Nanosecond pulsed discharges: generation, measurement and plasma processing

T. Huiskamp[1], F.J.C.M. Beckers[1], E.J.M. van Heesch[1], W.F.L.M. Hoeben[1] and A.J.M. Pemen[1]

[1] *Eindhoven University of Technology, Electrical Energy Systems Group, Department of Electrical Engineering, Eindhoven, The Netherlands (t.huiskamp@tue.nl)*

In this contribution we report on our recent progress in generating and measuring nanosecond pulsed discharges for plasma processing applications. The nanosecond pulses are generated by a single-line pulse topology which is able to output 0.5-10-ns, positive and negative 0-50-kV pulses with a rise time of less than 200 ps at a pulse repetition rate of 1 kHz. With D-dot and B-dot sensors and spatiotemporal resolved iCCD imaging we monitor voltage and current waveforms and the development of the streamer discharge. In addition, we perform several plasma processing experiments. The results show extremely high yields in ozone generation and NO removal. A general conclusions is that the shortest rise time pulses result in the highest plasma processing yields and the highest streamer velocities.

1. Introduction

It has been known for some time that pulsed discharges result in high plasma processing yields. In this project we developed (sub)nanosecond pulsed power technology to explore this further.

2. Technology

The nanosecond pulse technology consists of an adjustable, microsecond charged, pulse forming line, switched by a fast oil spark gap, that outputs 0.5-10 ns, ±0-50-kV pulses with an adjustable rise time with a minimum of less than 200 ps (example in Fig. 1) [1]. In addition, we developed high-frequency D-dot and B-dot sensors to measure the (sub)ns pulses [2].

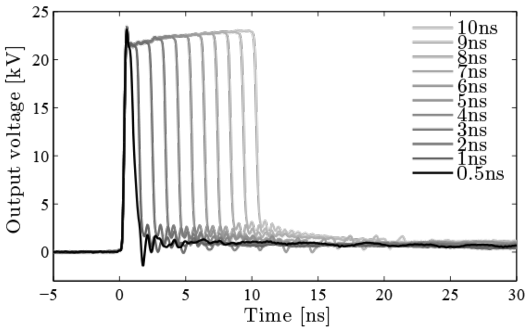

Fig. 1 Example waveforms of the ns pulse source.

3. Transient plasma interaction

In this topic we first studied the energy transfer from the pulse source to the highly dynamic plasma load with the result that we can achieve a very high energy transfer (over 90 %) [3]. Second, we studied the development of the streamer discharges in the plasma reactor with spatiotemporally resolved iCCD imaging [4]. The conclusion from the imaging results is that the development of the streamers is a complex interaction of the length of the plasma reactor and the local voltage in the reactor as a result of the propagation and attenuation of the very short nanosecond pulses.

4. Plasma processing

Finally, we studied ozone generation and NO removal with the nanosecond discharges and found that the shortest rise-time pulses result in the highest plasma processing yields (at the cost of high by-product formation). Figure 2 shows an example. The maximum obtained ozone yield was 190 g/kWh in air and the maximum NO removal yield was 2.5 mol/kWh.

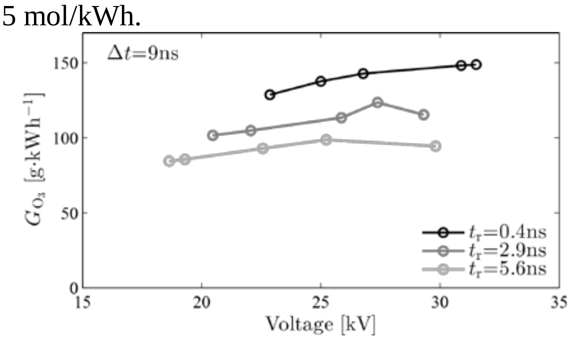

Fig. 2 O_3 yield for 9-ns pulses with different rise times.

5. References

[1] T. Huiskamp *et al.*, IEEE T. Plasma. Sci, **43** (2015) 444-451.

[2] T. Huiskamp *et al.*, IEEE Sens. J., **16** (2016) 3792-3801.

[3] T. Huiskamp *et al.*, Plasma Sources Sci. T., **25** (2016) 054006.

[4] T. Huiskamp *et al.*, Rev. Sci. Instrum., **87** (2016) 123509.