Transfer of electron flux energy to ceramics formed in radiation synthesis

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Synthesis of luminescent ceramics based on YAG and MgF_2 is possible by direct action of a powerful flow of electrons with an energy of 1.4 MeV on the charge from the source powder. It is shown that for MgF2 there is a threshold of the flux power density equal to 13 kW/cm^2, above which the radiation synthesis of ceramics is realized. The existence of the threshold is explained by the fact that the processes associated with ionization of the material are dominant in the synthesis.

INTRODUCTION

he effect of radiation on materials leads to the creation of defects in them, stimulates diffusion processes, and chemical reactions in solids [1,2]. The result of radiation exposure can be a change in properties, structure, and phase composition. New radiation technologies have appeared and are being developed that provide a new level of modification of properties and synthesis of materials. Shows the possibility of synthesizing luminescent ceramics based on YAG:CE and MgF_2:W from powders of metal oxides and fluorides when exposed to the charge by a powerful flow of electrons with an energy of 1.4 MeV. The synthesis is carried out only at the expense of the energy of the radiation flow for 1 s, without any other additives to the charge with the composition necessary for compliance with stoichiometry. It was found that the synthesis of ceramics occurs at the same power densities above 15 kW / cm^2, although the melting temperatures of materials differ: 1260°C-MgF_2 and 2060°C-YAG. It is assumed that this effect is due to a high degree of ionization in the source materials.

RESULTS

Figures 2 and 3 show photos of samples obtained when the MgF_2 powder charge is exposed to a flow of electrons of different power.

When the charge is exposed to flows with a power density higher than 13 kW/cm^2, ceramic samples with dimensions up to 9x4 cm^2 are formed. Sample sizes are determined by the area of the crucible and the setting of the electron beam scanning system on it. The samples have the appearance of a frozen glassy mass.

The formation of MgF_2 ceramics from MgF_2 powder occurs when a flow of electrons with a power density above 13 kW/cm^2 is exposed to the open surface of the charge. The effect of flows with a power density of less than 11 kW/cm^2 on the charge does not lead to the formation of ceramics.

Attempts were made to estimate the dependence of the target temperature on the electron flux power density. Measuring the temperature of a target exposed to a powerful stream of high-energy electrons is a complex task. Direct contact and pyrometric methods do not provide reliable information. It is difficult to measure and experiment conditions. The effect of the flow is carried out within 1 s, the target is converted from a powder to a homogeneous composition when exposed. To estimate the target temperature during exposure, we used an indirect method, which is as follows. Plates of metals with different melting temperatures were placed in the charge. When exposed to the radiation stream, the charge and metal plates were heated. At the end of the experiment, the sample was destroyed, and the changes that occurred with the metal plates were visually examined.

Plates with dimensions of 8x3x0.5 mm were made of Cu, Fe, Mo, the melting point of which was 1080, ~1500, 2620°C. A charge made of MgF_2 powder with plates embedded in It was exposed to a flow of electrons with a power density from 8 to 20 kW/cm^2 under the synthesis conditions described above.

As can be seen from the presented results, after exposure to the charge flow with a power density of 8 kW/cm^2, at which the ceramic is not formed, the following changes are observed with metal plates. The Mo and Fe plates did not change shape, while the copper plate was rounded at the ends and covered with a layer of oxide. The mo and Fe plates were also oxidized. At 11 kW/cm^2, the copper plate was even more rounded, and the Fe plate was covered with a layer of oxide. The molybdenum plate has not changed, but it has become more brittle. At 15 kW/cm^2, the copper melted. The Fe plate was rounded, covered with a thick layer of oxide, and the molybdenum plate partially disappeared due to oxidation. At 20 kW/cm^2, copper and iron melted, only fragments of molybdenum remained, most of them disappeared due to oxidation.

Thus, it can be assumed that when exposed to a flow of electrons with a power density of more than 15 kW/cm^2, the charge temperature exceeds the melting temperature of copper, i.e. 800°C. The effect of an electron flow with a power density of 20 kW/cm^2 leads to heating of the charge formed by the ceramics to a temperature above 1500°C.

