Modes of unipolar and bipolar pulsed discharges in CO_2

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This paper reports the studies of unipolar and bipolar pulsed discharges in CO_2 in the pressure range from 0.1 to 1 Torr, the frequency range from 20 to 300 kHz and duty cycle values from 12 to 96%. We have demonstrated that with the pressure, frequency, inter-electrode distance and applied voltage fixed one may obtain different discharge structures only by varying the duty cycle values. For example, a unipolar discharge may contain the cathode sheath and the negative glow as well as the above regions and the additional dark Faraday space, the positive column and the anode glow. The unipolar and bipolar pulsed discharges may exist in two modes: one possessing a low discharge current and a diffuse positive column and another one possessing a high current and a contracted stratified positive column.

Pulsed gas discharges are widely applied in lasers, plasma display panels, for plasma nitriding, in light sources etc. Presently a great attention is devoted to the processes taking place in CO_2 plasma because this gas causes the greenhouse effect and because it is prevalent in the atmospheres of some planets and satellites of the Solar system. Therefore we have studied the modes of the unipolar and bipolar pulsed discharges in low pressure carbon dioxide discharge.

Experiments have been performed in the device with flat stainless steel electrodes located inside the discharge tube with the inner diameter of 56 mm, the inter-electrode distance being from 10 to 380 mm. A pulsed unipolar (negative rectangular) or bipolar potential from the generator in the 20–300 kHz frequency range, the duty cycle from 12 до 95 % and applied voltage values up to 1200 V has been fed to the electrodes. The range of the measured discharge current values did not exceed 200 mA. The CO_2 pressure values were from 0.1 Torr to 1 Torr.

We have revealed that an option of varying the frequency and the duty cycle in the pulsed discharge enables one to get not only different current values but to change the discharge structure in the broad range. Thus, keeping the gas pressure, the inter-electrode distance and the voltage applied across them one may get a unipolar discharge consisting of different parts by changing only the duty cycle values. With the duty cycle below 50% one observes the cathode sheath and the negative glow whereas at higher duty cycle values there appear, apart from the above ones, the dark Faraday space, the positive column and the anode glow. Similarly, one may change the bipolar discharge structure substantially varying the duty cycle, the negative glows near the both electrodes may be either symmetric with respect to the discharge center with the duty cycle about 50%, or a brighter negative glow would adhere to one of the electrodes (to which a short pulse of high voltage is fed), and near the other electrode (with a long pulse of low voltage) this glow may be absent.

Note also that the unipolar and bipolar discharges may exist in two modes: one with the low discharge current and a diffuse positive column and another one with a high current and a contracted stratified positive column. In the unipolar discharge the diffuse mode is observed in long inter-electrode gaps and with high values of the duty cycle, i.e. 80% and higher. In the bipolar discharge the diffuse mode takes place at the duty cycle values from 80% to 50% for the frequency of 20 kHz and this range narrows from 80% to 70% for the frequency of 200 kHz. In the high current mode the positive column (if it fits the inter-electrode distance) is usually contracted consisting of a multitude of narrow striations. The presence of such striations usually indicates that the positive column contains a large number of negative ions. In a diffuse positive column with a low discharge current the conversion of CO_2 molecules probably is much less efficient than in a contracted column with a strong current. This is also pointed out by the fact that the reduced electric field in the positive column in the low current mode amounts to about 15 V/(cm Torr), and in the high current mode it grows about twice as large.