

Title: PROGRESS TOWARDS A 20 KV, 2 KA PLASMA SOURCE ION
IMPLANTATION MODULATOR FOR AUTOMOTIVE
PRODUCTION OF DIAMOND FILM ON ALUMINUM

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PROGRESS TOWARDS A 20 KV, 2 KA PLASMA SOURCE ION IMPLANTATION MODULATOR FOR AUTOMOTIVE PRODUCTION OF DIAMOND FILM ON ALUMINUM

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INTRODUCTION

This paper provides the process requirements and the electrical design topology being developed to facilitate large scale production of amorphous diamond films on aluminum. The patented recipe, that includes other surface modification processes, requires various operational voltages, duty cycles, and current load regimes to ensure a high quality film. It is desirable to utilize a common modulator design for this relatively "low voltage" recipe. Processing may include target part cleaning, ion implantation, plasma deposition, and vacuum chamber cleaning. Modulator performance will have a direct impact on plant size and system economics. Unfortunately, process requirements are in a regime that is not easily achievable by solid state or very efficiently by vacuum tube devices.

To accommodate the various process requirements, we are developing a modulator based on series connected hot decks utilizing high current, high voltage IGBT devices. Although some manufacturers have released 2500 volt devices, we have chosen the 400 ampere, 1700 volt devices, for this first development, because of their superior switching performance. To protect the IGBT's from voltage transients, in addition to the typical (internal) back swing and output freewheel diodes, individual IGBT varistors and snubbers are utilized in combination with an output fault limiting resistor. Power to each hotdeck is provided by a low capacitance isolation transformer with I/O via fiber optics. To ensure appropriate IGBT gate control, a tailored 50 amp driver with a complementary outputs is utilized. To ensure IGBT safety margin and minimize system ringing, a series output resistor limits hard faults two times the IGBT's continuous rating. The intent is to ensure reliability of the switching system, regardless if the protect system fails.

Adjustments in system voltage are accommodated by phase control of the transformer-rectifier. For vacuum chamber cleaning, polarity reversing switch are required.

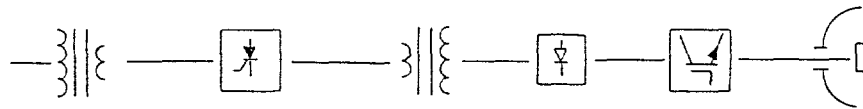
A review of the system requirements and design approach will be presented in addition to test results.

SYSTEM CONFIGURATION

To rapidly commercialize this plasma processing procedure, maximum use of utility and commercial equipment will be utilized, as shown in Figure 1. A reverse connected 3Ø utility transformer will provide the 20 kV for the implant procedure. A phase controller will provide adjustment in process voltage. For low voltage deposition (few kV) a tap changer may be required to maintain a good power factor (not presently included). A flexible system may be configured as shown in Figure 2. A switch box, in combination with internal modulator polarity switches, can be used to clean the process vacuum chamber with it's associated cleaning electrode. A high voltage step-up transformer may also be used for the typical 100 kV nitrogen implant process. Figure 3 shows the simplified block diagram of the IGBT hot deck with polarity reversing switches. This first Los Alamos construction will not use reversing switches, cables will be manually changed to reverse polarity.

IGBT SERIES SWITCH DECKS

Twenty series connected hotdecks are connected as shown in Figure 4. Power to the individual hotdecks is provided by low capacitance windings wound on a common core. To limit and equalize transient and static IGBT voltages, each hot deck has a low inductance RC snubber and varistor. Leakage current is absorbed by an output "pull-down" resistor (not shown on Fig. 4). The pulldown resistor is chosen to limit the plasma inter-pulse voltage to ~50 v to prevent sputtering and deposition. Although one may not absolutely require RC snubbers, the author believes they may be beneficial as varistors can have poor time response characteristics (10-100 nS) in the regime



13.8 kV to 480 V (3Ø) PHASE CONTROLLER 480 V to 13.8 kV (3Ø) RECTIFIER SOLID STATE INPLANT OBJECT
 UTILITY LINE INPUT (VOLTAGE ADJUSTMENT) (REVERSE CONNECTED) (AC TO DC) PULSE MODULATOR
 (UTILITY) (COMMERCIAL) (UTILITY) (COMMERCIAL) (CUSTOM)

