Structure commonalities of nanostructured diamond particles obtained during various kinds of synthesis

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Introduction

1. Certification of nanostructured particles of diamond powders obtained under various synthesis conditions at high pressures to identify common characteristics and differences in their substructure elements. 2. Determination of the possibility of using powders to obtain monophase nanodispersed polycrystalline materials.
Diamond powders, differing in synthesis conditions, of the following varieties: 1. Detonation synthesis diamond (UDD) obtained from explosives. For the study, we used powders obtained in Ukraine, Belarus, Russia (5 types of powder). 2.Dynamic synthesis diamond obtained by shock-wave treatment of a carbon substance - graphite (three types of powder) and soot (one type of powder). 3. Diamond of static synthesis obtained by processing graphite under conditions of quasi-hydrostatic compression in the absence of a catalyst-solvent (type 2). 4.Diamond of natural origin (Popigayskoye deposit, type 1).

Methods

X-ray phase analysis and transmission electron microscopy combined with microdiffraction.

Results

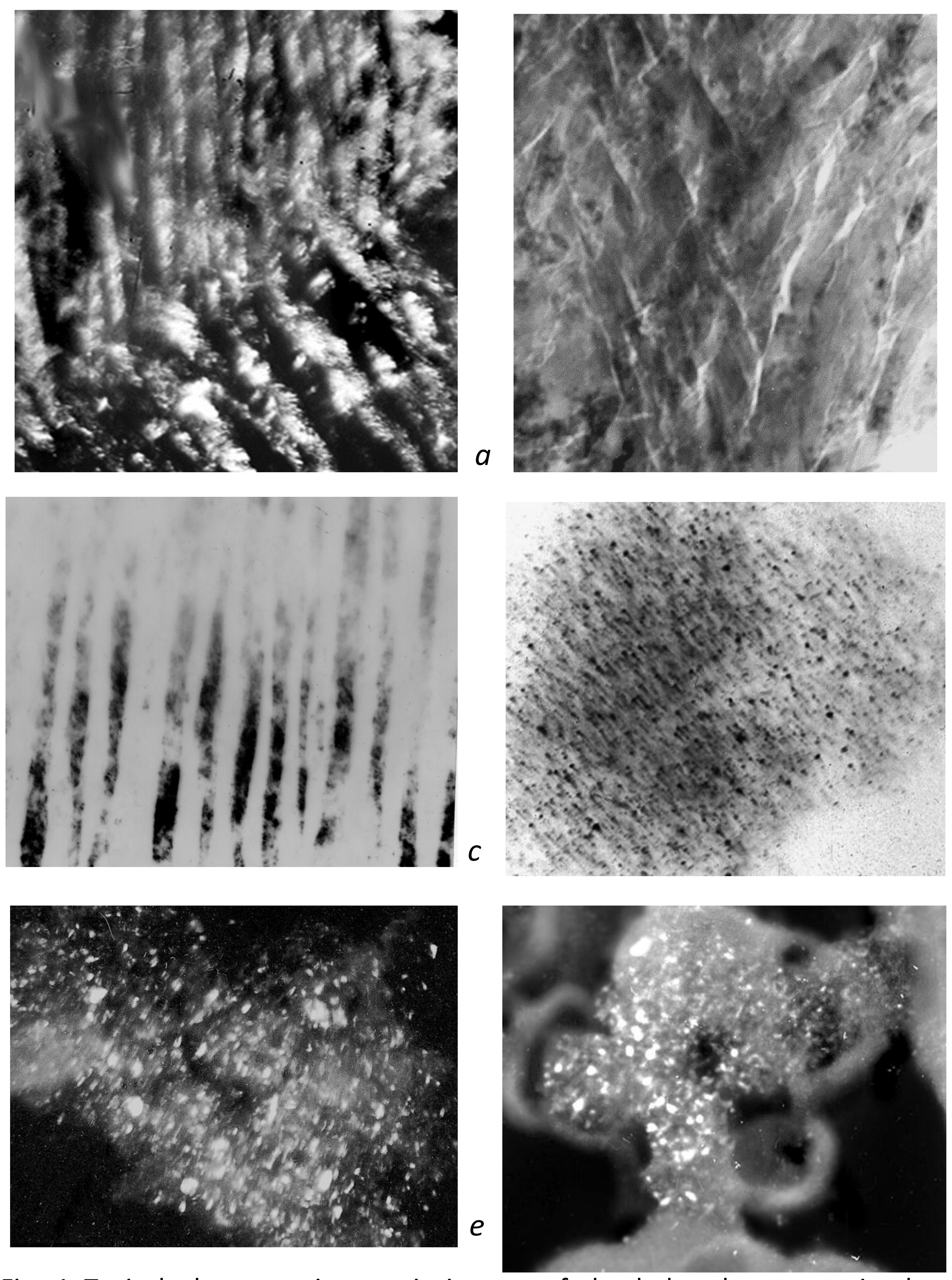

Fig. 1 Typical electron microscopic images of the lath substructure in the particles of the studied diamond powders: diamond particles of dynamic synthesis (a), static synthesis (b), natural (c), detonation synthesis of UDD (d, Snezhinsk; e, Belarus), dynamic synthesis from carbon black (e).

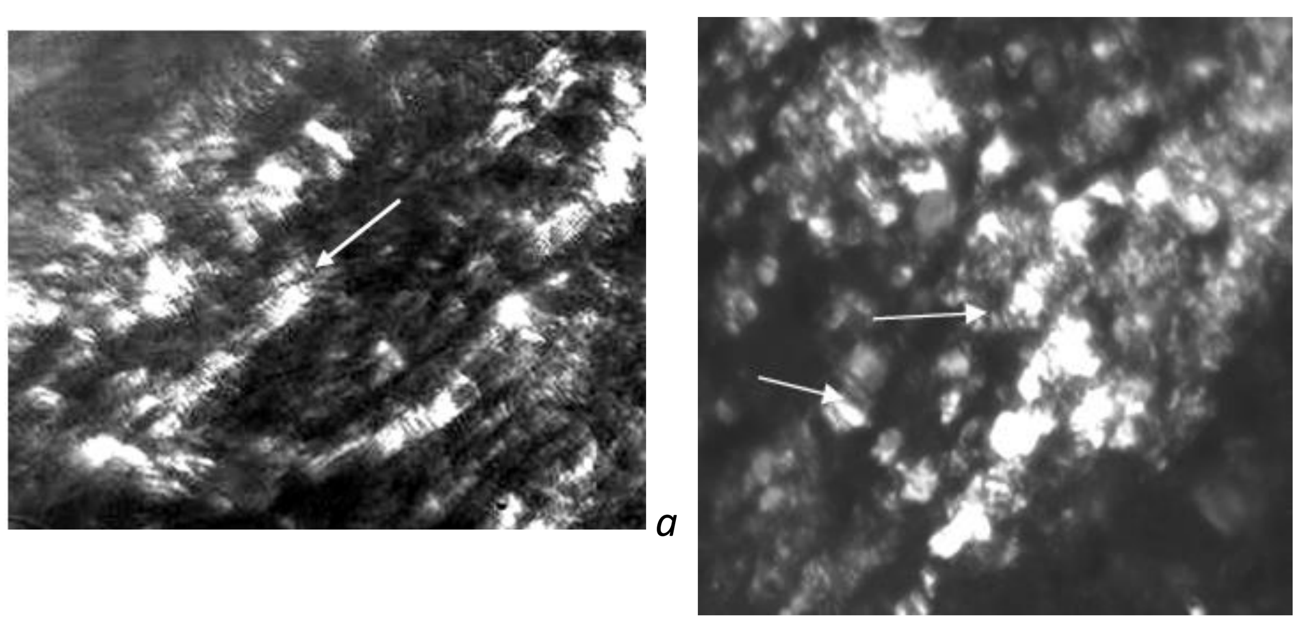

Fig. 2 Intra-lath substructure (basic stacking faults) in laths of particles with a high lonsdaleite content (a) and twinned cubic diamond nanoparticles are indicated by arrows in (b).

