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NEW SOVIET RADIO INSULATING MATERIALS

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In the past decade, great progress has been made in the Soviet Union in the development of insulating materials. Two decades ago, scarcely three or four types of special ceramic insulating materials were used in radio engineering; now, Soviet scientists have developed scores of ceramic compounds for various purposes. The improvement in the quality of radio ceramics produced at present in comparison with the prewar type is clearly shown in Table 1, which lists the more important electrical properties of ceramics.

Table 1. Comparative Characteristics of Prewar and Present Radio Ceramics

	Prewar	Present
Dielectric constant	From 0.5 to 80	From 5.0 to 10,000
Temperature coefficient of dielectric constant in the temperature range 20-80°C	Not standardized	Positive from + 110 x 10^{-6} to + 30 x 10^{-6}; negative from - 1500 x 10^{-6} to - 50 x 10^{-6}
Dissipation factor at radio frequencies at 20°C	Down to 0.0012	Down to 0.0001
Ultimate bending strength (in kg/sq cm)	Up to 600	Up to 3,000

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Along with the improvement in the electrical properties of radio materials, of no less importance has been the improvement of their physical and mechanical properties, i.e., moisture resistance, heat resistance, thermal expansion, heat conductivity, and mechanical strength.

A great many raw materials are used in the production of modern radio insulating materials, especially radio ceramics. While the ordinary electrotechnical porcelain contains porcelain clay, feldspar, and quartz, the production of the modern radio ceramic requires, in addition to clays, oxides of barium, calcium, titanium, strontium, zirconium, and other elements. This necessitates a complex technology and new methods for forming and firing parts.

GOST (State All-Union Standard) No 5458-50 for high-frequency ceramic materials subdivides these materials into six classes and establishes definite electrical, physical, and mechanical indexes for each class, as shown in Table 2.

Table 2. Electrical and Physicomechanical Properties of High-Frequency Ceramic Materials (Radio Ceramics), According to GOST 5458-50

Class	Group	Dielectric Const at f Equal to 0.5-5 Mc	Temp Coef of Dielectric Const for t = +20-+80°C and f = 0.5-5 Mc	Dissipation Factor ($\tan \delta$) for f ≤ 1 Mc: t = 20° ± 5°C	t = 80° ± 5°	When Moist
I	a	130-170	$-(1500 \pm 150) \times 10^{-6}$	6×10^{-4}	8×10^{-4}	8×10^{-4}
	b	70-90	$-(700 \pm 100) \times 10^{-6}$	6×10^{-4}	8×10^{-4}	8×10^{-4}
II	--	20-35	$-(50 \pm 20) \times 10^{-6}$	6×10^{-4}	8×10^{-4}	8×10^{-4}
III	--	[illegible]	$+(30 \pm 20) \times 10^{-6}$	6×10^{-4}	8×10^{-4}	8×10^{-4}
IV	a	7.5	$+(110 \pm 30) \times 10^{-6}$	8×10^{-4}	10×10^{-4}	10×10^{-4}
	b	7.5	$+(300 \pm 200) \times 10^{-6}$	20×10^{-4}	30×10^{-4}	22×10^{-4}
V	--	6.5	$+(110 \pm 30) \times 10^{-6}$	12×10^{-4}	18×10^{-4}	15×10^{-4}
VI	--	7	Not standardized	12×10^{-4} at 300° ± 10°C	--	--

Class	Group	Ultimate Strength Under Static Bending (kg/sq cm), at Least	Density (gm/cu cm), not More Than:	Hydroscopic Factor (%) not More Than:	Name of Material in This Class
I	a	800	4.3	0.02	Tikond-150 (T-150)
	b	800	4.3	0.02	Tikond-80 (T-80)
II	--	800	4.3	0.02	Termokond M (TK-20)
III	--	800	4.0	0.02	Termokond R (TK-R)
IV	a	1400	3.2	0.02	Radiosteatite
	b	1400	3.2	0.02	Steatite
V	--	2500	3.4	0.02	Ultraporcelain
VI	--	600	2.8	Up to 20	Corundum ceramic

The main advantages of the new radio ceramics produced by Soviet plants are the high stability of their electrical characteristics and also the availability of materials with positive or negative temperature coefficients of dielectric constant. The latter permits temperature compensation of the parameters of oscillator circuits. It is very important that various parts of very small size can be mass-produced from these materials. Metalized radio ceramics guarantee hermetic seals for various parts of radio equipment.

