Spectroscopic study of plasma produced from CFC targets irradiated by pulsed plasma streams

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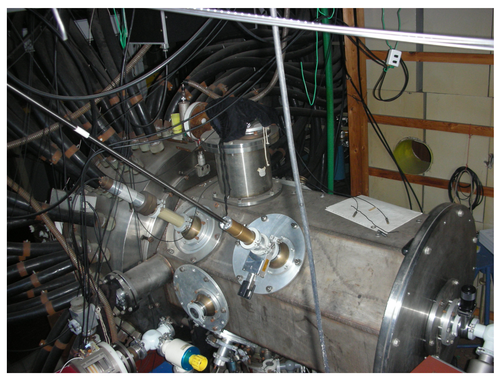
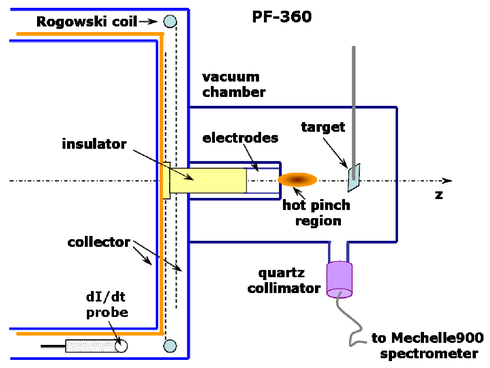
Introductions

Investigation of plasma-surface interactions and associated processes is of primary importance for development of plasma physics and technology. Numerous experimental studies are carried out in this direction in various laboratories with the use of different plasma sources, including those of the plasma-focus (PF) type.

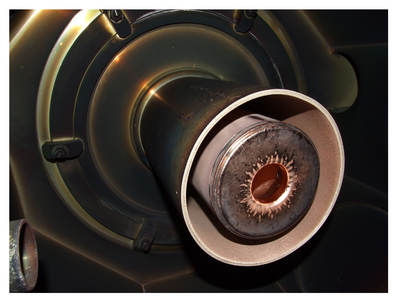


The main aim of the presented study was to investigate the optical emission from intense plasma streams during their free propagation and interactions with carbon-fiber-composite (CFC) targets within the PF-360 facility operated at IPJ. The PF-360 machine equipped with Mather-type coaxial electrodes made of copper tubes, could be used for our studies because it generates pulsed plasma streams containing intense beams of fast ions. It makes possible to study the main problem of plasma-material interactions by investigation of evaporated materials.

Experimental set-up



The PF-360 experimental facility was equipped with two coaxial electrodes of about 300 mm in length, and of 170 mm and 120 mm in diameter, respectively. The inner electrode (anode) was embraced with a ceramic insulator of 80 mm in length. Discharges were initiated at the initial deuterium filling up to p_0 = 6 hPa and they were supplied from a condenser bank of 234 μF capacity, charged initially to 30kV, 105 kJ.