FIGURE 1: MODULATOR POWER SYSTEM BLOCK DIAGRAM

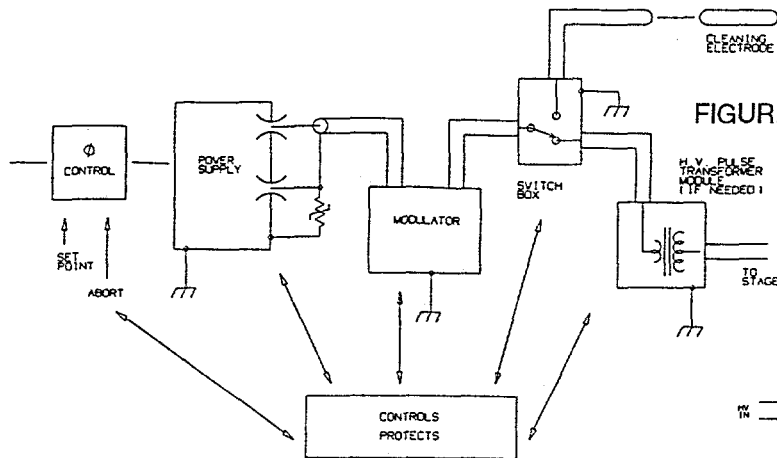


FIGURE 2: MODULATOR SYSTEM DETAIL

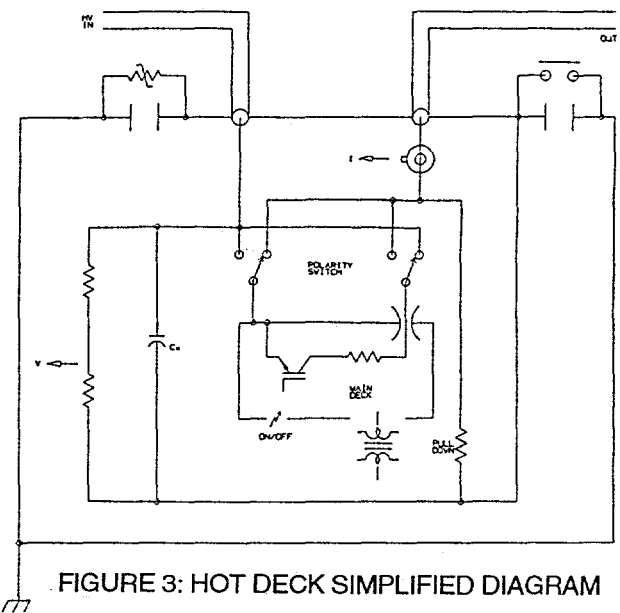


