Formation of the discharge over semiconductor surface in trigger unit of cold-cathode thyratron

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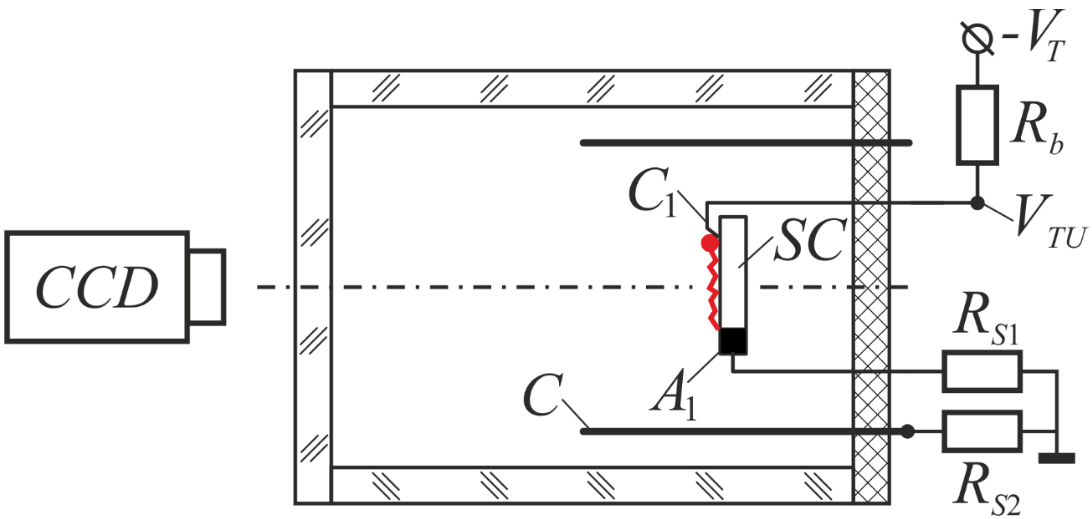
Introduction

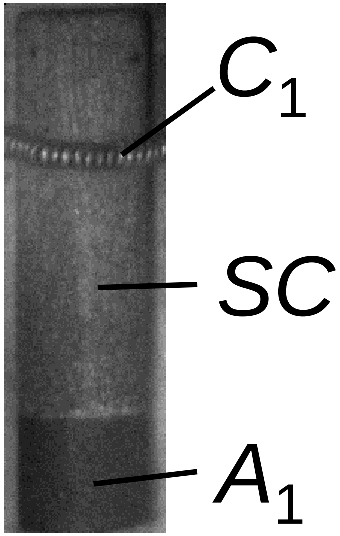
Currently hollow-cathode low-pressure discharges are widely used for different applications. One of them is in high-current switching devices based on low-pressure hollow-cathode pulsed discharge (cold-cathode thyratrons or pseudospark switches). As in the case of classical thyratrons, a range of operating pressures of the switch corresponds to the left branch of Paschen's curve. Under these conditions, for both self-breakdown of the main gap of the thyratron and for external discharge triggering a considerable pre-breakdown electron current is required. For the case of external triggering, this current is provided due to a special trigger unit that is placed in the main cathode cavity.

One type of the trigger units is based on a discharge over a semiconductor surface. For such trigger units the delay time to breakdown in the thyratron main gap involves the delay time to initiation of the surface discharge, delay time to interception of the surface discharge current to the main cathode cavity and delay time to discharge development in the main gap. Our previous experiments have shown that the main contribution to jitter in delay times to breakdown in the thyratron main gap is provided by jitter in delay times to discharge initiation in the trigger unit and interception of the trigger discharge current to the main cathode cavity.

In this report the results of investigation of the trigger unit based on a discharge over the semiconductor surface are presented. Data on surface discharge formation and delay times to current interception to the cathode cavity were obtained.

