POSSIBLE DIRECTIONS OF ELECTRON GUN WITH A WIDE BEAM APPLICATION FOR RADIATING TECHNOLOGIES AND MEDICINE

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The electron gun with a wide beam output is a version of the direct action particle accelerator which is operated without any vacuum pumps. The gun provides a powerful electron beam in an atmosphere or other gas environment. The gun forms a 160-180 keV electron beam with 400 W average power. Rather large irradiation fields can be formed by several guns cooperation. On the basis of this gun the experimental installations for realization of researches and improvement of radiating technologies of processing of various materials and sterilization of medical products was created. As electron beam energy is rather low, the electrons do not penetrate deep into material. It creates optimum conditions for superficial sterilization of products, the radiating influence on material of which is not desirable. In particular, it concerns to an eye artificial crystalline lens made from special plastic. For industrial application the radiating processing of various polymers in order to improve their operational properties (durability, wearability, termoresistivity etc.) is of interest. The gun allows to create high-efficiency installations.

1. INTERACTION OF LOW ENERGY ELECTRONS WITH SUBSTANCE

The primary electrons passing in substance transfer their energy to atoms and molecules of substance, causing excitation and ionization [1]. Charged and neutral splinters of molecules formed as a result of chemical connections break have a high chemical activity and quickly react with each other and with other molecules. The new active particles - free radicals and secondary ions – participate in chemical reactions thus the changing the material molecular structure and forming the substance with new properties. The high chemical activity of reacting particles makes possible a realization of chemical reactions even at very low temperatures (down to temperature of liquid helium). Thus the necessity of initiators and catalysts usage also disappears, that allows to create a high pure materials. The radiation-chemical reactions take place in a rather thick layer even for small energies of primary particles. It allows to process already fabricated products.

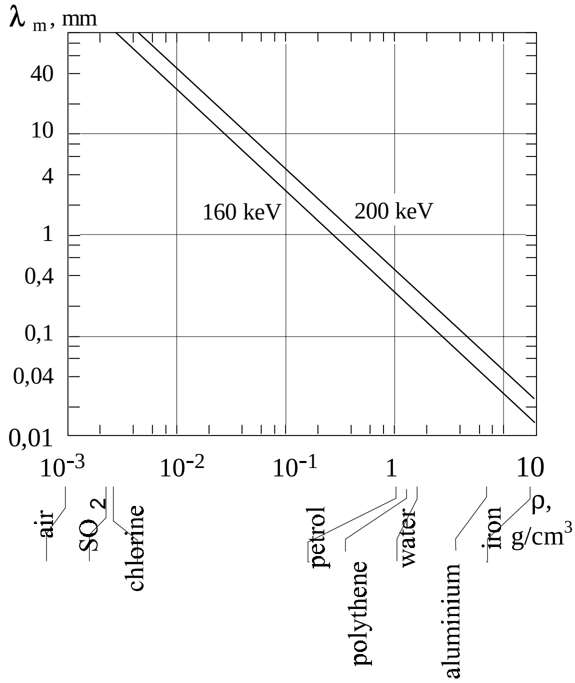

Fig.1. Penetration length of electrons λ with energy 160 and 180 keV in different density substances ρ.

Low energy electron beams can be most effectively used in gas environments, where their penetrating ability makes about 15-20 cm. However, the x-rays arising at interaction of primary electrons with substance has considerably large penetrating ability that allows to influence on internal areas. In this case much higher dozes of an irradiation are required because the efficiency of x-rays and substance molecules interaction is much lower. The electron beams with small penetrating ability are necessary for processing the products superficial layers to prevent influence of a beam on internal areas.

2. APPLICATION OF ELECTRON BEAMS IN INDUSTRY

The polymerization reaction output is proportional to capacity of the absorbed doze P by approximate dependence P^n (usually n ~ 0,5) and may be more then 10^6. So energetically these processes are rather effective. It is possible to carry out a radiating polymerization at temperature, optimum for molecular circuits growth, unlike the catalyst initiated polymerization that as a rule requires a higher temperature.

