CZ9827312

The Trichel Pulse Corona in $N_2 + CCl_2F_2$ Mixtures: The shape of pulses.

L. Vagnerová, D. Dindošová, J.D. Skalný

Plasma Physics Department, Faculty of Mathematics and Physics,
Comenius University, Mlynská dolina F-2, 842 15 Bratislava, Slovakia

Introduction:

An important feature of the point-to-plane negative corona discharges in air, or in some other electron attaching gases, is a fact, that over a wide range of applied voltages the regular current pulses of amplitude mA can be observed. The negative ions are believed to be responsible for an appearance of a such phenomena named Trichel pulses, because if electronegative component in the gas mixture absents, the first current pulse leads to a glow or arc transient phase of the discharge. However, if sufficiently high resistance is used in the external circuit and the capacity of the discharge gap is low, even in electropositive gases the Trichel-like pulse regime can be initiated [1]. If some critical amount of electronegative gas is added, the pseudo Trichel pulses regime is altered to the regular one. Although lot of papers paid the attention to this peculiar phenomena (see ref. in [2]), further studies are needed to clarify the differences in the minimal concentration of the electronegative impurity in the mixture needed for the occurence of the regular Trichel pulse regime. Most of studies has been done in $N_2 + SF_6$ mixtures because of their technical importance. In the present study the formation of regular Trichel pulses in $N_2 + CCl_2F_2$ is studied. The emphasis has been on the consequences of different electron attachment mechanism in SF_6 and CCl_2F_2 on the behaviour of the discharges.

Experimental apparatus:

The experimental set up designed by Černák [2], partially reinstaled, was used in our experiments. The gaseous mixture of nitrogen with freon R-12 was prepared by mixing the flows of these gases in the mixing tube. The flow-by volume velocity of both gases was controlled by the mass-controlled flowmeters. The discharge tube was filled with the prepared mixture and the pressure within the interval (10-50) kPa was adjusted. The concentrations of R-12 in the mixture was changed within the interval of 0.05 to 2.0 % by volume. Two stainless steel, hyperbolically shaped (radius of 37 μm or 63 μm respectively) electrodes were used in the experiments.

Experimental results:

The experiments has shown that the traces of freon R-12 in the electropositive nitrogen are sufficient for the existence of the regular Trichel pulse regime of the negative corona discharge. The critical concentration for the appearance of regular Trichel pulses lies below the value 500 ppm, what was the lower limit of the used mixing system. At all pressures and concentrations of freon R-12, the negative corona was observed independently on the value of the resistor used in the external circuit. Three differently shaped pulses, shown in Fig. 1, 2, 3a and 3b were observed. The first type, wave-like, was dominant at voltages slightly above the onset voltage, when the electrode, having the larger radius, was used. In experiments with sharper point electrode wave-like pulses were registered rarely and if, only at pressures below 20 kPa and low overvoltages. In both cases the repetition frequency of pulses linearly increased with the increasing mean value of the. discharge current. The form of the observed current pulses, which is far of the form of the typical Trichel pulse in air, is very similar to this, reported by Černák for experiments performed in N_2 + SF_6 at very high concentrations of SF_6 in the mixture (30%).

