UDC 669.24/29.018:[539/25+539/26]

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ON THE MECHANISM OF STRUCTURE FORMATION OF DEAD-HARD CARBON PHASE IN THE NANOCOMPOSITE SYSTEM OF Fe – C FOR WOODWORKING TOOLS

In the article hypothesized that the formation of particulate gray superhardness carbon phase occurs through a stage of transition nanocarbon component of the mixture into a liquid state under high-sintering method of consolidation.

Introduction. Currently there is a rapid development of researches and developments in the sphere of nonmaterials and nanotechnologies – strategically important research area in developed countries which are related to the new technological revolution. These researches are interdisciplinary between physics, chemistry, biology, medicine and material science and require new instrumentation for diagnosing, clean rooms, new organizational approaches.

Along with the development of new techniques and new technologies new challenges for the development of all economic sector including the medical, food, cosmetic, automotive, electronics, etc are offered because of more complete study of the processes occurring at the atomic and molecular level.

Compositional materials are becoming fundamentally new qualities if they are based on nanostructured “building blocks”. Their mechanical, magnetic, and optical properties have considerably changed. Such composites are greatly known because of increase of hardness and strength, on the other hand, the increase of their elasticity and super flexibility is also possible.

In the past decade, the authors have worked to find ways to create a composite material based on Fe – C tool with a use of nano-carbon additives and nanotechnologies. We study the possibility of replacing expensive fullerenes used by several authors, by the cheaper nanocarbon materials.

Main part. As a result of sets of works some samples of nanocomposite material based on Fe – C with inclusions of dead-hard particles (Hμ from 10 to > 30 GPa) with a high elasticity of a diamond-like phase and ironcarbon matrix of high hardness (Hμ 5–11 GPa) were obtained. Macrohardness of nanocomposite samples is in the range 60–90 HRC. The composite basis of all the samples has nanostructured state – crystallite size ~10–40 nm. To obtain nanostructured composite a high-energy method of consolidation of powder materials was – sintering under high pressure and nanocarbon additives – fullerene soot, multiwall nanotubes, extract fullerene soot, fullerene black and ultrafine particles of diamond (UDD). For comparison, we prepared samples with the introduction of the C_{60}, C_{70}, single-walled nanotubes, carbon microparticles with 3, 4, 9 mm size and a standard graphite in the same conditions. Carbonyl iron powder was used for iron base. The ratio of Fe: C was 97–90: 3–10 wt %. All samples with nanocarbon additives contain dead-hard phase. The size, shape and number of superhard phase vary and are determined by compaction parameters modes except the state of the original components and preparation charge technology [1].

These results allow suggesting that with the application of high-energy method of nanopowders consolidating the formation of “superelastic and hard carbon particles” in the Fe – C nanocomposite is not only from fullerenes but also from other cheaper nano-carbon additives: fullerene soot, multiwall nanotubes, etc.

Four main types of gray phase were defined during the analysis of the microstructure of all samples (Fig. 1 and 2):

– Gray phase “calculous” without trace of grinding, polishing, with a smooth relief;

– Gray phase “foundation” is ground and polished;

– Gray phase with a relief “zigzag” without trace of grinding-polishing with a rolling topography and disperse inclusions;

– “Dark-gray smooth phase” with cut or rounded.

Each of morphology phases is characterized by its particular resistance to indentation of diamond indenter during microhardness measurements (Fig. 1): during measurement of microhardness many impressions are absent after application of the indenter (Fig. 2, *a*), in other cases, instead of usual quadrangular indenter impressions (Fig. 2, *d*) there are micro images or “luminous optical crosses” (Fig. 2, *b*) or penciled crosses (Fig. 1, *c*).

The diagonal of impressions is often determined according to the size of these crosses.

As a result of all analysis of the microstructure of all the samples we found that the main feature of the morphology of gray phase “foundation” is that the particles of iron base as though were inserted into this gray phase as if there was a gray phase during sintering in a liquid state. This is illustrated by the gray phase morphology of the "foundation" in the samples microstructure in Fig. 2 (90% Fe + 10% wt. C – fullerene soot).