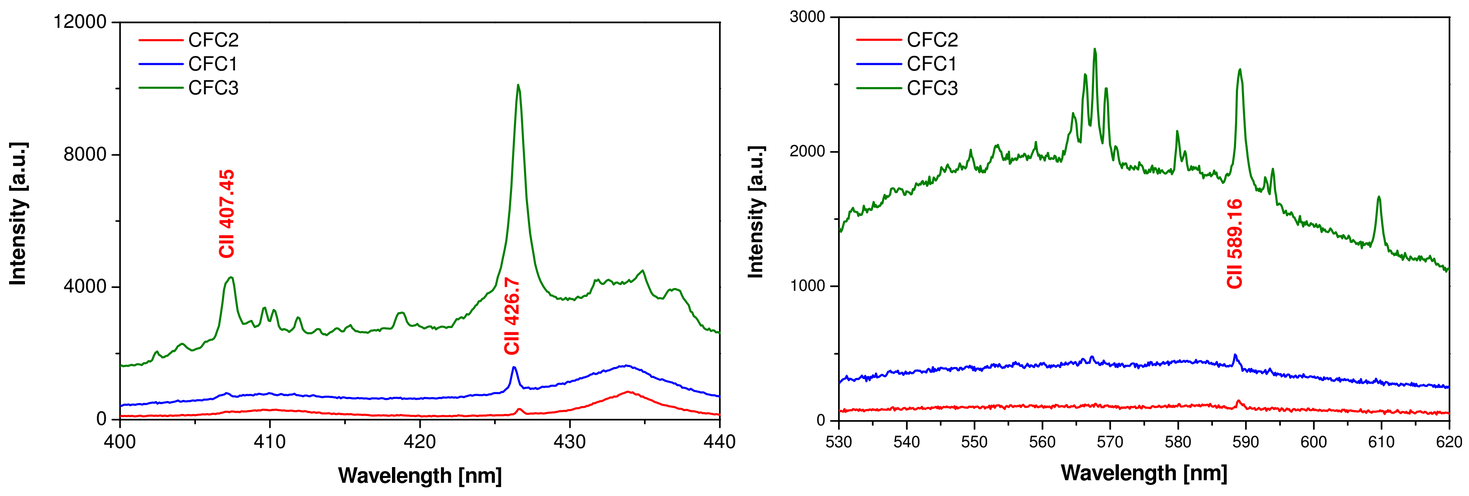


The maximum discharge current amounted to about 1.8 MA, and the pulsed plasma streams were emitted mainly during a characteristic current peculiarity (dip) occurring about 5 μs after the discharge initiation.

Experimental results

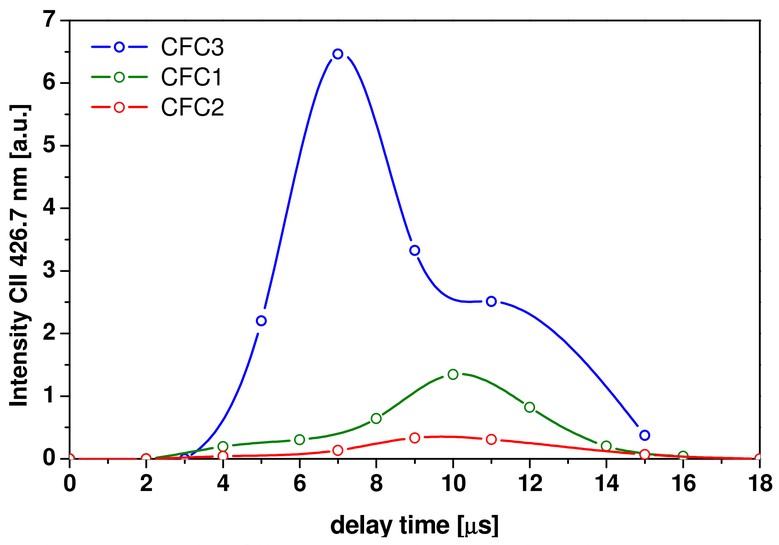
To perform experiments with CFC targets the use was made of samples cut in planes parallel to three different sides of the CFC cube. The surface of the samples Nos.1 and 2 were parallel to carbon filaments, while that of the sample No. 3 contained a higher number of filament ends. The samples were placed at the same distance from the PF-360 electrode ends and they were irradiated by similar number of shots as shown in the Table.
Optical emission spectra of plasma produced during the interaction of pulsed plasma streams with the investigated sample were recorded side-on by means the Mechelle®900 spectrometer coupled with an optical cable and the quartz collimator placed in the diagnostic port.

Number of CFC target	1	2	3
Number of discharges per target	11	9	10
Initial mass	13.4107g	14.2592g	11.9339g
Mass after interaction	13.4062g	14.2540g	11.9243g
Loss of mass	45mg	52mg	96mg
Loss of mass per one discharge	4.1mg (0.034%)	5.8mg (0.036%)	9.6mg (0.08%)



Exemplary spectra taken for three CFC targets for the following experimental conditions: 6 hPa, 30 kV, t_{exp} = 100 ns, delay was 6.8 and 7 μs after the discharge initiation, respectively.

