Electrical properties of pulsed glow discharge

Two new aspects

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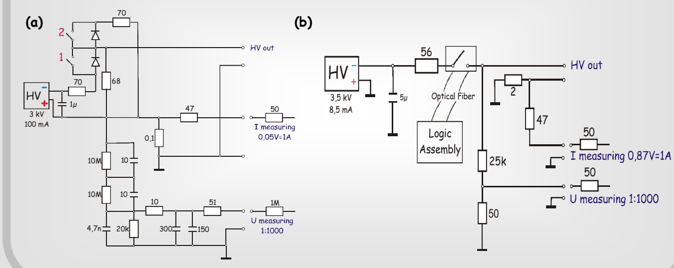
Introduction At the application of pulsed glow discharge (PGD) a transient power of several kW can be reached. This leads to a significant increase of the excitation and ionization efficiency of the sputtered sample atoms. Moreover, with pulsed mode temporally resolved optical emission spectrometry (OES) and mass spectrometry (MS) deliver additional information about the chemical bonds (1-6).

However, the practical application of pulsed glow discharge (PGD) requires an understanding of the processes taking place in the pulsed system. There are some publications, where attention was paid on the voltage-current characteristics and the current signal shape of PGD (7, 8). Nevertheless more attention should be paid on the electrical properties of the PGD. In this work the shapes of current, voltage and emission intensity signals, obtained with two different pulse generators are compared.

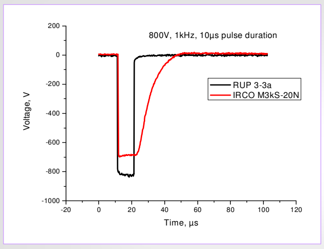
For better understanding of processes, taking place in the discharge the knowledge of the gas temperature is very important. Several authors have mentioned that heating of the cathode leads to changes of the voltage-current curve, mainly a decrease of the current at the same voltage. This can be explained by a lower gas density at the same pressure but at higher temperatures (9,10). This phenomenon gives an approach to estimate the gas temperature of the plasma.

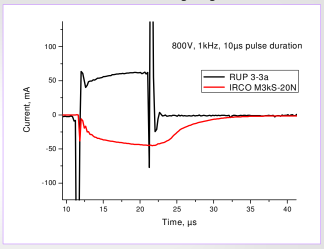
Experimental

Two power supplies with significant difference in the electronic circuits were compared. "RUP3-3a"(a) unlike the "IRCO M3kS-20N"(b) has an additional high voltage switch, which discharges the load after the termination of the pulse.



Differences in electronic circuit lead to a differences in the current and voltage signals behaviour.

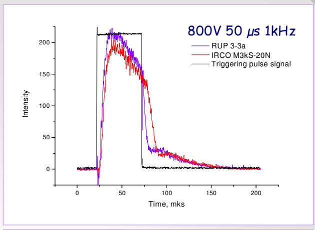




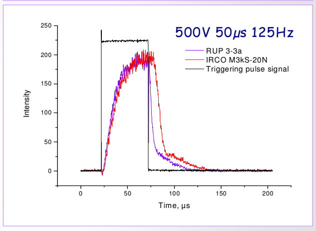
During the pulse switch 1 is on and 2 - is off (Fig. a). To terminate the pulse the first switch is turned off, but at the same moment the second is turned on and discharges the residual load current. Therefore there are no voltage and current signals after the termination of the pulse.

Light emission measurements

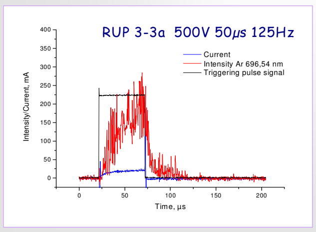
Light emission shapes of Ar (696,54 nm) during the pulse time measured with "RUP3-3a" and "IRCO M3kS-20N" where compared. It was observed that the behaviour of current and light signals is similar. When the "RUP 3-3a" generator is used, the second switch discharges the cell after the pulse termination. This leads to the sharp fall of current and emission signal. In case of "IRCO M3kS-20N" power supply the residual current in the system is not discharged after the end of the pulse. This means that the plasma doesn't disappear after pulse termination and still emits light.

