Application of the gas-discharge surge arresters in X-ray devices and low voltage instrumentation

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Abstract. Usage of the gas discharge in science and engineering is discussed. Application examples of the compact gas-discharge tubes in the X-ray devices and low voltage instrumentation appliances for the surge protection are presented.

1. Introduction
The electrical discharge in gases is widely used in science and in leading branches of industry. The partial list of the application fields where gas discharge brings benefits includes optics, metrology, materials science, electronics, radio engineering, mechanical engineering, healthcare and illumination.

For instance, fluorescent lamps utilize ultraviolet light of the discharge in mercury vapors [1] which excites the phosphor of the lamp and thus engenders the white light. Mercury-vapor lamps with fused quartz casing don’t have any phosphor and used for ultraviolet disinfection of the medical chambers, kindergarten and school rooms, also for bactericidal cleaning in tap water. High-pressure sodium lamps [2] are implemented worldwide as a reliable and energy-efficient light source for road lighting and as plant grow light for the agricultural and decorative plants. The gas discharge is also necessary for the operation of the lasers with gas working medium [3]: carbon dioxide [4], helium-neon, helium-cadmium and other suchlike gas mixtures.

The magnetron discharge systems with high pulse current emitted from the cold cathode are capable to create intensive electron beams [5]. Magnetron sputtering of the metal targets [6] is widely applied for thin film growing. The cathode sputtering in vacuum chamber by means of the arc discharge allows formation of the coatings with various chemical compositions [7–16] and cleaning of the dielectric surfaces with the flow of neutral particles [17]. The spectra of electric discharge with the liquid nonmetallic cathode [18, 19] can give useful information related to the dangerous impurities (e.g. heavy metals) existing in the liquid.

2. Surge protectors
It is usually required in electrical and electronic systems to avoid the arising of the high-voltage pulses in the electronic components designed for the low-voltage signals. This requirement can be satisfied using the surge protectors (also referred as surge arresters): metal oxide varistors, transient voltage suppressors, thyristor surge protection devices, air spark gaps and gas-discharge tubes. Each type of the listed surge protectors has its own properties fit for the certain exploitation conditions.
The surge arresters in the form of the gas-discharge tube have negligible small capacitance (often less than 1 pF) and can handle relative high currents. In case of the high-voltage pulse the surge arrester creates short circuit between its pins thus dissipating the excessive energy. The gas discharge tubes are manufactured in the cylindrical enclosure for through-hole mounting with large metal leads as well as in the compact surface mount (SMD) casing. The last is important for use in portable electronics such as radio receivers, walkie-talkies, MP3 audio players, mobile phones, smart watches, small wearable Holter monitors, electroencephalographs or pulse oximeters.

3. Gas-discharge surge protectors in instrumentation
The low-power glow discharge thyatron MTH-90 (figure 1) can be used as a gas plasma arrester in instrumentation. The discharge ignition voltage between the cathode and grid of the MTH-90 is over the range from 65 to 90 V. This feature is applicable for the X-ray tube current \( I_{\text{XRT}} \) measurement by means of the resistive shunt \( R_{\text{shunt}} \) (10 \( \Omega \)) to protect the instrumentation electronics from failure due to high-voltage pulses (figure 1(c)). In addition to the thyatron the resistive current limiters \( R_{\text{lim}} \) (100 \( \Omega \)) and the capacitive voltage limiter \( C_{\text{lim}} \) (470 nF) are used.

![Figure 1. Appearance of the MTH-90 thyatron (a), light of the glow discharge (b), circuit for the surge protection of the shunt resistor and additional instrumentation electronics (c).](image)

The modern gas-discharge surge arresters (figure 2) are nontransparent gas-filled tubes with metal or ceramic shell with two or three leads. One of the widespread examples of the general-purpose surge protectors is the EC90X unit manufactured by Epcos (part of the TDK Group). This device has two long axial leads and industry-standard tubular shape. The EC90X arrester has following electrical specifications: the direct current spark-over voltage is 90 V, the peak pulse current is 10 kA, and the insulation resistance is at least 1 GΩ [20]. Another widely distributed arrester is the Epcos S30-A230X unit in space-saving SMD casing; this device also features high insulation resistance (>1 GΩ), spark-over at 230 V (direct current) and peak pulse current of 1 kA [21].

The S30-A230X surge arresters were used for the electrostatic protection of the INA333 instrumentation amplifier (IA) [22]. Two arresters were connected between inputs of the IA and the ground circuit. Two 100 MΩ pull-down resistors \( R_{\text{bypass}} \) were plugged in parallel with the arresters for maintenance of sufficient value of the input bias current for the IA (figure 2(b)). In order to test the functioning of the protection the 6 kV pulse generator was applied. The IA has successfully continued the functioning after the surge test which indicates the high effectiveness of the protection.

![Figure 2. Appearance of the EC90X and S30-A230X arresters (a), connection of the S30-A230X surge arresters for the IA protection (b).](image)
4. Conclusion
Described technique of the surge protectors application is suitable for low voltage instrumentation such as precision current sensing, bioelectric activity registration and Wheatstone bridge based measurements due to high insulation resistance and very low capacitance of the gas-discharge arresters.

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