Experimental setup





Semiconductor cylinder *SC:* polycrystalline boron carbide-nitride;
l = 20 mm, D = 7 mm

Cathode C_1: copper spring wound around the semiconductor cylinder
Multipoint contact with semiconductor due to elastic properties of the spring

Anode A_1: made of graphite and pressed to the semiconductor

The distance between the electrodes C_1 and A_1 l_0 = (8 – 15) mm

Cavity C plays the role of hollow cathode of the cold-cathode thyratron

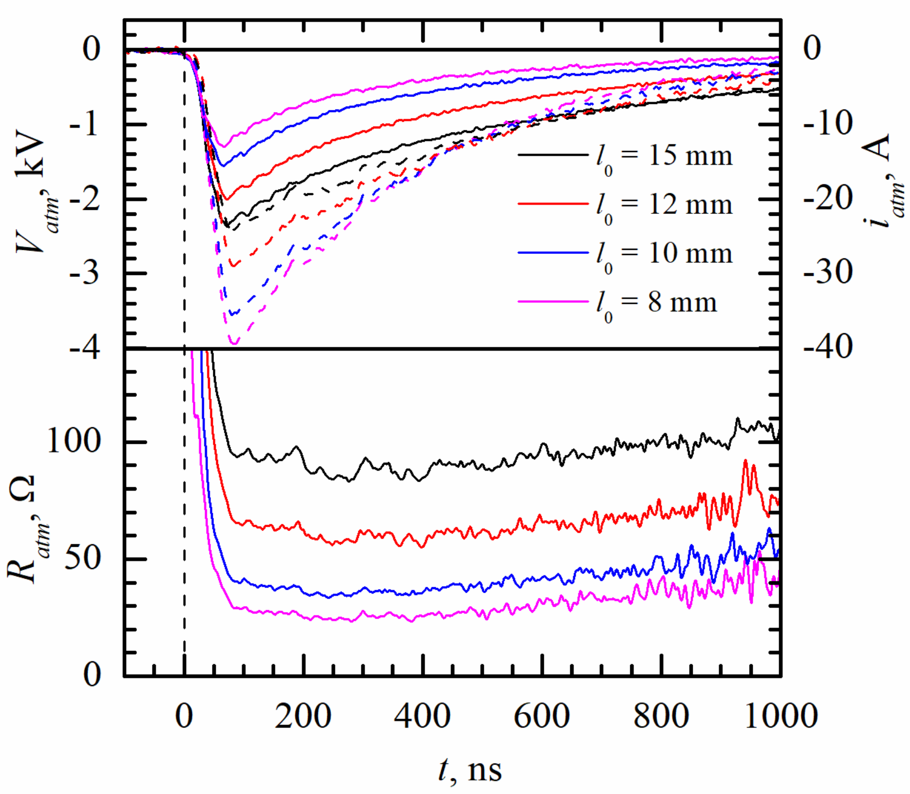
In current experiments cavity C is the hollow anode; D = 60 mm, h = 50 mm

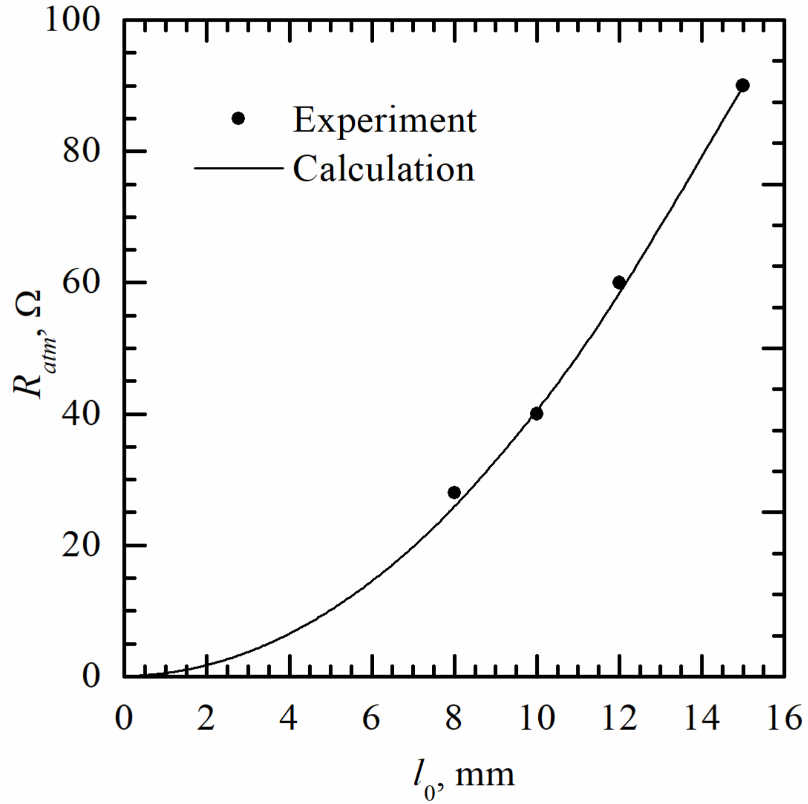
V_T = – 3 kV
R_b = 50 Ω
$R_{S1} = R_{S2}$ = 1 Ω
$p(H_2)$ = (0.01-0.25) Torr