Processes of radiating polymerization (seaming) and destruction of molecules cause improving of polymer properties. The radiation stimulates a creation of intermolecular connections: seaming a monomeasure molecules in polymeric circuits (polymerization) and modifying a linear one-dimensional polymer (for material that is already polymerized) in spatial. In the latter case chemical connections between the next molecules are formed. As a result the molecular structure with cross-connected polymer chains is formed. These cross connections reduce the mechanical displacement of molecules thus reducing high elastic properties of a polymer material and increasing its limit of elasticity. Basically polymeric materials work under intensive dynamic loading. In cross-connected materials there is no accumulation of unelastic deformations and hence durability of products grows. Operation temperature range for such materials expanded as well. The typical changes of the basic mechanical and operational characteristics of some polymer materials widely used in industry for different purposes are given in the Table 1. The similar results turn out at processing of other polymers.

Table 1. Typical changes of materials parameters after radiation treating.

Material	Parameters changing (increasing)			
	Module of elasticity	Elastic limit	Wear-ability	Tempe-rature, °C
Caprolon	1,0	3	1,6-1,7	—
Rubber	1,2-1,3	5-6	—	—
Silicon rubber	—	—	—	- 60
Polyuretan	—	—	1,7-2	—

The good results turn out at processing photopolymers used for manufacturing of the printed forms of a high seal. The application of photopolymers in typographical business allows considerably to speed up process of manufacturing of the printed forms and essentially to lower their cost. At the same time, the photopolymeric printed forms have insufficient durability, and in some processes (for example, metal covering) can not be used because of insufficient thermoresistivity. In the latter case more expensive metal forms are applied for seal processes realization. The radiating processing of the photopolymeric printed forms raises their durability and thermoresistivity in a number of times, that allows to use them instead of metal.

One of the most widespread technologies using combined radiating processes is radiating hardening of lacquer-paint coverings. As opposed to traditional technology, radiating polymerization lasts less than 1 second and does not require any additional polishing. Radiation-hardened coverings have high mechanical durability and chemical- and thermo-resistivity also. With the help of these processes create also thin layered plastics, insulating coverings on various substrates etc. Radiating hardening of binding substances is used in magnetic tape manufacturing, in a polygraphic industry and other processes. The good results are obtained for typographical paint hardening on paper money: it allows to increase a paper money lifetime.

The radiating modifying of textile materials allows to receive the following results: creation fabrics with a permanent creases, fireproof, hydrophile (well moistened) or hydrophobias (water-repellent) fabrics, increase a stability to pollution, reduction of static electricity accumulation, increase a resistance to rotting etc.

The radiation processes in gases basically are used for industrial gases clearing from harmful impurities. The greatest danger represent sulfur dioxide and nitrogen oxides contained in gas. The radiating method allows to neutralize about 80-90 % of these impurities.

The practical interest for application of radiating influence on water solutions is wastewater clearing both industrial, and household. First of all it concerns to neutralization of synthetic superficial-active substances (SAS), used for abstergent manufacturing. The radiating clearing, as against biological, influences all organic connections.

At radiating processing of water there is as well its sterilization, as the dozes necessary for decomposition of organic substances, contained in water, are much higher than dozes necessary for disinfection. In this case advantages of radiating disinfection consist that in water the active substances (chlorine, ozone etc.) are not added biologically.

3. APPLICATION OF ELECTRON BEAMS IN MEDICINE

The application of radiating technologies in medicine is based on biological action of ionizing radiation. Depending on irradiation doze the various results of radiating influence are possible: stimulation of development, genetic changes, sterilization, delay of growth, death of organism or chemical decomposition.

The process of medical materials and tools radiation sterilization is the first radiating process mastered in industrial scales. The radiating technologies are applied for processing surgical strings, syringes, surgical tools and other products containing metal, plastic or rubber, and also at preparation of vaccines.

Many wares used in medicine are manufactured from polymers and are designed for multiple use. For this wares the superficial radiation sterilization has essential advantage in comparing with high energy sterilization. Low energy electrons don't penetrate deep into material (penetration length for 200 keV electrons is about 0.1 mm) and so don’t influence on its properties. The experiments show that for many polymers their properties changing (i.e., change of polymer color) don’t occur for superficial irradiation doses up to 1-3 MGy.

