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**HIGH-DENSITY PLASMA SOURCE FOR
LARGE-AREA CHEMICAL VAPOR
DEPOSITION OF DIAMOND FILMS**

Principal Investigator

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Contract Dates: September 30, 1994 to March 30, 1995

Reporting Period: December 1, 1994 to December 31, 1994

Contract No. N00014-94-C-0199

Prepared for
Scientific Officer
Attn: Max Yoder
Office of Naval Research
Ballston Tower One
800 North Quincy Street
Arlington, VA 22217-5660

January 27, 1995

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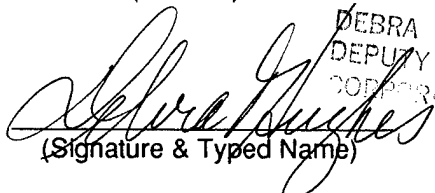
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HIGH-DENSITY PLASMA SOURCE FOR LARGE-AREA CHEMICAL VAPOR DEPOSITION OF DIAMOND FILMS

MONTHLY REPORT

Overview

During this program Science Research Laboratory (SRL) and the Plasma Processing Group in the Department of Chemical Engineering at MIT are developing a large-area, directed plasma/atomic beam source for diamond deposition. The plasma source is based on an inductively-driven plasma accelerator that efficiently produces a high density (10^{14} - 10^{17} cm⁻³) plasma over an area of 0.1-1 m². The goal of this effort is to experimentally demonstrate the technical feasibility of employing the plasma source for high-throughput diamond deposition, through characterization of plasma parameters and preliminary diamond deposition experiments. A reactor design study will also be completed during Phase I, leading to an engineering design of a large-area plasma reactor for Phase II implementation. The period of performance is from 30 September 1994 to 29 March 1995.

December Progress

The preliminary activity during December was the construction of the plasma beam reactor and diagnostics. The plasma reactor is based on an inductively-driven, large area plasma accelerator that is funded under a separate electric thruster program. Because of previous funding delay on that program, intensive effort was made to accelerate the construction of the plasma beam source. This plasma source consists of a 100-joule-per-pulse, 1 kilopulses-per-second driver, an inductive plasma acceleration coil, a gas handling system and a vacuum system. During December, fabrication of the pulsed driver components has been completed and assembly of the driver has begun. Construction of experimental stand and vacuum system was also completed. The fabrication of the high-voltage, low-impedance vacuum electric feedthrough was underway. The reactor backplate design, including heated molybdenum wafer substrate, has been submitted

for fabrication at the end of December with completion expected by the end of January. Tests of the optical emission spectrometer (OES) and thermal couple hydrogen atom detector were made on an existing microwave plasma reactor at MIT. Both of these analytical devices will be incorporated into the backplate of the reactor under construction at SRL. The measurements with the microwave plasma serve as calibration for the large scale experiments. The induction coil cooling unit was also fabricated and tested successfully.

During this month, however, delay occurred on the fabrication of the 20-cm diameter induction coil that is to be used to breakdown and drive plasma discharge. The manufacturer of the coil had difficulty in eliminating the stress on the glass substrate during fabrication. These coils were to be clad onto a thin glass substrate and etched to required patterns and dimensions. After etching, however, the glass substrate cracked when the completed, cooled coils were submerged into cleaning solution to remove etchant and mask. The same failure occurred on a second coil substrate. The cause of this failure is likely the mismatch between thermal expansion coefficients of copper and glass substrates. Since the processes of adhering and etching were at elevated temperatures and involved compressional forces, stresses were generated in the substrate which would cause the failure when temperature was changed. To overcome this problem, SRL has taken the following two steps. First, an epoxy-based substrate with thermal expansion coefficient better matching that of copper has been fabricated in a test run. The epoxy for this substrate is a high thermal conductivity epoxy that has a thermal conductivity twice that of stainless steel. The same material has been used in fabrication of induction coil cooling unit and has shown good mechanical strength. The 0.06-in thick substrate fabricated in the test run was subjected to thermal shocks from -25°C to 100°C in a few seconds and it had performed satisfactorily. A full-sized mold for casting the coil substrate has been designed and submitted for fabrication with completion due by the end of January. The substrate and coil will be casted at SRL as soon as the mold arrives. Glass fiber will be mixed into the epoxy to further enhance the mechanical strength of the substrate.

Besides the above approach, SRL has ordered two more sets of glass substrates made of soft glass with high thermal expansion coefficient and better mechanical properties. The thickness of the glass substrate has been increased from 0.06 inch to 0.09 inch. Delivery of these glass substrates are expected in the last week of January. Should the casted coils not perform satisfactorily, another attempt on glass-based coil fabrication will be made immediately.

Request for No-Cost Extension

SRL and MIT plasma processing group would like to request a 30-day or 60-day no-cost extension on this Phase I STTR program if this will no interfere with the Phase II review process. As mentioned above, the objective of this program is to demonstrate the technical feasibility of employing an large-area, high intensity plasma source for high-throughput diamond deposition, through characterization of plasma parameters and preliminary diamond deposition experiments using a plasma source developed at SRL for space propulsion under a Phase II BMDO SBIR. Due to funding delay of the BMDO program, the Phase II SBIR started in August 1994 instead of August 1993 as originally planned. This starting date is nearly the same as when this Phase I Navy STTR stated. SRL has accelerated the BMDO program on construction of the plasma source, including the 100-kW average power pulsed driver, with a target completion date of January 30, 1995. Most parts of the fabrication went smoothly. These include the fabrication of the pulser, the vacuum system, plasma probes and other diagnostics. However, as discussed earlier, the fabrication of the plasma-driving induction coil has experienced difficulties. Also, the delivery of high voltage capacitors for the third statge of the pulse compression chain is delayed until February 10, 1995. As a result, the operation of the plasma source will be delayed to middle to late February. This would reduce the experimental time of this STTR program to less than one month if this program has to be completed by 29 March 1995. In order to obtain sufficient data to demonstrate the suitability of this inductively-driven, high-intensity plasma source for large-area diamond film deposition, we request a no-cost extension of 30 or 60 days so that more detailed plasma characterization and diamond deposition experiments can be performed.