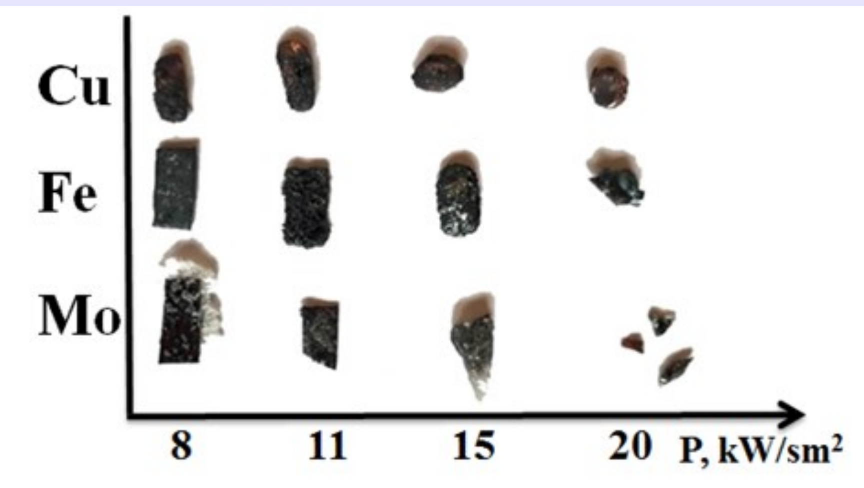

Fig. 4. Photo of extracted metal plates from samples.

EXPERIMENTAL SETUP

Ceramics were synthesized using the ELV-6 accelerator of the INP SB RAS. The ELV-6 accelerator generates a stream of electrons with an energy of 1.4 MeV and a power density of up to 100 KW/cm^2. An accelerated electron beam is removed from a high vacuum to a medium with atmospheric pressure through a differential vacuum pumping system. The resulting divergent beam is directed to the irradiated surface. The radiation scheme is shown in Fig.1. in the experiments selected for the present conditions in the irradiation plane, the beam has a Gaussian distribution over a cross section with a diameter of 7.5 mm at half the intensity. The beam using a system of deflecting electrodes scans the irradiated surface at a speed of 1 cm/s, as shown in figure 1A. the Beam is shifted from position 1 to 2, then from 3 to 4, and so on. Position 3 is 10 mm away from the position.

Special crucibles with dimensions of 120x50x32 mm were made for synthesis. In the upper part of the crucible, a 5 mm deep recess is made with a collar around the edge or, additionally, with a cross in the middle. The crucibles were made of copper, which provides a good heat sink from the charge during irradiation. The electron beam affected the charge for a short time, at each point - 1 s, the total scanning time over the entire area of the crucible with the charge was 36 s.