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One of the most interesting varieties of radio ceramics produced at present is the seignetto ceramic, first studied by B. M. Vul', Corresponding Member of the Academy of Sciences USSR and Stalin Prize winner. Seignetto ceramic is distinguished by its exceptionally high dielectric constant, nonlinear dependency of dielectric constant on applied voltage, and by its piezoelectric effect. These characteristics invite extensive applications; in particular, it can be used for the production of miniature capacitors of high capacitance (see appended figure) and for crystal elements (as in pickups, for example). It can be used as a nonlinear circuit element as, for example, in dielectric amplifiers. Many Soviet scientists are now working on problems involved in the application of seignetto ceramics.

Along with ceramic electric insulating materials, glass of varying composition is used extensively in radio engineering. Soviet scientists and engineers have now worked out the production technology of glass with assigned physical and electrical properties. Industry is producing types of glass with different softening temperatures which do not change their properties when acted on by acids and bases. These types have definite coefficients of thermal expansion and breakdown voltages which considerably exceed those of ceramics. Glass hardened in a special manner (stalinite) can withstand heavy shocks.

Fibers made from very fine flexible glass threads (glass fiber) are extensively used as insulation. Easily fused glass of special composition is used as a dielectric in miniature capacitors with low capacitance. The ability of glass to fuse easily with various metals (given the proper choice of coefficients of thermal expansion for glass and metal) makes it useful in obtaining hermetic seals for some radio components.

However, ceramic and other inorganic materials cannot satisfy all requirements of radio engineering for insulating materials. In many cases, insulating materials are required that have enough flexibility so that thin, strong filaments, sheets of any thickness, and even films can be made from them. Moreover, high electrical properties of the materials must be maintained. These requirements can be fulfilled by plastics. The discovery and use in engineering of these organic substances has been of enormous importance, and now plastics are used in almost all branches of industry.

The synthesis of plastics and their ability to change from the liquid to the solid state is based on the complex chemical effects of polycondensation and polymerization. For example, the solid polystyrene is obtained from the liquid hydrocarbon styrene by means of polymerization. Polymers and the materials produced from them (varnishes, synthetic fibers, films, and others) have been thoroughly studied and are being used in the radio industry and in other branches of the economy.

Let us discuss briefly some of the more remarkable new plastics. Plastics are subdivided into two groups, thermoplastic and thermoreactive, on the basis of their physicochemical properties. Thermoplastic materials soften under heating, harden after cooling, and can be softened again. In contrast to these materials, thermoreactive materials suffer a sharp change in properties under heating. In hardening, they obtain considerable mechanical strength and lose their ability to be softened again by heating. Both groups are used in the pure form or mixed with various fillers for the production of radio components.

Plastic radio parts designed for use in high-frequency circuits are produced mainly from pure polymers without fillers. Among the high-frequency plastics with good electrical properties are polystyrene, polydichlorostyrene, polyethylene, and polytetrafluoroethylene (see Table 3). These are all neutral or weakly polar dielectrics which are obtained by the combining of simpler molecules. Tube sockets, coil forms, extrusions, insulators, and other radio parts are poured under pressure from polystyrene. Polystyrene films are used in capacitors of the paper type; these capacitors are close to the mica type in properties.

Filaments and films of polystyrene are called styroflex. Film styroflex can be produced in thicknesses down to 0.015 mm. A feature of styroflex capacitors is their very high insulation resistance; their time constant exceeds several score hours. Polystyrene insulation is also used in the production of high-frequency cables.

