Topic number: 5

TIME RESOLVED SPECTROSCOPY OF HIGH POWER PULSED MICROWAVE DISCHARGE IN NITROGEN

Jaroslav Hnilica, Vít Kudrle, Petr Vašina

Department of Physical Electronics, Masaryk University,
Kotlářská 2, CZ-61137 Brno, Czech Republic
yaryk@mail.muni.cz

Introduction

Main advantages of pulsed microwave discharges are the lack of electrodes, ability to control the processing plasma by additional parameters like pulse duration and repetition frequency along with the pulse amplitude in order to increase effective production of various types of charged and excited particles in plasma.

Although there are many studies of pulsed discharges, they have mostly used common supplies like dc, radiofrequency, microwave, with relatively low peak power (10^2 – 10^3 W). However, in this work we use very short pulses with peak power around 10^5 W. The conditions in this type of plasma are substantially different from the common case. Such high power input produces highly non-equilibrium plasma containing energetic electrons, highly excited species, metastables, radicals etc., which can be advantageous for many plasmachemical applications. Such information can be important in radar systems, which work in high altitudes (i.e. low pressure), where microwave breakdown often limits the maximum usable radar power or the maximum pulse length [1].

We continue in our previous works [2, 3, 4, 5] focused on nitrogen plasma. In presented work we can use our new spectrometer equipped with ICCD. We carried out a time resolved diagnostics of high power pulsed microwave plasma operating at reduced pressure with this equipment.

Experimental set-up

We have developed the apparatus with suppressed plasma–wall interaction. Plasma is produced in spherical glass vessel with inner diameter of 0.5 m, on one side covered by reflective foil, which reflects and focuses the microwaves radiated on opposite side by horn antenna. Microwaves with 3 cm wavelength (X-band) are generated by radar magnetron (peak power reaches 80-100 kW). The pulses have duration 2.25 μs and are repeated 400 times per second.

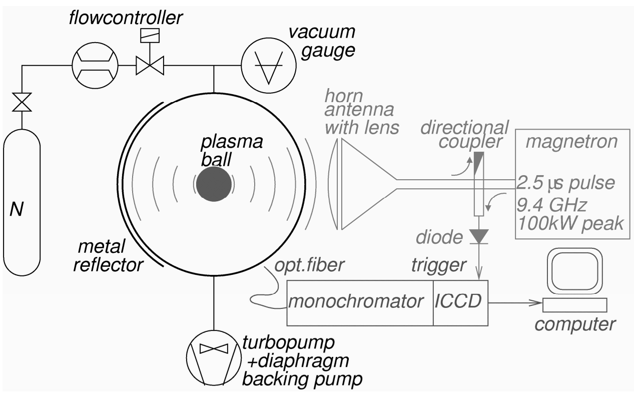

Fig. 1: Experimental setup.

The horn antenna is designed to spread the power over a larger surface in order to reduce electric field strength under a breakdown limit near the glass wall. Only when focussed by dielectric lens into the centre of the glass vessel, the electric field has sufficient intensity there and a plasma ball is formed. The pressure of working gas (nitrogen) is measured by a capacitance absolute gauge and controlled by a gas flow meter and by varying rotation speed of the turbo pump. The operating pressure is in the range 20–2000 Pa.

The spectra were measured with Jobin Yvon FHR 1000 monochromator with ICCD detector.

Calculation

The spectrometer allow us to measure spectra with very good spectral and temporal resolution. We measured temporal evolution of intensities of selected spectral lines and then we fitted it by simulation program DMESS [6], which simulated and fitted optical emission spectra. The program calculated rotational temperature of our spectra from this fit. Our work was focused on evolution of spectra of the second positive system of nitrogen, especially on the vibrational band 0-2 and 1-3 for three different pressure during the pulse.

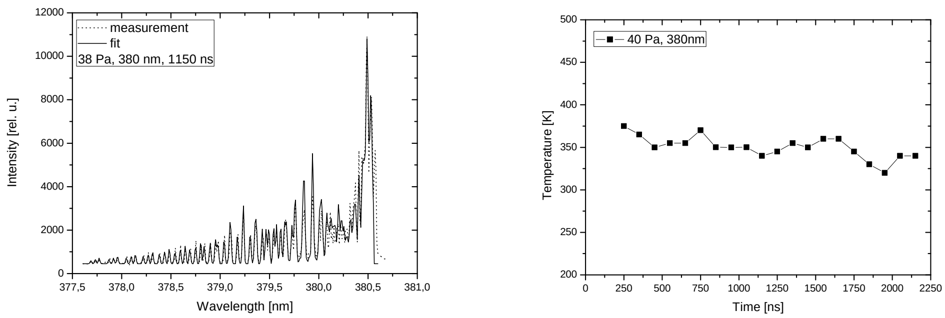

Fig. 2: On the left picture is intensity of vibrational band 0-2 of the second positive system of nitrogen for pressure 40 Pa in time 1150 ns and comparison with fit and on the right picture is development of rotational temperature of vibrational band 0-2 of the second positive system of nitrogen during the pulse in the same pressure.

Acknowledgements

This work was financially supported by project of Czech Ministry of Education MSMT 0021622411, by projects of Czech Science Foundation GA 104/09/H080 and GA 202/08/1106.

References

[1] J. Benford, 2007, High power microwaves (New York, Taylor & Francis)
[2] M. Meško, 2004, Plasma Sourc. Sci. Tech. **13** 4 562–568
[3] Z. Bonaventura, 2005, Plasma Sourc. Sci. Tech. **14** 4 751–756
[4] M. Meško, 2006, Plasma Sourc. Sci. Tech. **15** 3 574–581
[5] Z. Bonaventura, 2008, J. Phys. D: Appl.Phys. **41** 1 015210
[6] L. Lazar, 2008, Chemicke listy **15** 102 1158–1161