Fig. 3. Twins in grains of UDD particles (arrows 1) and groups of grains with internal interfaces (arrows 2) - a; General view of a flocculent UDD formation with grains of non-uniform size - b and a large grain of regular faceting surrounded by nanodispersed UDD grains (c)

Electron microscopic studies revealed the following most characteristic general features of the substructure of the particles of the studied varieties of diamond.
1. The particles of the studied diamonds are mostly polycrystalline and are presented in the form of plates. In the case of UDD, the particles are flat flocculent formations. The size of particles in their developed surface ranges from 1 to 5-7 microns or more. An insignificant fraction of single-crystal particles was identified only for diamonds obtained under conditions of static and shock synthesis. The size in the developed surface of such particles reaches 10 microns and more.
2. The most characteristic element of the substructure of particles of all these types of diamond is a lath, which in most cases is dispersed along its length. Laths inside the particles are grouped in packages (Fig. 1, a-c). Only in the case of particles with a high content of hexagonal diamond in the laths there are basic stacking faults and their fragmentation is practically absent. Fragmented laths consist of two-phase (lonsdaleite + cubic diamond) and / or (monophase - cubic twinned diamond) nanosized fragments. Among the studied samples, the highest content of lonsdaleite is characteristic of static synthesis diamond (and reaches 80%), the lowest (up to 20%) - for UDD. We also established the presence of lonsdaleite in UDD by comparative analysis of microelectron diffraction patterns from individual sections of particles that differ in the area of the lath substructure in the area from which the microelectronogram is taken.
3. The sizes of the fragments along the length of the laths determine the degree of nanostructuring of the particles. Among the studied diamond powders, the smallest fragment sizes (they are usually called grains) are characteristic of UDD (the main component is 3-7 nm - Fig. 3, b) and diamond synthesized from soot - 1-2 nm (Fig. 1, f).
4. Laths in diamond particles (with the exception of UDD) in most cases are in the form of packets, including those misoriented with each other In particles-flakes of UDD from other manufacturers, there are only separate areas of such a substructure. Areas of the lath substructure are also detected in flaky formations of diamond obtained under shock-wave processing of soot (Fig. 1, f).
The width of the laths varies both within individual particles and in different particles of all types of diamond. The maximum width of 30–40 nm is found for particles of static synthesis and natural origin diamonds.
5. The nanoparticles of all studied diamonds have twins. This is most typical for UDD particles, as well as in monophase (based on cubic diamond) fragments formed during the dispersion of laths in diamond particles obtained by dynamic and static synthesis. Twins in the particles of these diamonds are shown in Fig. 3, a and 2, b, respectively.
6. In the particles of powders of all varieties of diamond, two types of substructure elements that are abnormal in size are revealed: groups of nanograins with identifiable internal interfaces (Fig. 2, a) and single-crystal grains, which often have a regular polyhedral faceting. The sizes of single-crystal grains can reach 20 nm and more (Fig. 3, b, c).

Conclusion

1. It was established for the first time that the studied varieties of nanostructured diamonds have a lath substructure. According to [1],
the formation of such a substructure is due to the graphite - diamond martensitic transformation.
2. It was revealed that it is fragmentation (dispersion of laths along the length) that determines the nanostructuredness of powder particles of the studied diamonds.
3. It was revealed for the first time that the particles of the studied diamonds contain anomalous in size monolithic polycrystalline formations of nanograins and single-crystal grains of regular crystallographic faceting, which indicates that already in the process of diamond synthesis, its nanoparticles are consolidated by the type of self-assembly (or self-association). A similar process takes place during P – T sintering of UDD [2].
4. Our data on the structural characteristics of UDD indicate that the synthesis of such diamond is carried out in two stages: the formation of graphite and its subsequent martensitic transformation into diamond. This was discussed in detail earlier [3].

References

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