

ELECTRON- MICROSCOPIC STUDY OF SILICOSIS-HAZARDOUS DUST

![Fig. 1](image)

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Fig. 1

Figure 1: Fig. 1

Fig. 2

Figure 2: Fig. 2

Abstract

Full Text

PHYSICAL CHEMISTRY

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ELECTRON-MICROSCOPIC STUDY OF SILICOSIS-HAZARDOUS DUST

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We carried out a study of dust formed during the drilling of blastholes in the mines of the Kizel coal basin, which is characterized by a predominance of hard rocks with a high quartz content. Samples were taken in the following way. During drilling, at the work site, at a height of 1.5 m above ground level, a nitrocellulose membrane filter was placed, through which 100-200 liters of air were drawn. The filter with the deposited dust particles was dissolved in amyl acetate to obtain a 1.5-3% solution of nitrocellulose. By applying a drop of the solution to the surface of water, thin films were prepared in which the dust particles were included.

Fig. 1

Fig. 2

After drying, the specimens were examined in an electron microscope. A preliminary study of films obtained in this way from clean membrane filters showed that they are transparent in the electron microscope and contain no foreign inclusions. The main work was carried out on an EM-3 microscope; a number of specimens were also studied in a UEMV-100 microscope.

Let us consider typical examples from the microphotographs obtained. In specimens with dust samples, formations of three kinds were detected. Figure 1 shows a photograph of a fragment of a mineral with linear dimensions of several microns. Microphotographs of such relatively large fragments are presented in a number of works devoted to the study of dust, including work (1), where preparation similar to that described above was used. Further, spherical particles, about 0.1μ in diameter, forming aggregates (Fig. 2), were detected, and, finally, semitransparent layers containing dark inclusions of spherical shape with

diameters of 0.01–0.1 μ (Fig. 3). Both of these types of formations require more careful consideration.

Let us first turn to the semitransparent layers. They cannot be particles of rock for the following reasons. It is scarcely possible to imagine,

so that, when drilling minerals that do not possess pronounced cleavage, large flat layers of approximately constant thickness repeatedly split off. These layers are fragile and often tear into something like brittle films, as shown in Fig. 4. Finally, in the study of samples of naturally settled dust deposited on a film substrate by the various methods used in electron microscopy (without the use of membrane filters), such layers were never found: the samples consisted of large fragments of irregular shape (of the type shown in Fig. 1) and highly dispersed spherical particles.

All that has been said above allows one to conclude that the semitransparent layers are secondary formations, whose appearance is due to the method of preparation. Let us now consider the spherical particles, which occur either in the form of aggregates (Fig. 2) or included in the semitransparent layers (Fig. 3). There is sufficient basis to regard these particles as highly dispersed particles of mine dust. Their spherical shape, unexpected at first glance, is explained by the fact that they are not monolithic particles, but aggregates of the finest fragments formed during drilling of the rock. It is known that, during fine grinding (with a vibratory mill or ball mills) of various materials—for example silica gel⁽²⁾ or the minerals kaolinite and halloysite⁽³⁾—the product of crushing is a collection of amorphous spherical particles with diameters of hundredths or tenths of a micron. The size of the initial fragments is apparently less than 10 Å, since the spherical particles are amorphous and their edges appear smooth when studied in an electron microscope with a resolving power of 10 Å⁽³⁾.

Consequently, in agreement with the literature data, we are justified in considering that each of the spherical particles shown in Figs. 2 and 3 is a particle of mine dust and represents an aggregate of the finest primary fragments. The formation of such aggregates apparently occurs in the immediate vicinity of the drilling source in the air medium, where the concentration of such fragments may be very high.

At present, considerable experimental material is known which indicates that the new surfaces formed during the mechanical destruction of solids contain uncompensated valences—free radicals—and, consequently, possess increased chemical activity. This has been established for quartz and other inorganic materials^(4, 5). The occurrence of free radicals under mechanical action has acquired particular importance for the mechanochemical synthesis of polymers⁽⁶⁾.