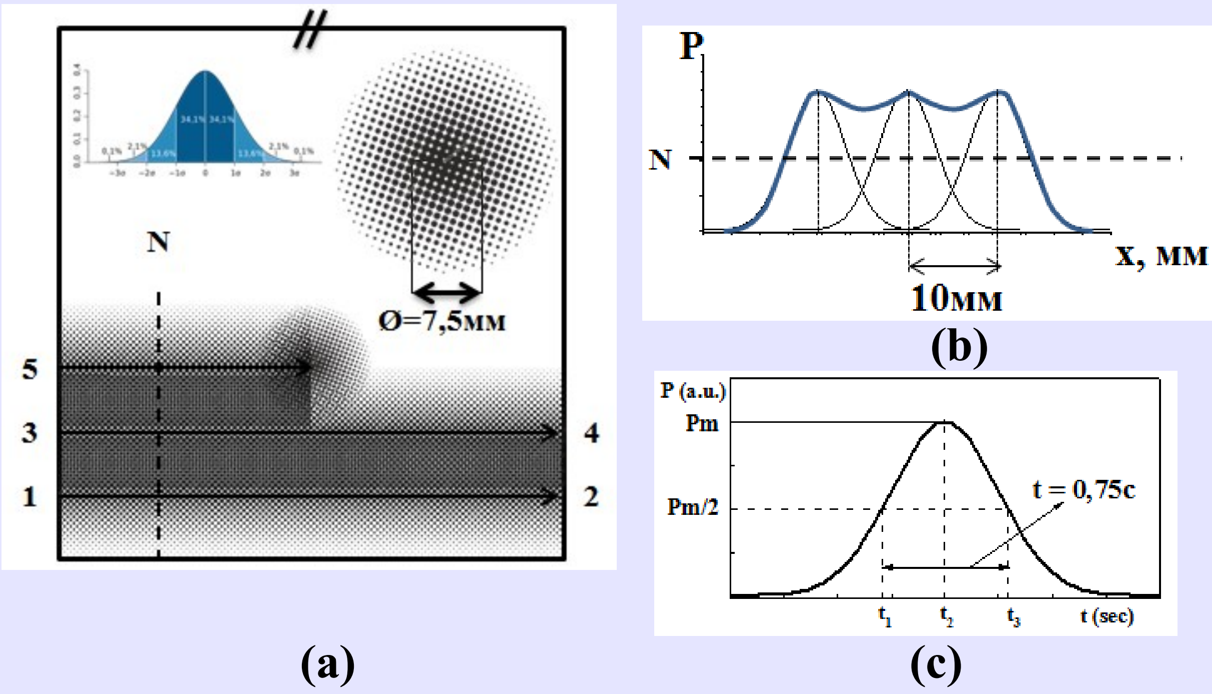

Fig 1. Electron beam scanning Scheme on the sample surface: distribution of the flux intensity in the beam (a), distribution of the absorbed dose on the target during scanning (b), change of the flux over time at a given target point (c).

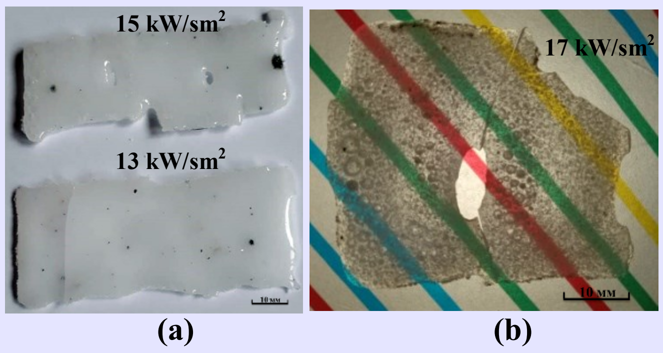

Fig. 2. Photos of ceramic samples synthesized under the influence of electron fluxes with power densities of 15 and 13 kW / cm^2 (a), synthesized at 17 kW/cm^2 and then polished (b).

Fig. 3. Photos of samples exposed to electron fluxes with power densities of 11 and 8 kW / cm^2.

DISCUSSION

Figure 5 shows schematically the dependence of the efficiency of forming ceramics on the power density of the electron flow. The effectiveness was evaluated visually based on the state of the synthesized sample. When the charge is exposed to a flow with a power density of 8 kW/cm^2, the ceramic is not formed. At 11 kW/cm^2, there is already a weak sintering of particles, which is already indicated in the figure by an efficiency value other than 0. When the charge is exposed to a flow with a power density of 13 kW / cm^2, a characteristic type of ceramic is formed, with an increase in the power density to 15 kW/cm^2, the type of samples does not change. With a further increase in the power density to 22 kW/cm^2, the type of samples does not change, the thickness increases by 1.5 times and changes slightly. Therefore, the efficiency of forming ceramics when exposed to a flow with a power density higher than 15 kW/cm^2 was assumed to be equal to 1.Accordingly, the efficiency of forming ceramics when exposed to a flow with a power density of 13 kW/cm^2 was assumed to be less than 1. As you can see, the dependence has a clearly expressed step-by-step character.

The existence of a threshold depending on the synthesis efficiency and power indicates that the synthesis is determined by ionization processes. The formation of ceramics occurs from intermediate products of radiolysis of the initial powder particles. The probability of meeting the necessary radiolysis products for synthesis is proportional to the product of the probabilities of their formation in the radiation field. Therefore, the probability of an encounter is described by a power dependence.

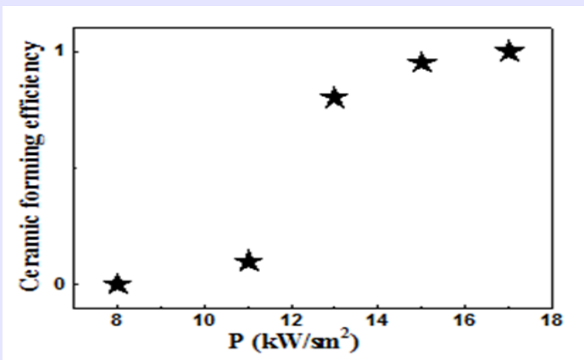

Fig.5. Dependence of the efficiency of forming ceramics on the power density.

CONCLUSION

Thus, under the used irradiation conditions, there is a high probability of atomization, decomposition (radiolysis) of the powder particles used for synthesis. Accordingly, there should be a high probability of the existence of atoms (ions) in the gas state in the interparticle space of the charge. This should lead to a catastrophic acceleration of synthesis reactions.