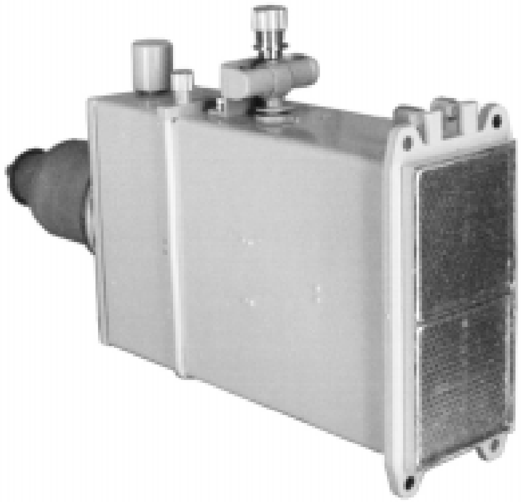

Fig.2. Powerful pumpless electron gun of module construction with wide electron beam.

4. POWERFUL ELECTRON GUN (160-180 keV)

Pumpless electron gun of module construction (Fig.2) is designed for creating a wide powerful elector beam in air or any other gas environment. The unit is designed and manufactured in State Concern "Istok" (Fryazino, M.R., Russia) [2].

The special powerful electron gun can be effectively used for the purposes mentioned above. Such gun is a version of the direct action accelerator. It is compact, durable, has small work preparation time. The gun has a rectangular output window with the sizes 100 $\times$200 mm^2. This allows to process rather large irradiation surfaces without application of any special scanners. A number of such guns can be easily enough incorporated in one installation if it is necessary to process surfaces of greater area. The main parameters of the electron gun with high average power of output beam are given in Table 2.

A number of installations are created based on these guns. They are designed for researching and improvement of radiation technologic processes of different materials processing. The essential advantage of these installations in comparing with analogous is their full inner irradiation protection. This allows us use them in usual laboratory rooms, where personal is placed. In this installations an adjustment of electron beam main parameters is possible in order to enlarge their experimental facilities.

On one of these installations a large number of experiments on superficial radiation influence of low energy electron beam on properties of different materials is carried out.

Table 2. The main parameters of the electron gun with big average power.

Average power of output beam (W)	400
Output window cross section (mm^2)	200$\times$100
Electrons energy (maximum) (keV)	200
Cathode current (A)	80
Output current (A)	10
Maximum power of superficial doze (kGy/s)	300
Duration of a pulse (μs)	5
Pulse frequency (Hz)	50
Gun dimensions (mm^3)	400$\times$230$\times$114
Gun weight (kg)	20

Good results were obtained for radiation processing of polythene (PE) and PVC products. In particular, substance durability increased in 2-4 times, module of elasticity in 1.2-1.3 times and elasticity limit in 3-5 times. The regimes of superficial sterilization of polymer wares that are widely used in medicine (artificial eye crystalline, correcting rings, cases for blood analysis) are determined also (Table 3).

Table 3. The results of radiation processing of polymer wares used in medicine.

Polymer wares	Electron energy, keV	Penetration length, 10^{-6} m	Superficial dose, kGy
Artificial eye crystalline	140	90	29
Correcting rings	120 140	60 90	25 30
Cases for blood analysis	140 180 180	90 150 150	660 1000 2000

5. EFFICIENCY OF LOW ENERGY BEAMS USAGE

The application of low energy electron beams is effective enough in various radiating technological processes connected with processing of a material surface, either occurring in gas or air environment, where the sufficient beam penetrating ability can be provided.

The gun provides rather high values of superficial irradiation dozes. This allows us create a high efficien-cy installations. For example, for processing the PVC wares the unit productivity can be about 140-150 m^2 per hour and 70-75 m^2 p.h. for polythene. AC energy consumption will not exceed 0.01-0.02 kW·h·m^2.

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[2] Simonov K.G. Elektronnye otpayannye pusky. - M.: Radio i svyaz, 1985 (in Russian).