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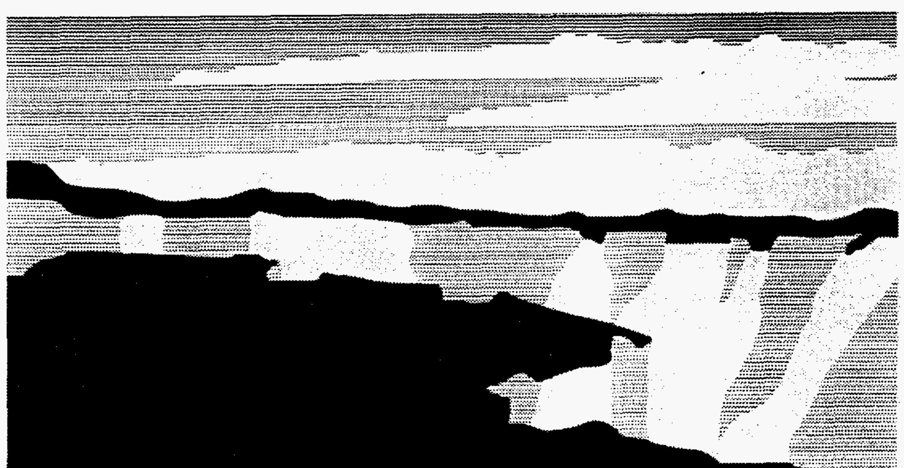

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CATHODIC ARC MODULATOR SYSTEMS FOR METALLIC PLASMA ION IMPLANTATION

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ABSTRACT

This paper describes the electrical design and operation of a cathodic arc modulator system for metallic plasma ion implantation. Depending on the ion implantation process recipe, various repetition rates, pulse widths, and currents are required. In addition, the cathodic arc system may be synchronized with a higher voltage "target" modulator system. The cathodic arc is water cooled and usually uses a self generated axial B-field, by use of a series connected solenoid around the arc anode. Typical arc currents of 800 amperes may be utilized with pulse widths ranging from 20 uS to 4 mS. Typical PRF's may exceed 400 Hz, with overall system power limited by our presently available 10 kW transformer-rectifier. The cathodic arc modulator system consists of a command charged 10 kV trigger generator, a high voltage arc "starter", and a low voltage, high current arc sustain circuit. The arc start and sustain circuits are independently adjustable and utilize a common IGBT device in a "hot-deck" configuration. This paper will provide circuit design and performance information in addition to various process applications.

MODULATOR DESIGN

To synchronize the arc with a target implant modulator, reliable and predictable triggering and arc sustainment are required. The arc voltage will vary as compared to a true vacuum metallic arc (30 to 50 V) due to magnetic field and possible additional plasma background process gasses. A recipe step may or may not use additional background plasma gases, such as oxygen, to implant metallic oxides (ceramics). Depending on process recipe, various axial field coils may also be used, smaller coils (lower inductance) may be used for short pulse application for metallic interface layer implants. Independently adjustable high-voltage arc start and low-voltage arc sustain circuits are used as shown in Figure 1 for operational flexibility. Figure 2 is a diagrammatic representation of the cathodic arc. The arc sequence is initiated by switching the IGBT hot deck. In a few microseconds, depending on the axial field coil, the anode-cathode arc gap is charged to the arc start voltage (~500 V). The arc is triggered and the discharge limited to ~100 amperes by the start circuit swamping resistor. After a few tens of microseconds, the isolating diode is forward biased and the low voltage arc sustain circuit provides the remaining pulse energy. A low resistance in the IGBT hot deck limits the current switched by the arc sustain circuit. A high voltage arc system would trigger reliably, but be inefficient in operation. A low voltage arc system is difficult to trigger reliably and with little jitter. This simple design has proved reliable and flexible with machine operations with typical voltage and current waveforms as shown in Figures 3 and 4. A photo of a filtered carbon cathodic arc for diamond deposition is shown in Figure 5.