We measured: current in the trigger unit i_{TU}
current to the cavity i_C
voltage at the trigger unit V_{TU}

Note: typical working pressure for cold-cathode thyratrons – 10^{-1} Torr

Length l_0 dependence of semiconductor resistance





Cavity *C* is under the floating potential. Atmospheric pressure (to avoid the discharge influence)

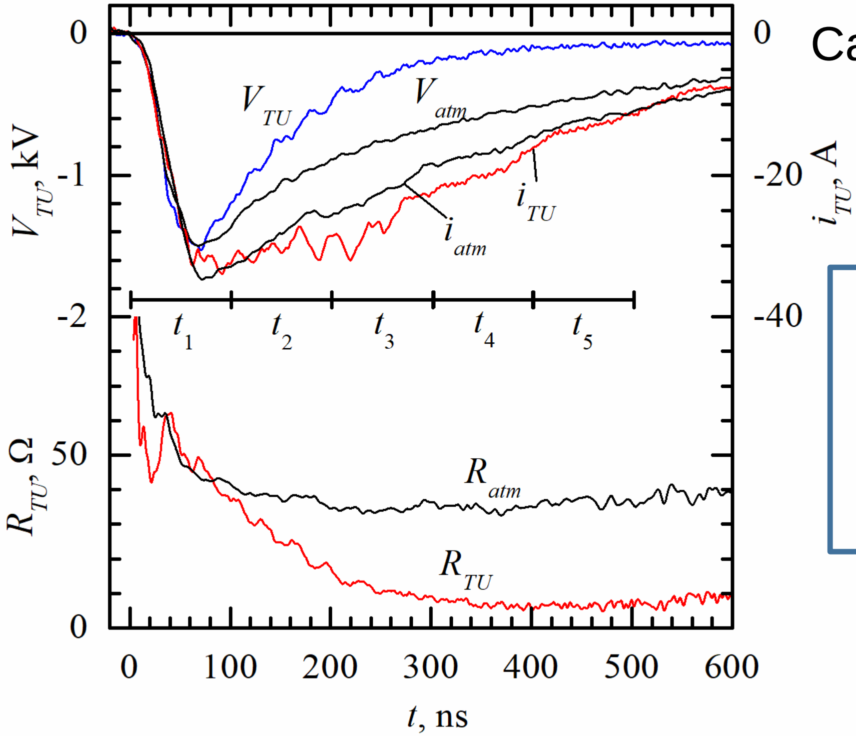
$$R_{atm}(t) = V_{atm}(t)/i_{atm}(t)$$

Average value of the semiconductor resistance increases with the increase of the distance l_0 between electrodes C_1 and A_1

Length l_0 dependence of resistance R_{atm} can be written as follows

$$R_{atm}(l_0) = 0.4 l_0^{\,2} \qquad (1)$$

Discharge development ($p = 10^{-2}$ Torr)



Cavity C is under the floating potential, l_0 = 10 mm

Resistance of the trigger unit

$$R_{TU}(t) = V_{TU}(t)/i_{TU}(t)$$

Divergence of the voltages V_{TU} and V_{atm} and currents i_{TU} and i_{atm} waveforms at t = 70 ns

