SELF-ORGANIZED FILAMENTS, STRIATIONS AND OTHER NON-UNIFORMITIES IN NON-THERMAL ATMOSPHERIC MICROWAVE EXCITED MICRODISCHARGES

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ABSTRACT

Self-organized filaments, striations and other non-uniformities have been observed in atmospheric argon microdischarges sustained with a microstrip split-ring resonator microwave induced plasma (MSRR-MIP) source. The coplanar electrode structure of the MSRR-MIP source allows filaments to form both across and over the discharge gap.

In this paper, we report the self-arrangement of multiple filaments (Figure 1b-e) as well as striations (Figure 1f-h) and other non-uniformities (Figure 1i) in microdischarges generated in argon at atmospheric pressure. The microdischarges are generated with a microwave induced plasma (MIP) source based on a microstrip split-ring resonator (MSRR). The principle of operation of the microplasma source and the experiment set-up have been recently reported in [1]. In a MSRR-MIP source, the discharge is ignited in a gap formed between the two ends of a microstrip resonator. All the discharges shown in Figure 1 except for 1d were created with a MSRR-MIP source with a gap size of 120μm. Figure 1d was obtained from a device with a larger gap size of 500μm.

The pictures in Figure 1 were taken with a digital SLR camera (Canon EOS Digital Rebel) with a 1-5x macro lens (Canon MP-E 65mm). Due to the high intensity optical emission of the discharges, the plasma source is not visible in the pictures, even though the pictures were taken with the lab lights on. For clarity, however, the borders of the microstrips (electrodes) have been drawn in white on the pictures.

Self-organization and pattern formation have been previously observed in DC [2] and dielectric barrier (DB) [3] micro-scale discharges. To the best of our knowledge, however, this is the first time that this phenomena is reported in a microwave excited microdischarge.

The number of filaments in the discharge increases with input power (Figure 1 b-c). Filaments self-arrange equidistantly (Figure 1) along the gap. The mechanism responsible for the self-arrangement is not well established at this time. Opposite to what happens in the DC discharge reported in [2] at intermediate pressure (75-200 torr) where the pattern formation is only obtained with decreasing powers, *i.e.* the patterned discharge extinguishes when the power is increased, in a MSRR-MIP the power can be increased and decreased without extinguishing the plasma. In that sense, the behavior is similar to that of a dielectric barrier discharge [4]. The physics underlying the filament and pattern formation in a MSRR-MIP, however, must be different from those responsible for the filament and pattern formation in DC and DB discharges. For example, in a MSRR-MIP source the sheath voltage around the electrodes (microstrips) is only on the order of 10V [1] and despite high luminesce that is reminiscent of an arc, the discharges are found to be close to room temperature ($T_{rotational}$ ~ 400K) [5]. Therefore, conditions are quite different from those occurring in the glow-to-arc transition in DC microdischarges. In a MSRR-MIP the plasma is in direct contact with the conducting electrodes, eliminating the possibility for non-uniform charge distributions such as those responsible for the formation and arrangement of short-lived filament structures in DB discharges. Furthermore, sustaining voltages in a MSRR-MIP are on the order of 35V, which are much smaller than those required in DC and DB discharges.

The coplanar electrode configuration in a MSRR-MIP source allows filaments to form both in-between and over the electrodes (Figure 1d-e). The preference of one geometry over another seems to depend on the gap size, the gas chemistry and contamination on the electrodes.

Occasionally, striations form along the filaments (Figure 1f-h). Striations have been observed in other non-thermal low-pressure plasma discharges but we are not aware of striation observation in atmospheric filamentary microdischarges. Striations, when formed, occur in all the filaments simultaneously and appear "stable", i.e. non-traveling.

Figure 1i shows a discharge where bright spherical domains of ~100µm in diameter have developed between filamentary discharges. Gas contamination arising from the polymer and epoxy used in attaching a glass tube around the source [1] is believed to play an important role in the formation of striations and localized bright domains.

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FIGURE CAPTIONS

Figure 1.- Atmospheric pressure discharges (Figures b-i) generated in argon with a microplasma source based on a microstrip split-ring resonator (figure a) operating at ~900MHz.