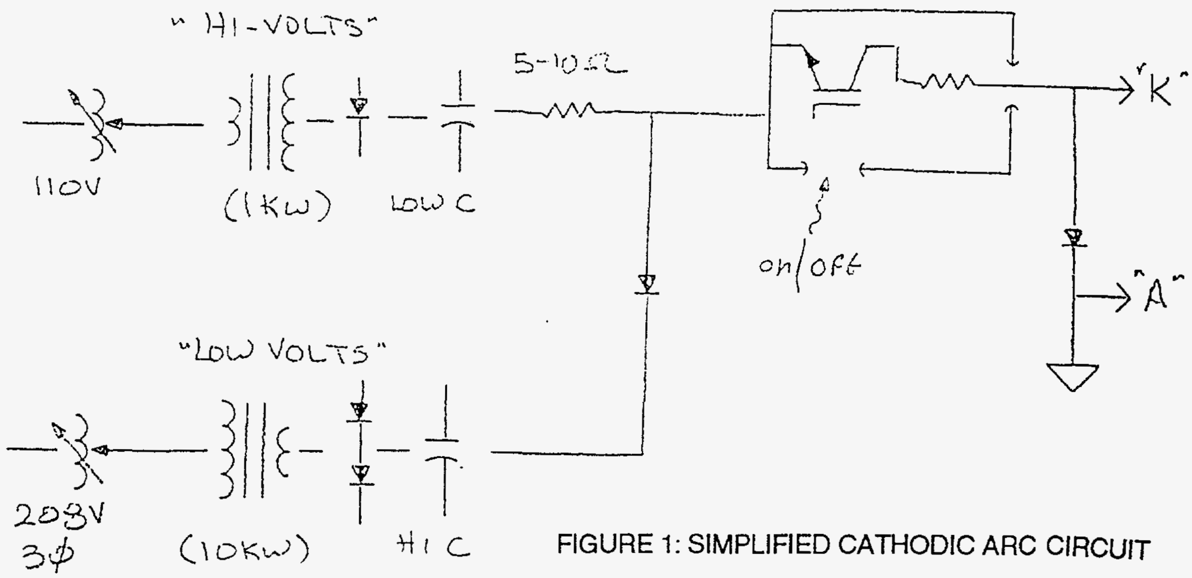

FIGURE 1: SIMPLIFIED CATHODIC ARC CIRCUIT

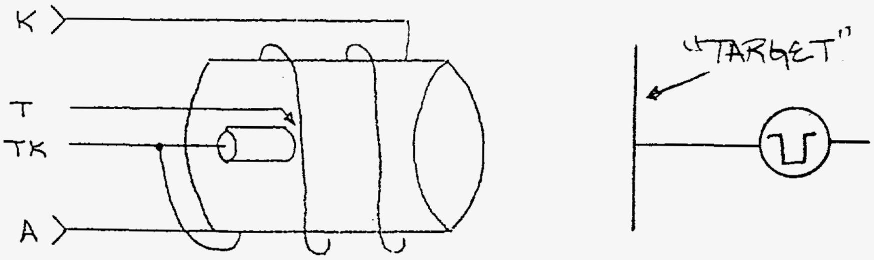

FIGURE 2: CATHODIC ARC WITH TARGET MODULATOR

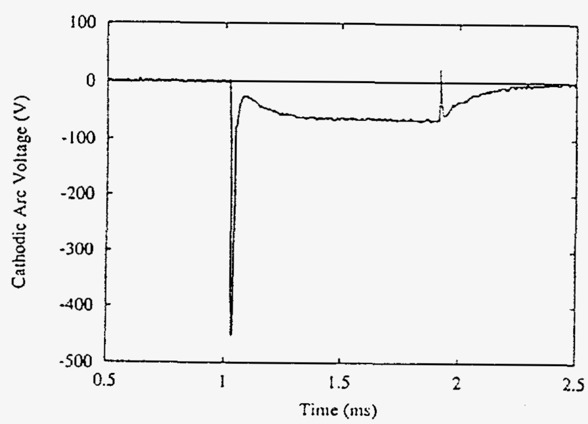

FIGURE3: ARC VOLTAGE

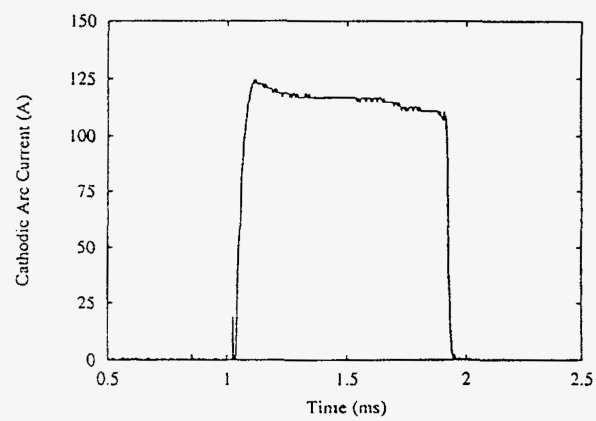

FIGURE4: ARC CURRENT

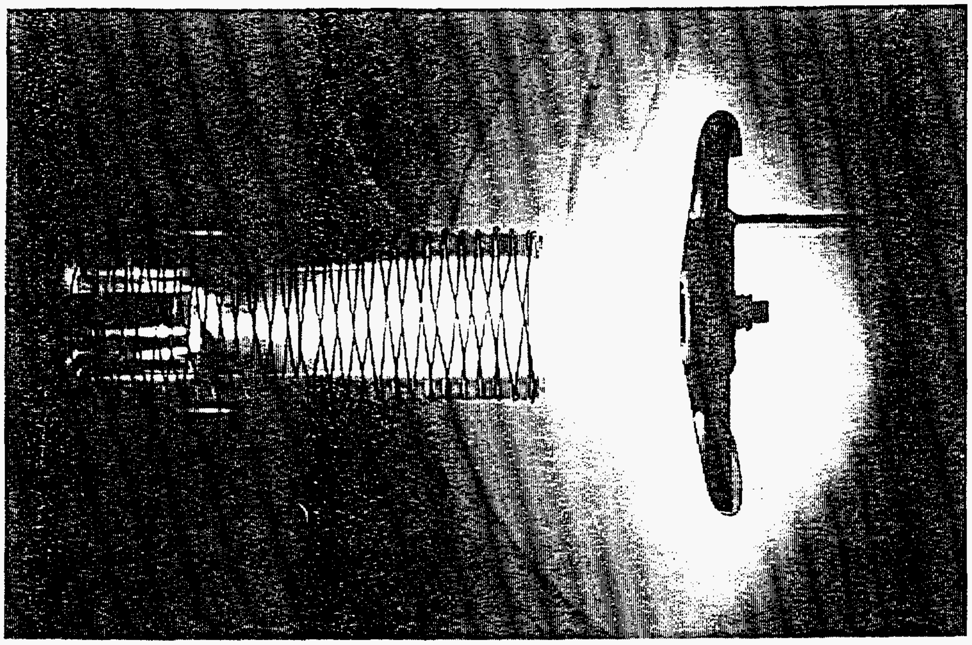

FIGURE5: FILTERED CARBON CATHODIC ARC

PROCESS REQUIREMENTS

Significantly different operational regimes are required for the cathodic arc depositions depending on the process recipe. To form adherent coatings, an interface layer is usually required. A typical Los Alamos ceramic coating process (patent applied) would first implant a metal stitching layer, then an ceramic interface layer, and finally build the adherent ceramic coating. For the stitching layer, short arc pulses are required (~20 uS) to match the typical HV implant pulses (20 - 50 kV) of the target modulator. The cathodic arc and target modulators are operated synchronously. Long arc pulses would be akin to "over-spray", the arc would lay down on the target surface with little or no energy, and create delamination problems. Once the "stitching" material has been implanted, an interface layer would be added by operating the cathodic arc and target modulator identically (short pulse), except now an oxygen plasma has been added to implant a metal oxide (ceramic). To grow a ceramic coating quickly, long arc pulses are utilized in an oxygen plasma. Low voltage target modulator pulses are used with the systems operating asynchronously. Figure 6 shows a ceramic coating after extremely severe impact testing. Cracks in the .3 micron range can be observed, but no delamination has been observed to date.