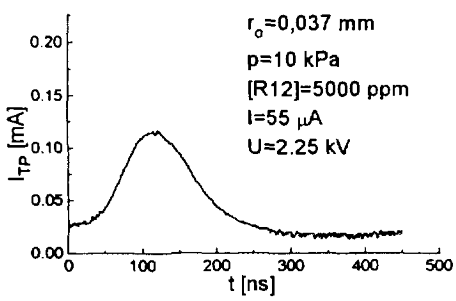

Fig. 1

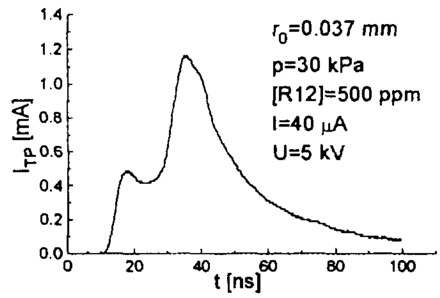

Fig. 2

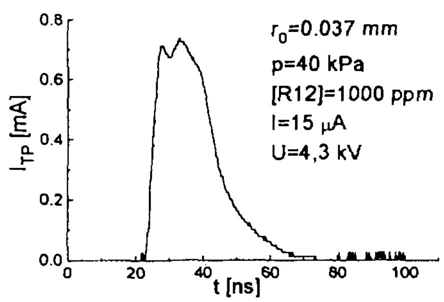

Fig. 3a

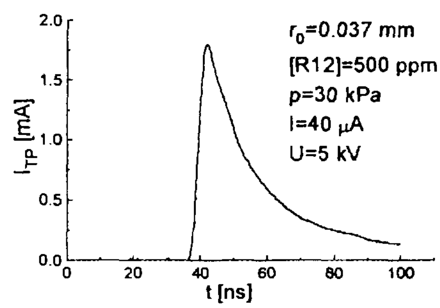

Fig. 3b

There is no mention about the existence of such kind of pulses at the densities of SF_6 relevant to our experiments [3], [4]. From the large values of the rise time of pulses in both mixtures (15 ns in SF_6 and 50-60 ns in CCl_2F_2) we conclude that the avalanche mechanisms is only active at the formation of the wave-like pulses. The differences between two measured values, corresponding to the mentioned mixtures, follows from the different mechanisms of the electron attachment by used electronegative impurities in nitrogen. While in SF_6 the generation of F- or SF_5- negative ions is possible via dissociative attachment at relatively high energies of electrons, the dissociative electron attachment by freon R-12 needs the nearly thermalized electrons and is active father from the cathode. That is why the ionization process of the first avalanche is stopped in SF_6 containing mixtures at the position, which is closer to the cathode than in the mixtures containing freon R-12. The rise time of pulses corresponds to the transport time of the positive nitrogen ions created by the first avalanche from the points where the head of the first avalanche was stopped.

Fig. 2 shows the form of the second type of pulses. These were predominantly recorded at higher overvoltages for both used electrodes and practically everywhere in experiments with sharper electrode. This type of pulses is characterised by very fast current growth and relatively very small half width of the pulse which decreases substantially, if the concentration of R-12 in the mixture increases. The measured rise time of leading edge of pulses does not depend on the concentration R-12, what is in agreement with results of Zentner [4] and Černák [3] accomplished in mixtures of N_2 with SF_6 at very low concentrations of SF_6 $c < 1.0$ %. The measured mean value of the rise time T = 2.5 + 0.5 ns was very close to values, reported by foregoing authors and

was not apparently influenced by the pressure of the gas mixture within the interval (20-50) kPa. Both the amplitude and the maximum rate of the current increase in the leading part of the pulse, increased at decreasing gas pressure as well as if the concentration of R-12 was increased. The measured form of pulses is very similar to the Trichel pulses measured in pure O_2. Thus we believe the mechanism associated with their formation is the same like in oxygen, and we can call them Trichel pulses.
Randomly the third type of pulses was registered, especially at pressures 30 and 40 kPa. The existence of these, rather peculiar, double peaks were experimentally proved earlier by Černák [2] in $N_2 + SF_6$ mixtures. He attributed that the change of the pulse shape is caused by the transition from the mechanism proposed by Morrow, valid for I type of pulses, to the mechanism associated with the formation of a cathode directed streamer, proposed by Černák. The last one mechanism describes well the form of II type of pulses. Thus the camel-like pulse is the intermediate form between these two, previously reported forms. Because in are experiments the continuous regime of the discharge was use, the chances to observe this curious form was limited. The best way how to observe them, is to use the single shoot pulse regime, recommended by Černák [2].

Conclusions:

Despite of the different attachment processes of electrons by SF_6 and CCl_2F_2, the increasing part of the current pulses observed in $N_2 + CCl_2F_2$ mixtures were very similar to those, observed in $N_2 + SF_6$. That is an evidence the origin of the negative ions does not play any substantial role in the formation of the initial part of the Trichel pulses.

References:

[1] Sigmond R.S., Goldman A., Goldman M., Laan M., Bjones B., Olsen I.H.: 11th ISPC Loughbrough, UK, August 22-27 1993
[2] Černák M, Hosokawa T. : IEEE Trans. on Electr. Insul. 24 (1989), 699-708
[3] Černák M., Hosokawa T. : Czech.J.Phys. B 39 (1989), 1032-1036
[4] Zentner R. : Z. Angew. Physik 29 (1970), 294-301