Cathode spots ignition

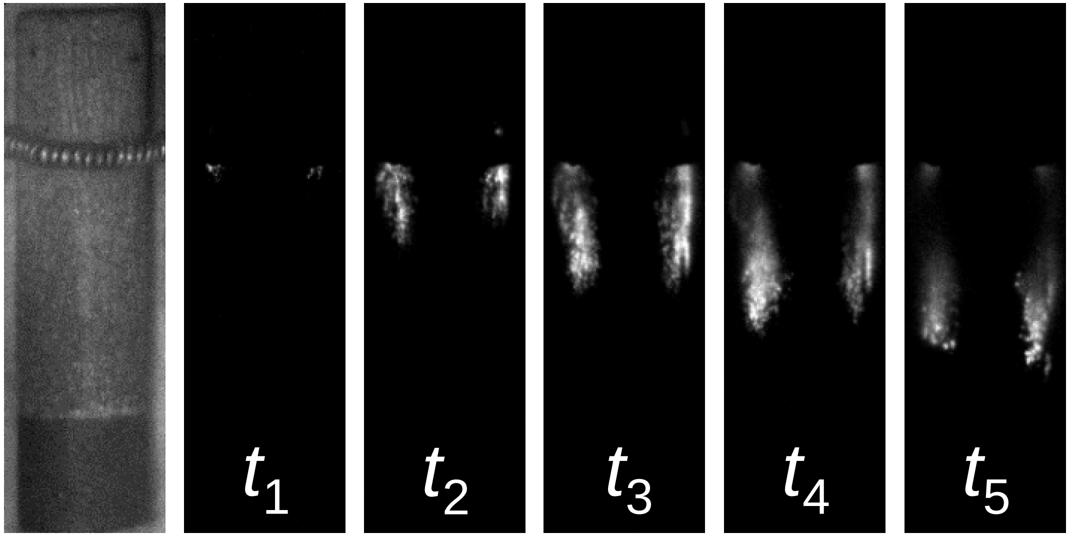
Velocity of the discharge propagation decreases in time

Interval t_2 – 25 km/s

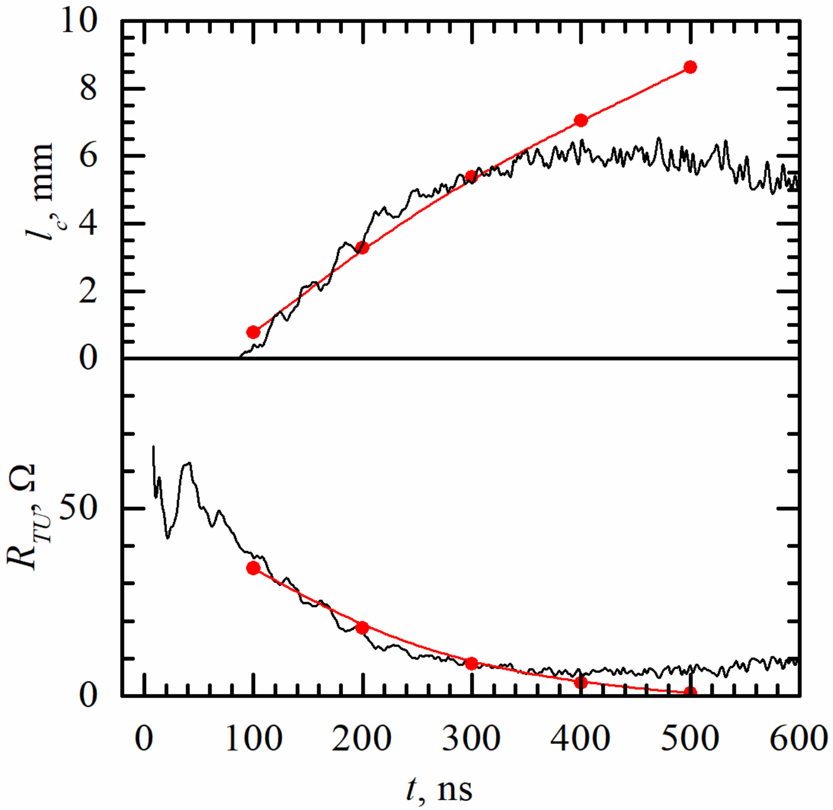
Interval t_5 – 15 km/s

Surface discharge shuts the past part of the semiconductor

Trigger unit resistance R_{TU} decreases



Estimation of the discharge column length



experimental column length l_c and estimated trigger unit resistance R_{TU}

$$R_{TU}(l_R) = 0.4 l_R^{\ 2}$$

calculated trigger unit resistance $R_{TU} = V_{TU}/i_{TU}$ and estimated column length l_c