An analysis of the selected spectral lines enabled the dynamics of the plasma emission to be studied, as shown below.

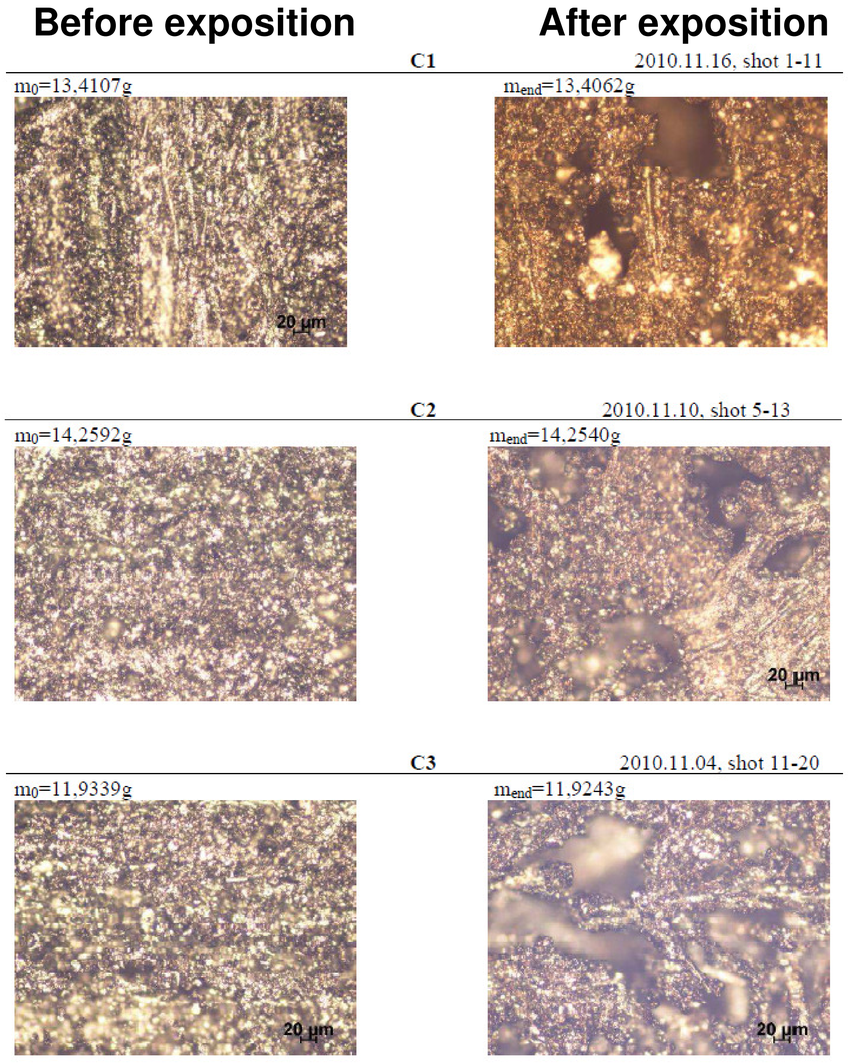


Intensity of the CII 426.7 nm line as a function of time after the discharge initiation.

Additional information about behavior of the irradiated samples was obtained from a comparison of a loss of mass (see the Table) and microscope analysis of their surfaces (see pictures).

The strongest erosion was observed for the C3 sample with a high number of the filaments ends.

Before exposition **After exposition**



Conclusion

Temporal changes in the observed carbon-lines were investigated in details. It was found that the carbon scattering and evaporation depend strongly on the target fiber-structure orientation. In some experiments carried out with the C2 target the recorded spectra contained a small quantity of other impurities elements, what enabled more accurate analysis of the carbon-lines to be performed. The performed measurements have showed that at the described experimental conditions the emission of the carbon-lines started after about 2-4 μs after the discharge-current peculiarity (dip) and there was observed the high-intensity continuum radiation. The obtained results deliver new information about behavior of the CFC targets during their exposition to high-power plasma streams.