[99I] - ADVANCES IN DESIGN OF MICROWAVE RESONANCE PLASMA SOURCE

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Abstract:

ADVANCES IN DESIGN OF MICROWAVE RESONANCE PLASMA SOURCE

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Most applications of microwave power in industrial heating processes involve the use of relatively crude and inefficient microwave process cavities. However, recently the development of microwave technologies for a variety of new applications has led to novel designs of high efficiency resonant cavities. A microwave resonant cavity can be described as a resistant circuit element in a microwave network, where the frequency of resonance of the element is a function of its characteristic complex impedance. Our previous publications reported about exploitation of a single mode resonance cavity with a high efficiency for generation of microwave (MW) plasma at atmospheric pressure that was summarized elsewhere [1]. The microwave resonance plasma source (MRPS) of the TM01p single mode cylindrical cavity that was firstly published in 2001 [2] operates at atmospheric pressure as a plasma torch. The MRPS was designed assuming the resonant frequency of 2.45 GHz. This is the mode, which is characterized by an axially symmetric distribution of electric field strength. Predominantly, the single resonant mode cavities operating in the TM011 and TM013 were employed.
From that time a lot of applications of the microwave resonance plasma source were developed. The original design of the single mode resonance cavity was advanced. State of the art summarizing recent advances in design of the TM01n single mode cylindrical resonance cavity is presented here.
Different aspects of the MRPS design has been explored such as low pressure operation (~20 kPa), waveguideless microwave launch design, powder/liquid precursors feeding design, and variety of MW-power supply. The following sections summarize both the theoretical and experimental endeavors to explore these aspects.

Low pressure MRPS design
In order to treat polymer surfaces, a low temperature of plasma is required.

Lowering plasma temperature can be reached by reduction of operating plasma pressure. The low pressure was sustained by fore-vacuum pump with in 10-20 kPa. Gas precursors were injected through three injection ports by a throttle valve. Minimum temperature of ~500 K at the electron density of ~1012 cm-3 with argon precursor flow rate of ~3 ℓ/sec. This temperature is comparable with conventional plasma sources for polymer surface plasma treatment.

Transmissionless line microwave launch design for MRPS
Microwave plasma system utilizing high Q (quality factor) resonant cavities can be subject to difficulty in tuning, resulting in reduced operational stability and power coupling. Operators of such systems have experienced difficulty in tuning a load to maximize MW-power coupling and tuning instability once a match. The transmissionless line MRPS operates in a fixed configuration where there are neither coupling nor tuning mechanics and, therefore, a magnetron based microwave generator is not subjected to the long lines phenomenon. A magnetron matches directly to the MRPS. This transmissionless line design eliminates the need of building a microwave guide coupling to the MW resonance cavity in order to convert MW-power to the kinetic and thermal energy of plasma.
MRPS with high 6-kW power supply
The proposed design of the MRPS is capable to run over a wide range of power levels and mass flow rates as well as higher plasma temperature. The MRPS with high 6-kW power supply allows an enhancement of a flow rate of gas precursors from 3-5 ℓ/min to 50-100 ℓ/min. In this case, the MRPS can be commercialized as an industrial prototype for a variety of industrial applications.

MRPS operating with integrating launch design
A conventional power supply for the 6-kW magnetron based microwave generator is bulky block, which sometimes holds back promising applications of the MRPS. The integrating launch is intended for an increase of microwave power, which is going into the MRPS, using the
compact conventional 1-kW magnetrons with their squashed power supplies. This integrating launch design allows combination of the 1-kW magnetrons to supply a microwave power gradually increasing in factor of two, three, etc, i.e. 1-kW, 2-kW, etc. Thus, the MRPS operating
with integrating launch design allows operation at the multi-level MW-power.

MRPS operating with variable power supply
The MRPS operating with variable power supply is proposed for reduction of microwave power, which is directed into the microwave resonant cavity. Current piece of work is focused on
modernization of a compact power supply. Redesign of the conventional power supply allows for
lower plasma temperature operation. A variable power supply allows the function of the MRPS with MV-power less than 1 kW, i.e. in the range between 300 W and 1 kW.

Feeding design of powder/liquid precursors into MRPS
The design of the MRPS allows feeding of precursors, nomenclature of which spreads from gases through liquids to solids in form of powder. In order to realize the great potential of the MRPS, a special shape of nozzle as well as a direct feeding of precursors into the microwave plasma cavity was designed. The nozzle design provides to feed solid precursors in form of powder into plasma torch, avoiding a plasma slab in side of the microwave resonant cavity, that extend an utilization of powders such as polymers or plastics causing a degradation of powder materials.
Techniques to improve MRPS performance are discussed, including those for increased isolation, constant frequency operation and variable Q-factor. This demonstrates the flexibility that allows this MRPS to be integrated more easily into existing industrial lines without further extensive rebuilding of them.

REFERENCES
1. A.L. Taube and G.M. Demyashev “Microwave Resonance Plasma Source” (invited chapter)
– in: Wiley Encyclopedia of RF and Microwave Engineering, Editor-in-Chief: Kai Chang.
John Wiley & Sons, New York, 2004, (in press).
2. E. Siores, A.L. Taube, and G.M. Demyashev “TM013 resonance cavity microwave plasma
torch” – Proceedings of the IMPI’s 36th Annual International Microwave

Symposium. April
18-21, 2001. San Francisco, USA, p. 75-78.

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