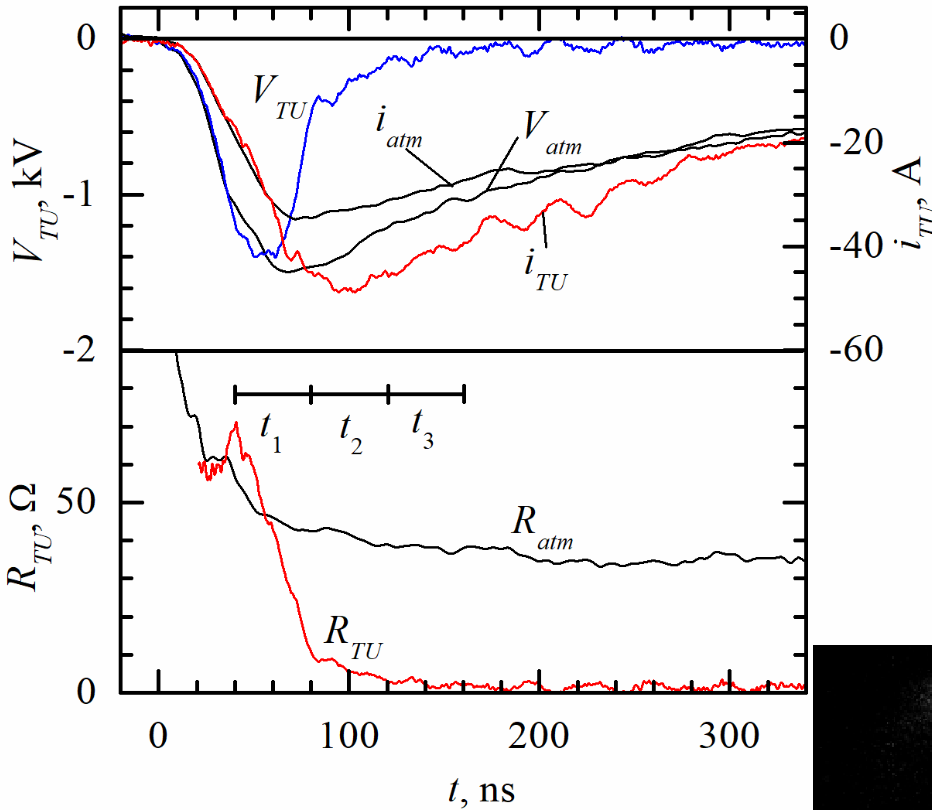
$$l_c(t) = l_0 - \sqrt{2.5 R_{TU}(t)}$$

Column length $l_c = l_0 - l_R$, l_R – length of the uncovered part of semiconductor

Divergence in experimental and estimated values of l_c and R_{TU} at $t > 450$ ns

Column resistance becomes compared with the resistance of uncovered part of semiconductor and should be taken in to account

Discharge development (p = 0.25 Torr)



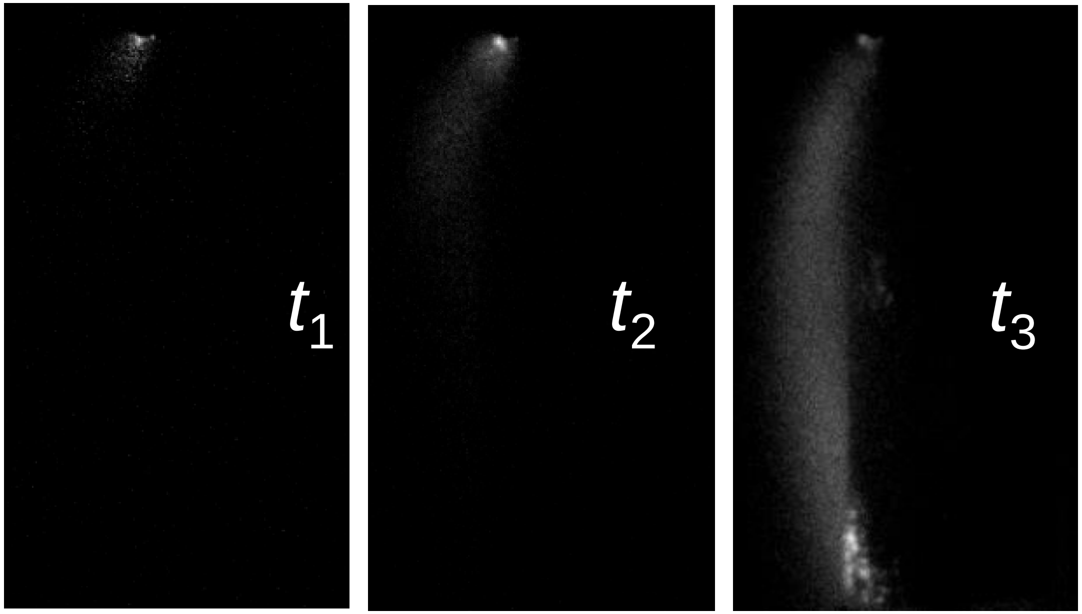
Cavity C is under the floating potential l_0 = 10 mm, thyratron working pressure

