Nanocomposite magnetic powder materials using mechanochemical Synthesis

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Abstract

The materials showing high structure dispersity are developed on the quartz base and they are obtained by mechano-chemical technology. Depending on the processing conditions and subsequent applications the materials produced by mechano-chemical reaction show concurrently magnetic, dielectric and electrical properties. The obtained magnetic-electrical powders classified by aggregate complex of their features as segnetomagnetics, contain a dielectric material as a carrying nucleus, particularly the quartz on that surface one or more layers of different compounds are synthesized having thickness up to 10~50 ㎚ and showing magnetic, electrical and other properties.

Keywords : mechano-chemical reaction, magnetic-electrical powders, segnetomagnetics

1. INTRODUCTION

The composite materials showing concurrently dielectric and magnetic properties have now found their particular place in microelectronics aimed at developing proven memory and storage devices as well as to creating different transducers, modulators and electromagnetic spin and acoustic spin wave generators. Such materials are classified as segnetomagnetics. The reversibility of polarization in electromagnetic field; reversibility of magnetization in magnetic field; double optical refraction (natural and modulated) and absorption; dependence of resonance frequencies of spin waves on the applied magnetic field and stable operation within millimetric and IR bandwidth are the most important factors determining their applications.

One of the most promising and effective ways in developing of segnetomagnetic materials having required properties is a targeted synthesis of solid solutions and production of materials showing nanocomposite structures of surface layers. The above mentioned layers may be performed in certain stratified sequences of crystalline, amorphous or organometallic structures having different properties varying in a very wide range including electrical, dielectrical, magnetic and many other properties depending on the special applications of such materials.

2. EXPERIMENTAL

The mechanochemical synthesis is applied to obtaining such powder composites when concurrently to intensive dispersion of particles in dynamic highly powered mills the chemical reactions are proceeding between substances subjected to milling. Specially selected conditions of mechanical processing of powder mixtures having predetermined compositions will result in obtaining particles showing layer-by-layer changes in phase compositions, structures and properties. The potentialities of mechano-chemical synthesis applications are limitless, making possible to obtaining materials with

divers combinations of structures and properties across the particles notable for their high dispersity, including particles classified as segnetomagnetics.

In the Institute of Combustion Problems the materials showing high structure dispersity, are developed on the quartz base and they are obtained by mechano-chemical technology. Depending on the processing conditions and subsequent applications the above mentioned materials show concurrently magnetic, dielectric and electrical properties.

3. RESULTS AND DISCUSSION

The obtained magnetic-electrical powders contain a dielectric material as a carrying nucleus, particularly the quartz on that surface one or more layers of different compounds are synthesized having thickness up to 10~50 ㎚ and showing magnetic, electrical and other properties. Such materials are classified by aggregate complex of their features as segnetomagnetics. The synthesis of surface layers of quartz particles is proceeding with involvement of different organic compounds and halogenides in reaction, including the salts of transition metals. The properties of obtained materials are determined by used modifying additions and by conditions of mechano-chemical processing. So, in process of quartz dispersion in centrifuge-planetary mills at platform rotation rates up to 700 r.p.m., and rotation rates of milling vessels up to 1200 r.p.m., using different alcohols and iron chloride as modifying agents, a quartz powder was produced showing ferromagnetic properties. The obtained material was investigated by IR, EPR and Messbauer spectroscopy methods. The induced ferromagnetism of quartz was determined by variations of relatively "efficient" index of magnetic permeability (μ) of the powder compacted into the tablet of 1.4~1.5 g/㎤ density. The quartz ferromagnetism was registered after five minutes of processing [1].

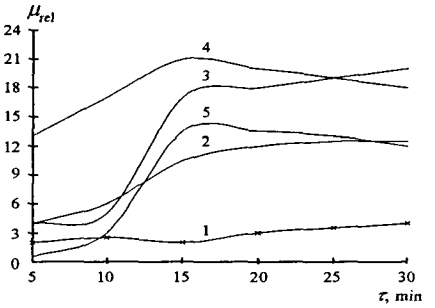

Fig.1. Dependence of magnetic permeability on the time duration of activation of quartz (1), quartz with additions of 5 % ethanol (2), buthanol (3), ethyleneglycol (4), 15 % iron chloride (5).

Fig. 1 presents the investigation results obtained for changes in quartz magnetic permeability with processing time duration. With extension of processing time from 5 minutes to 30 minutes the magnetic powder permeability increases from 2 to 4. With 5 % alcohol (ethanol) addition to the reaction mixture, the quartz magnetic permeability increased from 4 to 12 during 30 minutes of milling process. In presence of butanol known as effective modifying agent of the surface of particles subjected to dispersion, the magnetic permeability of studied material increased within 30 minutes of processing. The use of bibasic alcohol (ethyleneglycol) as organic addition results in showing of ferromagnetic properties by quartz even after 5 minutes of material processing. Its magnetic permeability increased to 13. After more prolonged exposure to processing (over 15 minutes) the magnetic permeability increased up to 21. Then a certain decrease of value was determined down to 17. With use of iron chloride as a modifying agent the magnetic permeability of treated quartz didn't exceed 14.0. It is known [2] that the magnetically ordered state of deformed particles

is determined by formation of defective structure consisting of charged hole centers with formation of collective spin. In this connection a significant role is attributed to the structure of surface layers those formation is mainly determined by alcohol additions. In conditions of intensive mechanical processing (high local temperatures and pressure) a destruction of organic compounds and their interactions with active deforming centers are occurred on the surface of quartz particles [3].

This results in modification of particle surface with inoculation of organic complexes on the sililenic (=Si*) and siloxane (=SiOSi=) reaction centers. So, for example, in case of alcohol use there are hydroxyl and metaxyl groups. The presence of transition metals promotes the polymerization of solid surface resulting in occurring of metal-polymer formations. The results of spectral analysis methods confirmed that the ferromagnetism of the quartz subjected to mechanochemical processing is resulted of formation of ordered defective structure and iron-containing clusters in polymer matrix on the surface of the particles to be dispersed in presence of alcohols (ethanol, butanol, ethyleneglycol) and iron chloride. The obtained experimental results confirm possibility of capsuling of mechanically treated solid quartz particles into the metal-polymer nanostructure sheath showing magnetic properties, for example of "claspol" type. The metal-polymers of "claspol" type are the polymer matrices with metal clasters in the cavities [4]. They have unique electrical, physical and magnetic properties that wide range is determined by multiphase structure of metal nanoparticles interacting with polymer matrix.

4. CONCLUSION

The similarity of the structure of surface layers of quartz particles subjected to mechano-chemical processing and nanostructure "claspol" materials is also confirmed by the fact that the characteristics of ferreomagnetic quartz are changed with time, after its processing completed. The magnetic permeability of the sample is decreasing within first two months down by 15~20 %. Then the characteristics are stabilized. The observed changes are related with defective structure of the particles, elastic stress relief, and changes in electron density and magnetic moment of deformation zones. This process of stabilization of the studied properties may be intensified by short time annealing of the powder at 100~150℃ temperatures.

Acknowledgements

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