[See table on following page.]

Table 3. Basic Properties of the New Organic Materials Used in Radio Engineering

Name	Density (gm/cu cm)	Dielectric Const	Dissipation Factor for rf and t = 20°	Heat Resistance*	Frost Resistance	Ultimate Bending Strength (kg/sq cm)	Impact Strength (kg-cm/sq cm)
Polystyrene	1.03-1.05	2.5-2.7	~0.0002	60-70°	--	400-1,000**	6-10[1]
Polydichlorostyrene (symmetric structure)	1.4	2.5-2.7	0.0003	90-100°	--	400-1,000	4-8
Polyethylene	0.92-0.95	2.0-2.3	0.0003	60-80°	down to 50°	--	--
Teflon	2.1-2.3	2.0	0.0002	to 200°	down to 100°	--	--
Eskapon	1.0	2.7-3.0	0.0005	80-110°***	--	--	12-7***
Silicon-organic Materials	--	2.3-3.5	0.0003-0.0010	150-200°	down to 60°	--	--
Polyamide resins (kapron, polyuretane)	1.1-1.2	3.5-4.2	0.02-0.04	80-100°	down to 50°	1,000	50-100

*Temperature of maximum heating in operation.

**Depending on the degree of orientation of the molecules.

***Depending on the degree of polymerization.

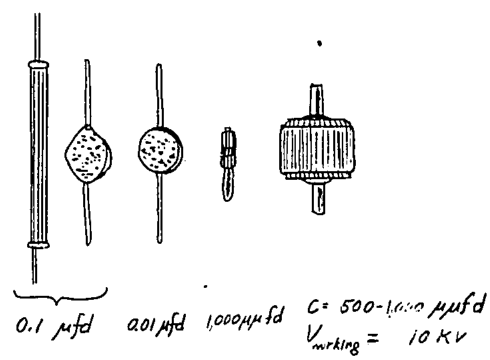
Polydichlorostyrene is close to polystyrene in its properties, but its heat resistance is better. Polyethylene is used to insulate high-frequency cables and some assembly parts because of its electrical properties, elasticity, frost resistance, and nonhygroscopic qualities. Sheets, films, shaped parts, and cable insulation are prepared from polytetrafluoroethylene, better known as teflon. Teflon is characterized by its high chemical stability and heat resistance.

Eskapon, a new synthetic material which replaces ebonite, was developed in the laboratory of P. P. Kobeko, Corresponding Member of the Academy of Sciences USSR. Eskapon, obtained by the polymerization of synthetic rubber, is characterized by high heat resistance, high electrical properties at radio frequencies, and is easily worked mechanically. It is used for the production of assembly parts.

The newest group of plastics includes polyamide resins, which have exceptionally high mechanical tensile strength and impact resistance, high heat resistance, and good adhesion and elasticity. Very fine filaments and fibers can be obtained from these materials. Polyamide resins are known under the names of nylon, polycaprolactame, capron, and also polyurethane. These materials are used mainly to replace silk in the insulation of wires and for mechanical protection and hermetic sealing of paper and ceramic capacitors and other parts. A defect of the organic materials listed above is their comparatively low heat resistance.

Professor K. A. Andrianov has developed new electrical insulating materials, namely, silicon-organic high-molecular compounds. These compounds may be liquid, elastic, or solid. They do not break down at temperatures of the order of 200°C. Silicon-organic insulation is used extensively in the form of varnish coatings to improve the moisture resistance of radio parts. The elastic properties of silicon-organic compounds also make them useful for heat-resistant insulation for wires, cables, and other parts which must operate under difficult conditions. Silicon-organic insulation is a notable accomplishment of Soviet science and is finding ever-increasing practical application.

[Appended figure follows:]



Seignetto Ceramic Capacitors (3/4 actual size)

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