Diagnosis of large volume pulse modulated Ar-H2 plasmas

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2D06

Two Color Fiber Optic Interferometer for Gas and Plasma Density Measurements

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A 2-color, 4-beam Fiber Optic Interferometer (FOI) with $\sim 10^{-4}$ wave sensitivity when sampled at 1 μs intervals is being built to measure gas and plasma densities. The final instrument will be completed under a 2 year SBIR contract; initial results from one beam of the instrument will be presented. The FOI uses 1310 nm and 1550 nm CW diode lasers and is contained in a ~6" x 17" x 17" volume, which makes the system compact and portable. The two colors enable the FOI to measure neutral gas and plasma densities simultaneously [1], so that partially ionized plasmas can be characterized. The multiple beams in the complete instrument will allow rapid characterization of gases and plasmas, including the measurement of correlated density variations.

Neutral gas and electron density profile measurements have been taken as a function of time from a supersonic nozzle designed for z-pinch loads and a cable gun. The project goal sensitivity of $\sim 10^{-4}$ wave will allow simultaneous measurement of neutral and electron density-length integrals down to $\approx 6 \times 10^{15}$ Ar atoms/cm^2 and $\approx 7 \times 10^{13}$ electrons/cm^2. For a typical path length of 10 cm in nozzles or opening switch plasmas, these numbers correspond to densities of 6×10^{14} Ar atoms/cm^3 and 7×10^{12} electrons/cm^3. A description of the FOI and initial density measurements with sensitivity of $<10^{-3}$ of a wave will be presented.

1. B.W. Weber and S. Fulghum, Rev. Sci. Instrum. **68** (2) 1227 (1997).

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2D07

Diagnosis of Large Volume Pulse Modulated Ar-H2 Plasmas

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Diagnosis of Large Volume Pulse Modulated Ar-H_2 Plasmas

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Atmospheric pressure plasma in pre-mixed Ar/H_2 (Ar: 84% molar concentration) flow was generated experimentally at pulse-modulated approach. The plasma torch has a special kind of feature; the length of coil region is extremely large, 158 mm. Ratio of the coil length to coil diameter is about 3:2, which is usually opposite in the ordinary torch. This huge coil length should have caused high plasma region and thus, should be more suitable for materials processing. Pulse modulation of plasma helps to understand the changes of plasma responses with time, and thus, this technique is likely to be helpful to control the plasma energy and species concentration in time domain for better application of radio-frequency (rf) inductively coupled plasma (ICP). The numerical model [1], which used 2-dimensional field variations and was for optically thin and local thermodynamic equilibrium (LTE) considerations, revealed many characteristic properties of plasma for sudden change in active power of plasma. The model was found effective to predict different response times of plasma. Experimentally generated pulse-modulated plasma [2] reported on-time and pressure effects upon the atomic argon line intensity at 751 nm wavelength. Both works were for same torch configuration.

Our present work is to reveal spectroscopically measured results of the new ICP torch with large coil length. In addition, the ICP code of Ref.1 was changed for current pulsation and used in predicting ICP responses for the same operating conditions of experiment. Experimentally, the source side power was 30 kW before pulsation and thus, the plasma power would had around 25.6 kW considering 85% matching efficiency. Please note that the change of plasma power during pulsing period was not measured due to lack of facility. The rf power was pulse modulated by imposing an external pulsed signal to switch a MOSFET. The other operating conditions were: 760 Torr pressure, 85 slpm total gas flow rate, 0.45 MHz nominal frequency of the supply, 67% duty factor (10 ms on-time and 5 ms off-time), and 100 to 61.7% shimmer current level (SCL). Monochromated emission of atomic argon at 751 nm was detected and stored to see the pulse effect. The time constants for rising and falling time, measured with the help of current intensity after pulsation, were 0.114 and 0.054 ms respectively. Please note that these time constants are the measure of times required to reach the intensity from 10% to 90% and 90% to 10% of its final or steady-state value after the pulse-on and pulse-off, respectively. The same time constants, measured by atomic argon line intensity at 751 nm, were 4.6 and 3.6 ms respectively; and numerically these values were found as 4.99 ms and 4.44 ms respectively. The power level varied between 33 to 7 kW theoretically during the pulsing period and the coil current between 210 to 120 A. The coil current needed to produce the 25.6-kW plasma at steady-state before pulsation was 189.4 A.

[1] J. Mostaghimi, K.C. Paul and T. Sakuta, *J.Appl. Phys.*, **83**, 1898-1908 (1998).
[2] T. Sakuta, K.C. Paul, M. Katsuki and T. Ishigaki, *J. Appl. Phys.* [will be published in Feb. issue. 1999]