These facts prompted us to check for the presence of free radicals on particles of silicosis-hazardous dust. Several series of dust samples were selected for study: directly from the borehole during drilling, one week old, and two years old. By the method of electron paramagnetic resonance it was established that dust samples of the first two series contained $3\text{--}6 \cdot 10^{17}$ unpaired electrons per 1 g*.

Figure 3

Figure 3: Figure 3

Figure 4

Figure 4: Figure 4

An approximately twofold lower concentration of free radicals was determined in dust samples two years old. For comparison, we note that a concentration of free radicals in the range 10^{16} – 10^{17} per 1 g was established for quartz ground with a vibratory mill ⁽⁴⁾. The presence of free radicals on the surface of mine-dust particles gives us grounds, as it seems to us, to put forward the following two assumptions.

1. The semitransparent layers shown in Figs. 3 and 4 are the product of the interaction of free radicals located on the surface of settled mine-dust particles with the material of the membrane filter. As a result of such chemical interaction in the surface layer of nitrocellulose

* The study of dust samples by the EPR method was carried out by Yu. N. Nedoshivin, for which the authors express their gratitude to him.

To the article by V. M. Luk' yanovich and V. V. Makhinko, p. 609

Fig. 3

Fig. 4

its structure changes, it becomes insoluble in amyl acetate, which also leads to the appearance of semitransparent layers after dissolution of the main mass of the film in amyl acetate*. Consequently, in Fig. 3 we have a microphotograph of such a layer with dust particles embedded in it—the initiators of formation of this layer. As for the aggregates of spherical particles (Fig. 2), their appearance is not difficult to explain if one takes into account that a sufficiently thick deposit of dust accumulates on the film, so that its upper layers may not be in contact with the film. The aggregates of particles found here may prove sufficiently strong and may not be destroyed during further preparation.

2. The cause of silicosis is the interaction of free radicals located on the surface of dust particles with lung tissue. This appears quite probable if one takes into account the high chemical activity of free radicals. As one of many examples, we point to the occurrence of the polymerization reaction of styrene and methyl methacrylate at room temperature as a result of vibratory milling of a mixture of these substances with quartz; the free valences that arise during the crushing of quartz initiate chemical reactions ⁽⁸⁾. Thus, one may suppose that, under the influence of free radicals, lung tissue passes into a cross-linked state, which is one of the signs of the disease. In this respect the insoluble layers formed from nitrocellulose

(Fig. 3) may be regarded as a certain model of what lung tissue turns into under the action of silicosis-hazardous dust.

If the views set forth are correct, then the dissolution of quartz spherical dust particles in lung tissue (it is known that such dissolution of quartz particles does occur) must be accompanied by the exposure of ever new free radicals and their gradual entry into action. Therefore the harmful action of dust must take place over time. At the same time, the circumstance that free radicals may be enclosed inside dense spherical dust particles may be one of the reasons for their stability when the dust is stored under ordinary conditions.

In light of the views set forth, one should expect that dust formed during the crushing of any hard materials will cause pulmonary diseases if this dust contains free radicals in a sufficiently active form. This consideration is consistent with the fact that, in addition to silicosis, other types of pneumoconiosis are known. Thus, silicate dust causes silicatosis, coal dust—anthracosis, etc. One of the aims we had in mind when writing the present article was to raise the question of the possible harmful, physiologically speaking, action of dust formed during the comminution of hard materials, because of the presence in it of free radicals. Further investigations in this direction should, in all likelihood, include the study of such dust by the method of electron paramagnetic resonance in combination with the study of its physiological action.

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* Analogous phenomena—the loss of solubility of latexes, collodion films, and

similar materials under the action of various radiations—have been described more than once in the literature on electron microscopy (⁷).

Note: Figure translations are in progress. See original paper for figures.

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