Epoxy resins and materials based on them

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Epoxy resins are among the most important types of synthetic resin, which is governed by their unusually wide range of properties and the variety of areas of application of materials based on them. These include electrical insulation compounds, various paint and varnish materials and powder paints, and binders for composite materials of most varied designation—from fishing rods and sports equipment to constructional elements of airplanes, missiles, and ships. They also include adhesives working at temperatures from absolute zero to +300 °C in air, in water, and in different aggressive media, and also many other materials.

The world production of epoxy resins in 2000 exceeded 1 Mt. The expected increase in the consumption of epoxy resins in the United States and Western Europe is 3.5–4% per annum, and slightly lower in Japan. The production of epoxy resins in China, South Korea, and Taiwan is developing intensively.

About half of all epoxy resins are used for the production of coatings, including powder paints, and here the latter area of application is developing at the highest rates. Roughly 25% of epoxy resins are used for the production of electrolaminates, including non-flammable laminates. In the USSR, in 1989 roughly 57 kt of epoxy resins was produced at eight large enterprises, and the consumption exceeded 100 kt. The production of epoxy resins in Russia does not at present exceed 10–12 kt/year, and here over 9% of production is done at the Ufa Ufakhimprom Open Joint Stock Company.

With respect to the chemical nature of the initial feedstock, all epoxy resins can nominally be divided into two groups:

- resins based on diphenylolpropane (so-called epoxy–bisphenol-A resins);

- resins based on other types of feedstock. Epoxy–bisphenol-A resins account for over 70% of the world production of epoxy resins. The range of epoxy–bisphenol-A resins is extremely wide: from low molecular weight liquid resins (molecular weight (MW) ≈ 350) to solid oligomers with a MW over 5000; high molecular weight resins with MW = 30 000–50 000 and containing end epoxy groups are well known. In connection with the intensive development of the production of powder paints abroad, solid resins account for a significant proportion of the production of epoxy–bisphenol-A resins. In Russia, practically all resins produced are liquid or medium-viscosity resins; the main grades are ED-22, ED-20, ED-16, and E-40. Solid resins of grades ED-8, E-41, E-23, E-49, E-05K, and some others are produced in small quantity. Solid resins are produced both in “dry” form and in the form of solutions in different solvents.

For the production of epoxy materials with a combination of properties that cannot be achieved using epoxy–bisphenol-A resins, use is made of epoxy resins based on other types of feedstock. Thus, for the production of low-flammability or non-flammable epoxy composites, wide use is made of resins based on tetrabromodiphenylolpropane. Foreign companies are producing a wide range of brominated epoxy resins, and previously in the USSR a whole number of resins based on tetrabromodiphenylolpropane were also produced. The grades of these resins were UP-631, EDB-12F, EDB-8F, etc. To produce materials with increased heat resistance, use is made of epoxy resins based on polyphenols and phenolic and cresol–aldehyde novolacs. Epoxy resin based on phenol–formaldehyde novolac of grade UP-643 and resin of grade ETF based on triphenol are now being produced in Russia in limited quantity. Abroad, for
the production of high-purity heat-resistant sealing moulding materials for the electronics industry, wide use is made of epoxy resins based on o-cresol–formaldehyde novolacs, but these resins are no longer produced in Russia.

To produce high-strength heat-resistant polymeric materials, use is made of epoxy resins based on aromatic amines, aminophenols, and heterocyclic compounds. The main area of application of these resins is as binders for composite materials, mainly carbon fibre reinforced plastics working at elevated temperatures.

There exists a wide range of epoxy resins that are hardly used independently but are intended for modification of the properties of epoxy composites and polymeric materials. These are primarily low-viscosity epoxy resins, mainly based on aliphatic alcohols, monophenols, etc., designed to reduce the viscosity of composites. Some epoxy resins, for example, based on tribromoaniline and phosphorus- or silicon-containing resins, are used as additives to lower the flammability of composites. On the basis of organosilicon epoxy resins, compounds are produced that work at subzero temperatures down to absolute zero. Epoxy resins are known that contain oligoether blocks in their structure; such resins are used for the production of materials of increased elasticity. Thus, whereas for typical epoxy polymers the breaking elongation amounts to 3–5%, for specially selected composites it can exceed 100%.

A whole number of epoxy resins have been developed and successfully tested, possessing specific features, for example, optically transparent resins with both a low and, conversely, a high refractive index, possessing a dielectric permittivity prescribed within certain limits, possessing the ability to absorb X-rays and γ-radiation, etc.

Unfortunately, the vast majority of epoxy resin grades previously developed are not now being produced in Russia. There are also virtually no new promising developments, while foreign companies are constantly reporting on the development of epoxy materials with improved or fundamentally new consumer properties.

NIIPM, recommencing work on epoxy resins, has set itself the task of revitalising the most promising of the previously developed epoxy resins and materials, and also creating new materials.

A trial plant in the Institute has the necessary equipment for the manufacture of modified epoxy resins, and also epoxy compounds. Epoxy–organosilicon resins of grades SEDM are being produced on the trial plant, and the production of solid epoxy–novolac resins for heat-resistant moulding materials, low-viscosity epoxy modified resins of grades K-115 and K-153A, and also other resins and compounds has been mastered.

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