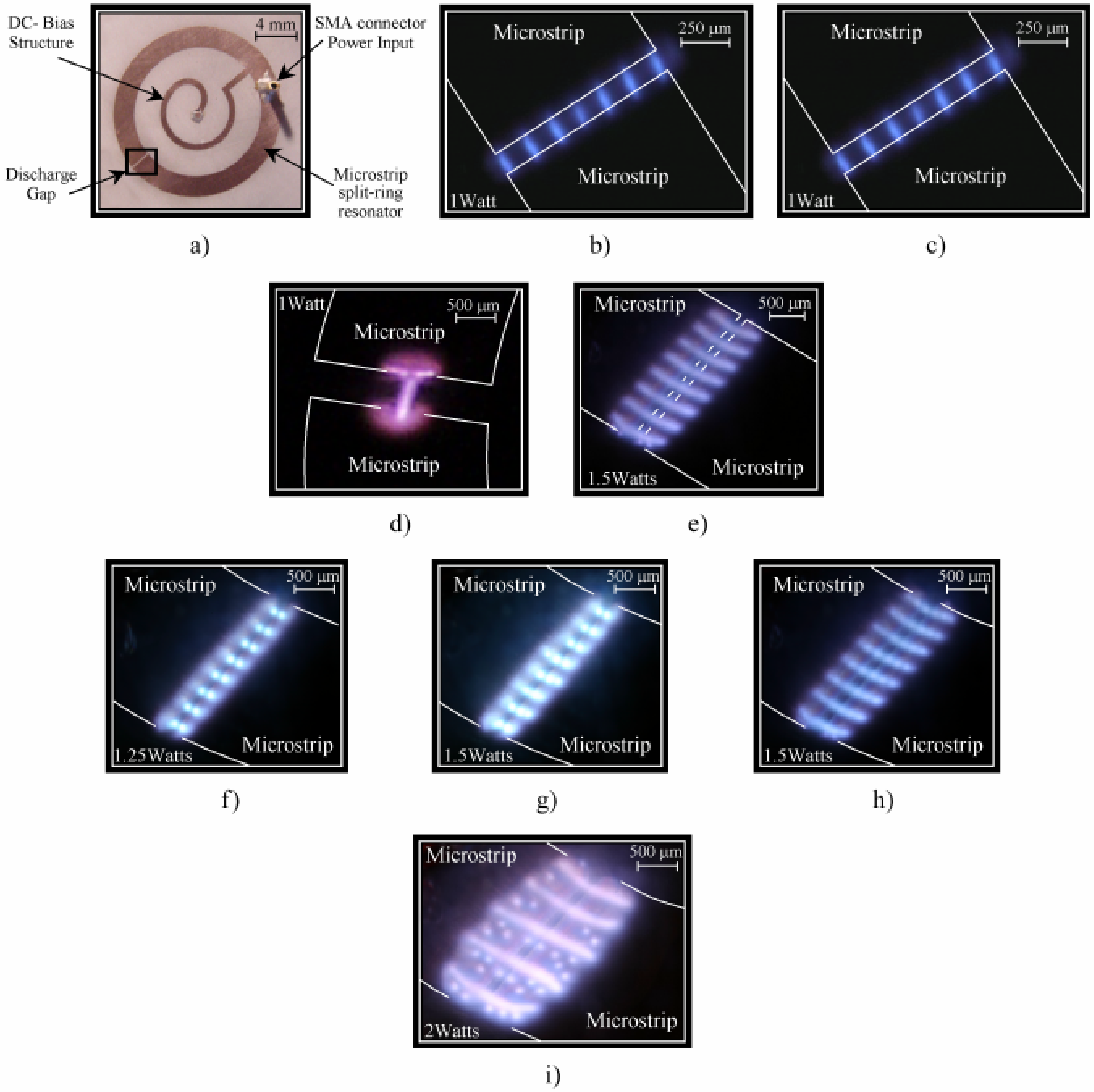

Figure 1.- Atmospheric pressure discharges (Figures b-i) generated in argon with a microplasma source based on a microstrip split-ring resonator (figure a) operating at ~900MHz. Scale bars and input power displayed on pictures.