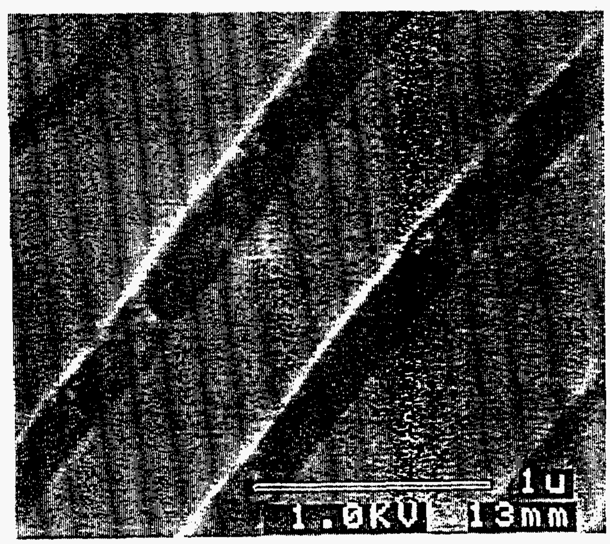

FIGURE 6: VARIOUS MAGNIFICATIONS OF CERAMIC COATING
NOTE DIFFERENT SCALES

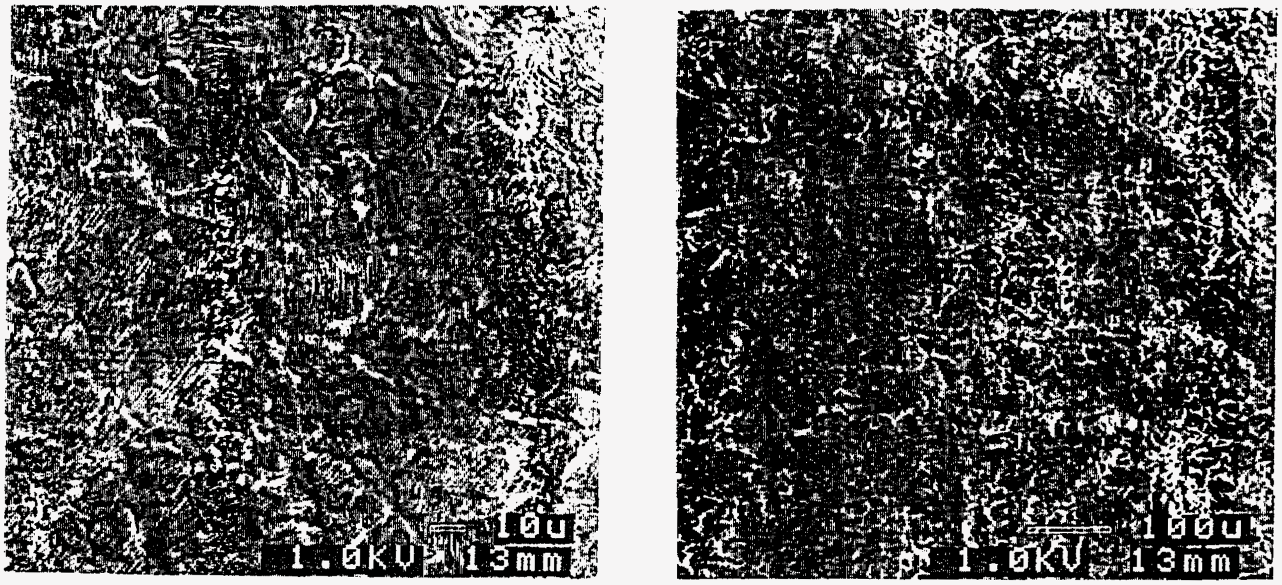

FIGURE 6: VARIOUS MAGNIFICATIONS OF CERAMIC COATING
NOTE DIFFERENT SCALES

CONCLUSION

Plasma processing is a modulator intensive technology. Many new applications and recipes are being developed to meet many military, consumer, and industrial applications. Modulator techniques for cathodic arc processing are simple and could be easily assimilated by industry once process recipe and material performances are determined. Los Alamos will continue to work with industrial and military researchers to identify and develop environmentally consious and advanced material process techniques.