efforts suggest that the low-frequency polarity switch causes a much more abrupt potential variation to support interesting transport phenomena, generating a "wave"of higher temperature electrons leading to more ionization, as well as "sheath capture"of a higher density bolus of ions that are then accelerated during polarity switch.

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