Sharp decrease in V_{TU} after the instant of cathode spot ignition

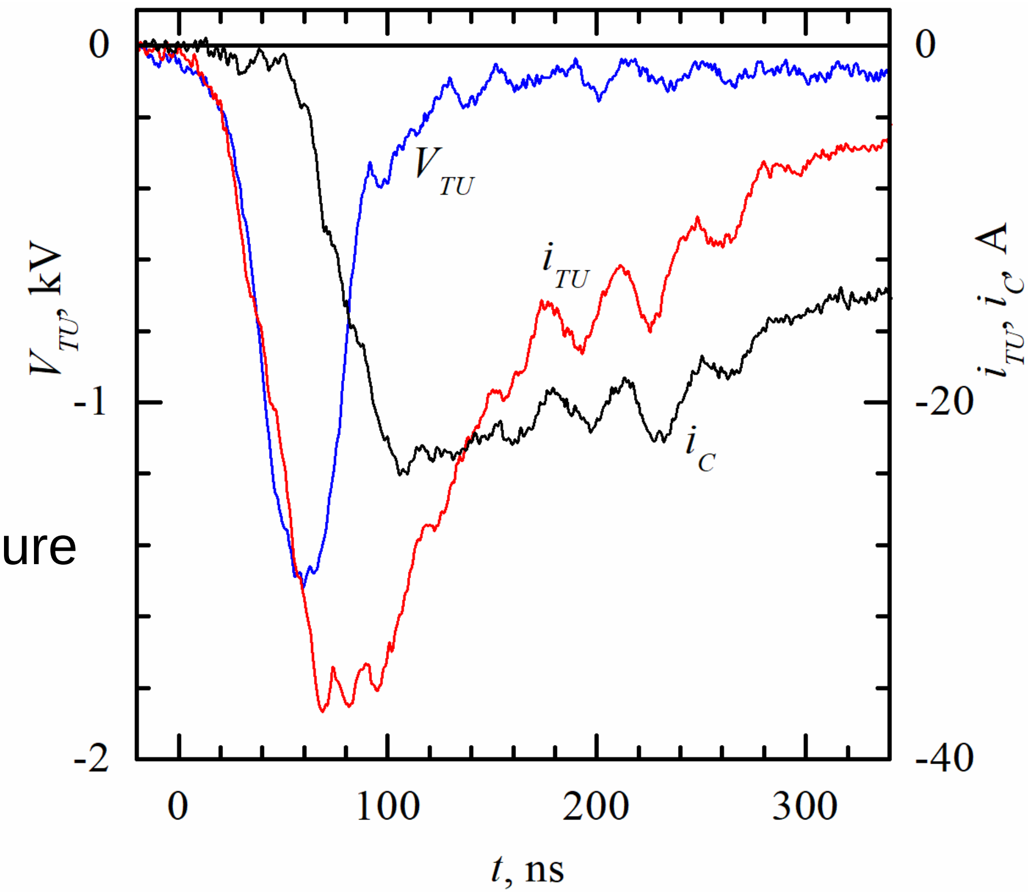
Cathode spot arises at pulse edge

No surface discharge is observed

Arc discharge



Current interception to the cavity C



p = 0.25 Torr
thyratron working pressure
l_0 = 10 mm

Cathode cavity is grounded by shunt R_{S2}

Cathode spot arises at pulse edge at t = 60 ns

Current interception to the cavity C just after the cathode spots ignition

Time delay to current interception and trigger discharge formation t_d = 60 ns

Conclusion

- Investigation of the discharge over the semiconductor surface in the trigger unit of cold-cathode thyratron was carried out
- The greater the distance between trigger unit electrodes the higher resistance of the trigger unit
- For the pressures less than the working pressure of the thyratrons discharge propagation over the semiconductor surface is observed
- Method for estimation of the discharge column length is proposed
- For the working hydrogen pressure discharge in the trigger unit burns in the regime of an arc discharge