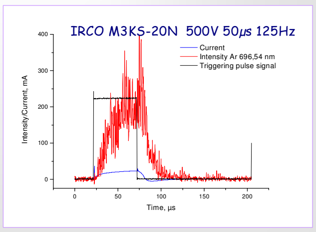


It was found out that with decreasing voltage the light emission shapes is changing. Mainly, the maximum of intensity is moving to the end of the pulse.



This emission shapes are products of averaging signals from 32 pulses. If the averaging mode of the oscilloscope is switched off and the emission of one pulse is recorded, one will see the following picture.

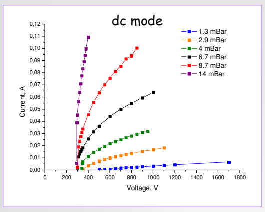


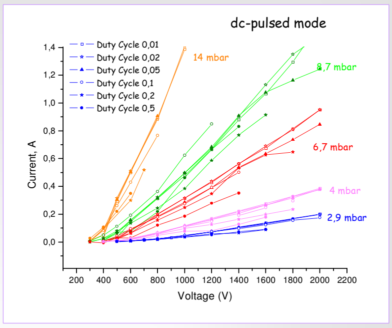


In case of the generator without second switch (IRCO M3kS-20N") the maximum of intensity appears after the pulse termination, in contrast to the "RUP 3-3a", where the second switch removes all signals after the pulse.

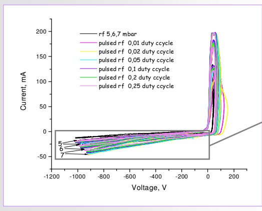
Voltage-current characteristics as a thermometer

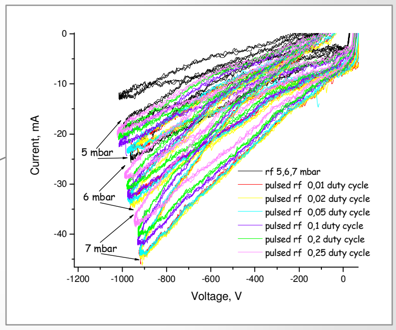
Electrical current in the dc and rf modes was measured as function of the discharge voltage under different pressures. In dc- and rf- pulsed modes influence of repetition frequency and pulse duration was additionally investigated. The current signals were averaged during first 10 μs (for the dc-pulsed mode) and last 1 μs (for the rf-pulsed mode).
Dc and dc-pulsed measurements were performed using a free-standing "Spectruma" Grimm-type source with 8 mm anode tube and the RUP 3-3a generator.





For rf and pulsed-rf measurements a special free-standing Grimm-type source with 4 mm anode and a free-running rf-generator (Forschungstechnik IFW 3,37 MHz) was used. The instantaneous current and voltage signals were measured by integrated current and voltage probes (unique measurement system, developed at IFW Dresden).





Changing of the current amplitude with the duty cycle can be explained by influence of the discharge power on the temperature of the gas. When the duty cycle increases the mean power consumption increases too, what leads to a heating of the plasma. Under constant pressure according to the thermodynamic law p=nkT an increase of the gas temperature leads to the decrease of Ar atom concentration and therefore of the current.

This phenomenon gives an approach to the discharge temperature estimation. Each V-I curve with the same slope is characterised by certain Ar atom concentration. Two V-I plots with the same slope can correspond to the low temperature and low pressure and to the high temperature and high pressure, but the Ar atom concentration is equal. Mainly, ($p_{high}/T_{high}=p_{low}/T_{low}$), from witch T_{high} can be calculated.
The V-I curves, measured under 0,01 duty cycle were assumed to correspond to the room temperature. For these curves, the dependence of the V-I slope on the pressure was plotted. By interpolating of the plot the pressures (p_{high}), which correspond to the higher temperatures (higher duty cycles) were determined. At the end, the T_{high} values were calculated.

Duty cycle **dc**-pulsed	Temperature ^0C	Duty cycle **rf**-pulsed	Temperature ^0C
0,01	20	0,01	20
0,02	36	0,02	19
0,05	55	0,05	20
0,1	74	0,1	25
0,2	116	0,2	33
0,5	149	0,25	44
dc f(U,p)	350	rf	123

Summary

1. Shapes of current, voltage and emission intensity signals, obtained with two different pulse generators are compared. At research of the pulsed discharge, particularly of the afterglow is very important to pay attention on the electronic circuit of the pulsed generator.

2. By the behavior of the voltage-current characteristics under the different duty cycles the temperature of the plasma can be estimated.

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