According to the analysis of samples microstructures produced in 2006–2009 it is hypothesized that the particles deadhard diamond-like carbon phase form through a phase of transition of nano-carbon component of the charge in the liquid state at high-sintering method of consolidation.

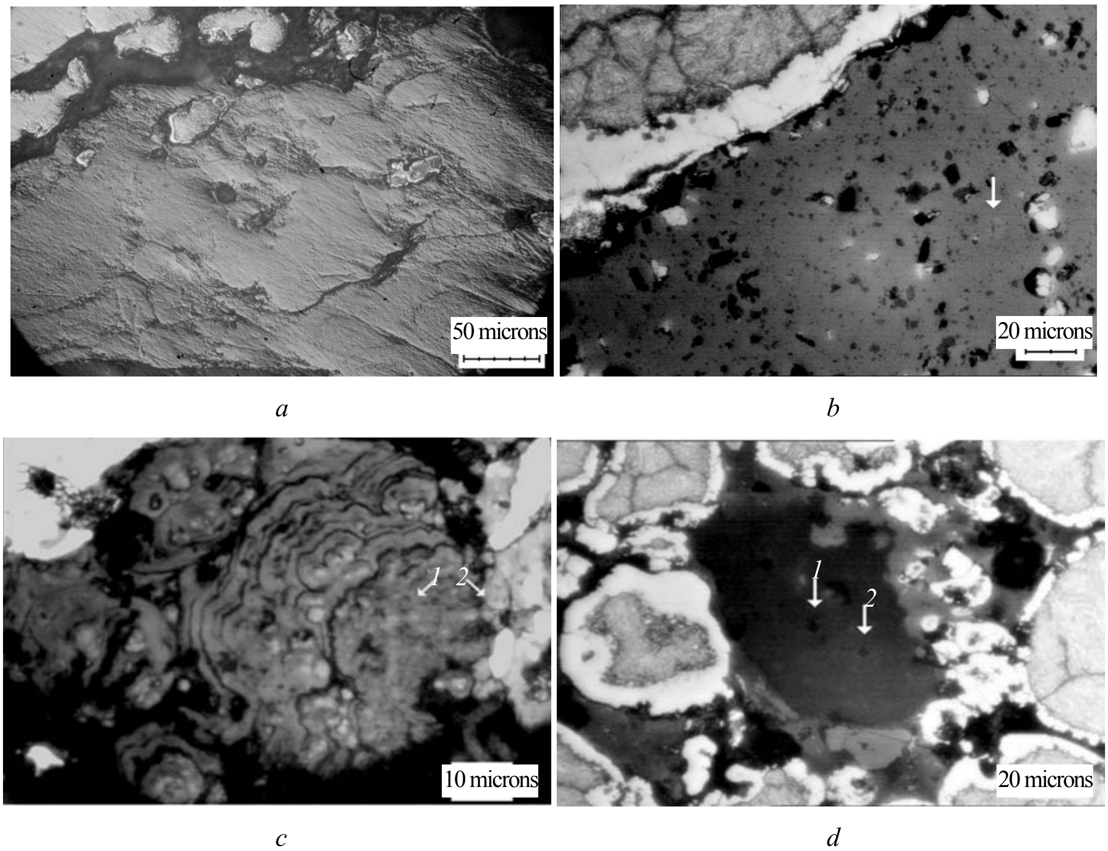
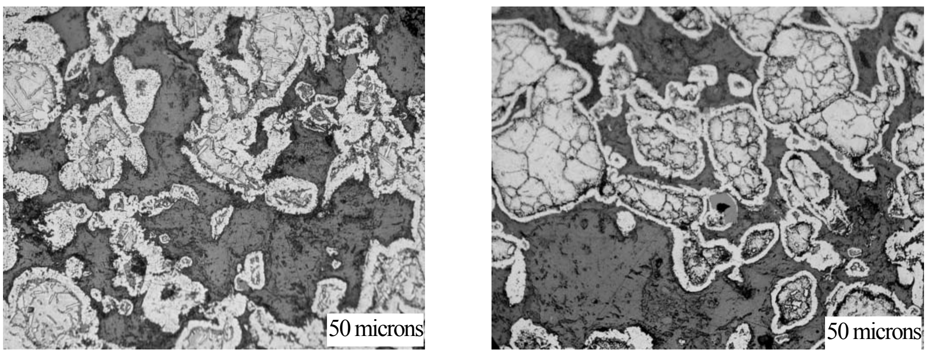


