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Silica and silica-based materials for sorption, catalysis and other applications

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Silica is a material widely used in many applications including sorption, chromatography, drying, storage, catalysis, production of polymer, tires, etc. The size of particles and/or granules, porous structure (including specific surface area, pore volume and pore size distribution) and surface concentration of silanols are the key characteristics of silica that determine its functional properties as an individual material or as a component in mixtures or composites. Silica is usually shaped as spherical granules with diameter of 4-7 mm or microspherical granules with sizes of 50-250 μm. Also, silica is used as a powder in some applications. In Russia, the problem consists in the limited production of silica. Granulated silica is produced by the Salavat Catalyst Plant (the Republic of Bashkortostan), while the production of powdered silica is rather low, and above 40,000 tons of silica are imported to Russia annually. Currently, the production of powdered and microspherical silica and silica-based materials is a challenge for the Russian industry.

The production of granulated silica (spherical granules) is based on the precipitation of liquid glass (nonstochiometric sodium silicate $Na_2O \cdot nSiO_2$) by H_2SO_4 combined with the shaping in column with organic oil. These types of silica are mainly used in gas- and petrochemistry as sorbents. Disadvantage of silica as a desiccant in comparison with alumina or zeolites is instability of granules in the presence of condensed moisture, the destruction of sorbent granules may lead to blocking of the sorption equipment. The development of water-stable silica is important to expand the application of silica as a sorbent. The synthesis of water-stable silica is based on the addition of powdered silica during the process of shaping of silica granules. This leads to the formation of hierarchical porous structure of granules and the decreasing of mechanic stress inside the granules that provide the water resistance.

The synthesis of powdered silica is rather important for tire industry because modern tires contain 25–40% of silica as a filler that improves the characteristics of tires and makes them more ecofriendly. This type of silica also can be produced by the precipitation of liquid glass by H_2SO_4 but without gelation process to keep the low bulk density and size of individual micropherical particles. The silica for tire production features moderate specific surface area (80–200 m^2/g) and wide mesoporous structure that is required for better distribution and bonding with the tire during the vulcanization process. Similar porous structure of microspherical silica characterizes silica used as a support for catalysts of ethylene and propylene polymerization. Wide mesopores are preferable for better contact with the polymers.

Powdered silica is used in food industry (as a sorbent for beer filtration), production of toothpastes, cosmetics, etc. However, the chemical purity requirements are higher for this silica. This type of silica can also be produced from the liquid glass, but the additional purification of the precipitate is required. If the chemical purity requirements for silica are high, the tetraethoxysilane (TEOS) can be used as a silica precursor.

The production of silica with ordered structure (MCM-41, SBA-15, etc.) with unique properties and high chemical purity can also be realized using liquid glass as a silica precursor. Thus, the production of inexpensive MCM-41 or SBA-15 becomes possible, and the application of these materials in sorption, catalysis, medicine, and other areas can be expended. The design of hierarchical materials based on native silica material diatomite and MCM-41 has been suggested.

Thus, the unique porous silica materials can be prepared even from inexpensive precursors such as liquid glass or diatomite. The Russian technology for production of granulated moisture-resistant and powdered silica is required and can be elaborated today in cooperation with the Russian academy and industry.

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