FIGURE 3: HOT DECK SIMPLIFIED DIAGRAM

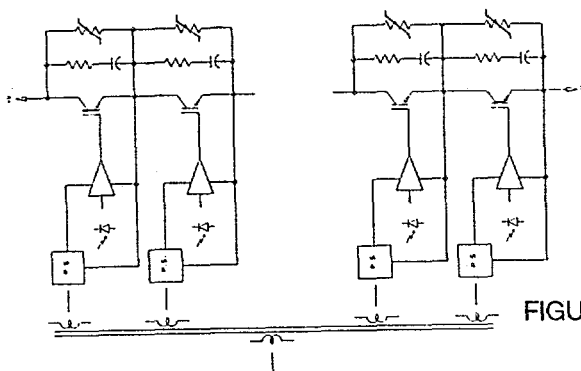
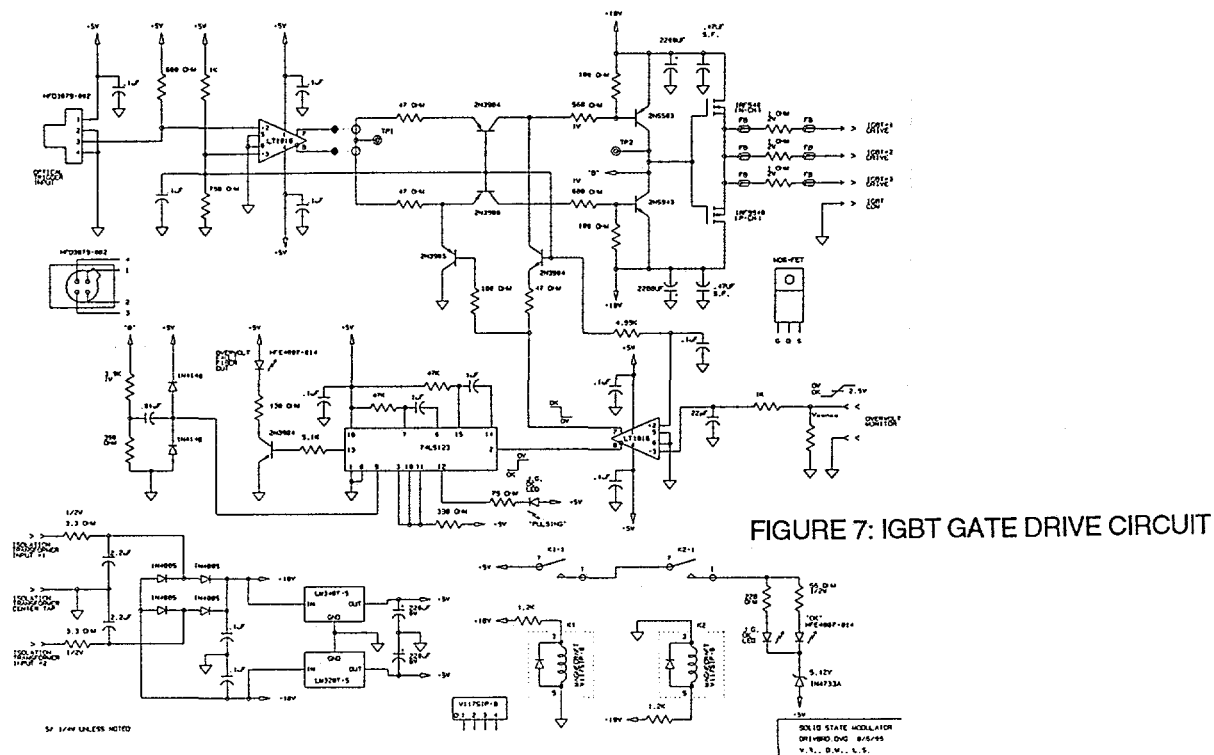
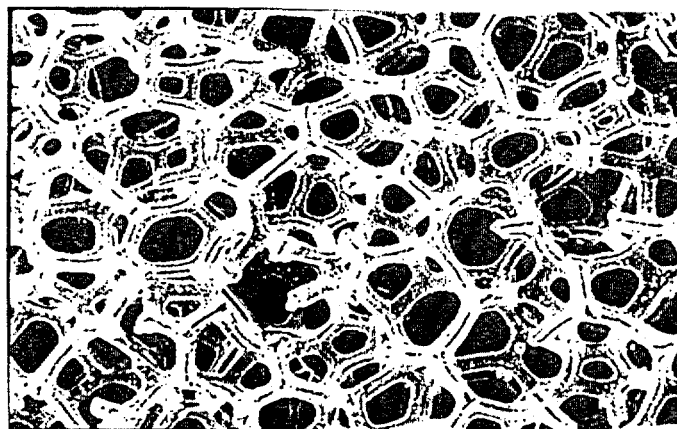
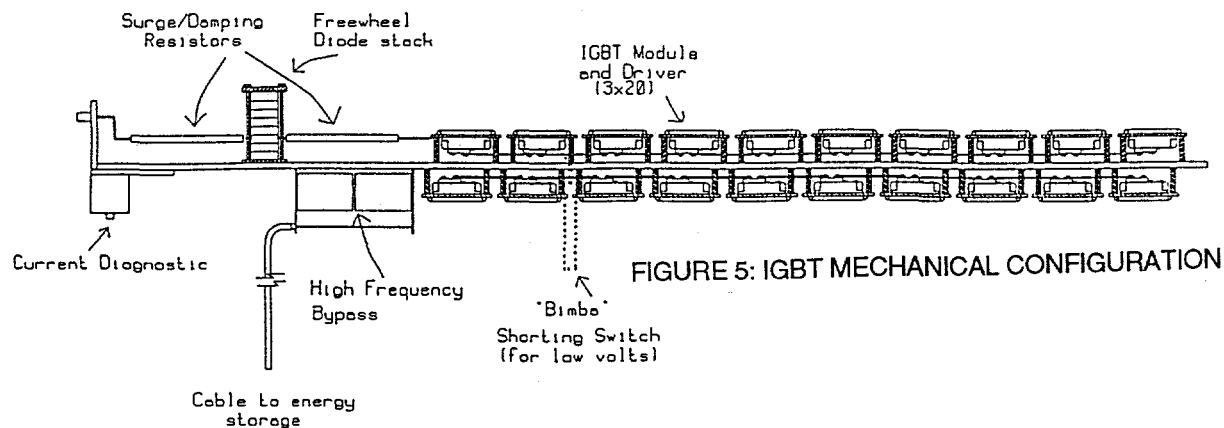