Fig. 1. The morphology of the gray phase in the samples – 90% of carbonyl Fe:
a – gray phase "calculous" – 10% of multiwall nanotubes, impressions ◆ are practically invisible, Hμ > 30 GPa;
b – gray phase "foundation" 10% of the fullerene soot, impressions +, Hμ = 77.91 GPa;
c – gray phase with a "zigzag" relief – 10% of fullerene black after use of impressions at the site of arrow *1*, at the load P = 100 g, Hμ = 28.28 GPa and P = 200 g, Hμ = 80.85 and 89.21 GPa, microhardness impressions are practically invisible, one impression bounced – moved out from particles to the right of the arrow *2*, the image is focused on the luminous optical cross (arrow *1*);
g – "dark-gray smooth phase", impressions ◆, Hμ = 35.81, 64.33 GPa (by the arrows *1* and *2*)



a *b*

Fig. 2. The morphology of gray phase "foundation" in the samples – 90% Fe + 10% wt. fullerene soot

Why does this liquid carbon state become possible to liquefy carbon at sintering our samples?

Sintering of these samples by tested technology of high-consolidation powder materials was carried out at high pressures – 4 and 5 GPa what is the limit for the existence of the liquid phase on the phase carbon diagram and the sintering temperature – from 950 to 1,200°C are lower than in the figure – in the range of 4,000–5,000 K.

However, we know that increasing the dispersion of particles, grains, and crystallites leads to lower temperatures of phase transformations [2, 3].

As a result we can assume that in a high-consolidation of nanocrystalline carbon condition the shift of boundaries of graphite – liquid – vapor-diamond towards lower temperatures and pressures is possible.

Consequently, the use of high-energy consolidation of nanocrystalline carbon under high pressure – 4, 5 GPa and nanodispersed carbon particles in our conditions is possibly and provide the conditions of formation of liquid carbon phase in the process of consolidation of the high-energy at temperatures from 950°C to 1,200°C, i. e. respectively from 1,223 to 1,473 K.

Such a hypothesis about the mechanism of structure formation of dead-hard diamond -like carbon phase is new and can be used to manage the development of creating new materials. The first experimental sample with a reverse ratio of the initial components – 90% fullerene soot + 10% wt was held on the basis of these findings. Fe. So, the composite samples were obtained with the three main types of gray phase: with a relief "zigzag", "dark gray smooth phase" with the cut and the gray phase is the "foundation" and it is the last phase which the basis of the composite (Fig. 3).

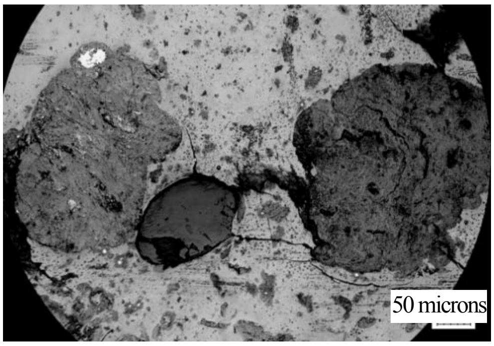


Fig. 3. The morphology of the particles and the "foundations" of the gray phase in the sample – 90% of fullerene black + 10% of carbonyl Fe

Conclusion. The first results of the experiment on the basis of the mechanism of structure formation of dead-hard diamond-like carbon phase which allows its use in the development of technologies and creating new materials using low-cost nano-carbon materials are fullerene soot, multiwalled nanotubes, fullerene black (the latter is actually the unused waste product of fullerene).

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Received 20.03.2012