FIGURE 4: SERIES IGBT CONFIGURATION



that may cause IGBT's to latch or over-volt. Computer modeling has shown transient loads and inherent differences in device and driver time delays can cause device over-voltage (and failure). All protection methods may be necessary to prevent IGBT device failure. To limit transient voltage and fault current during the frequent plasma arc-downs, output resistance is required to limit varistor excursions and protect the IGBT's. Large diameter varistors have a lower AC impedance and a more effective clamp voltage, but limits in varistor dynamic range are still required. A 20 series stack gives a 34 kV voltage compliance, with each deck having 3 parallel devices, a 1200 ampere continuous rating is obtained. The mechanical configuration will be implemented as shown in Figure 5. The IGBT hot decks form a parallel plate transmission line on each side of the ground return buss.

SNUBBER AND SERIES DAMPING RESISTORS

To help protect each transistor from voltage transients, low inductance snubbers will be used. Additionally, at high rep-rates, high power dissipation is also required (~400W at 2 kHz). We are developing two styles of water cooled IGBT snubber resistor. A new material "Reticulated Vitreous Carbon" (RVC) shows extreme promise. RVC is a glassy carbon available with various porosity, ligament diameter, and density. Resistivity can be chosen to optimize a design. The range of resistivities fall between that of "granular" carbons (as used in glo-bar or disc devices) and metals. Los Alamos has tested these devices to 15 kA/cm², 850 kA, and 130 J/cc. The resistance is not affected by oil or water and should be capable of "infinite" power dissipation due to "infinite" surface area. The glassy RVC is continuous from end to end and does not suffer from grain boundary problems as typical organic and ceramic carbon resistors. We are also examining the use of stainless steel gauze as a resistor element in the snubber networks. Our only consideration for an output fault limiting resistor at this time are RVC elements. Figure 6 shows the composition of the RVC material.

IGBT GATE DRIVE

Los Alamos has developed and tested a number of IGBT gate drive circuits. The author felt currently available gate drive modules have insufficient drive current for parallel networks of large IGBT devices. Any design must be cognizant of thermally induced timing drift and delay. Saturated switching circuits can be very sensitive with temperature due to storage delay effects. Circuit modeling shows over-voltage conditions (without protection) with differences as little as 25 nS in a series stack. We have also slowed down our 50 amp output gate drive switching speeds, to 120 nS Tr & Tf, to reduce the probability of IGBT latch-up and reduce turn-off transients. We found excessively fast IGBT gate fall times (in excess of IGBT "Ic" fall) can induce latch-up in some manufacturers devices. The gate drive board mounts directly to the IGBT's to minimize wiring inductance and improve reliability. The schematic is shown in Figure 7, and is capable of driving three IGBT's. The fast over-voltage protect will not be utilized "on board".

CONCLUSION

The system as described is presently being fabricated and will assume operational capabilities in early 1997. Many additional sub-systems such as polarity reversal and chamber cleaning process procedures will then be able to be further evaluated. For the amorphous diamond process to be successful, the automotive industry will require very reliable modulator systems that can be maintained by the average electronics technician. We believe this first effort is capable of meeting these goals.

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