THE INFLUENCE OF THE ELECTRON BEAM TREATMENT ON ALUMINUM AND IRON NANOPOWDERS

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Abstract. This work involves the differential thermal analysis of iron and aluminum nanopowders irradiated with electron beam of energy of 360 keV within 120 ns. The Differential Thermal Analysis of the irradiated samples reveals an increase in the amount of water particles absorbed by the surface of the nanoparticles, as well as the accumulation of defects inside the core of their crystal structure.
Keywords: Nanopowders, irradiation, iron, aluminum, temperature, differential thermal analysis

1. Introduction

The unique combination of structural and dimensional factors of metal nanopowders greatly improves their physical, chemical and thermal properties of materials in comparison to their bulk counterparts [1]. As such, the past decade has seen a significant increase in the research and use of nanoparticles in various field of application because of the ability of synthesizing and manipulating these materials desirably. Applications in areas such as electronics, energy, biomedical, mining, optoelectronics, pyrotechnics, military, materials etc. has brought about an increase in investments in nanotechnology research and development [2].

In essence, modification of surface, structural and thermal properties of nanoparticles make them more desirable for many industrial and research applications. Such modification methods include irradiation with high energy particles followed by Thermal Analysis Techniques [3]. This work uses differential thermal analysis to investigate the impact of electron beam irradiation on the thermochemical characteristics of iron and aluminum micro and nanopowders.

2. Material and Methods

The two primary subjects of this study are iron and aluminum nanopowders. The electric explosion of a metal conductor in an argon atmosphere yielded these metal nanopowders. (Fig. 1: Jeol JEM 2200FS microscope). The samples were irradiated with pulses of electron beam having kinetic energy of 360 keV for a duration of 120ns. This was carried out under normal atmospheric conditions [4].

Since differential thermal analysis (DTA) is the most sensitive method used to examine the structural alterations occurring in the nanocrystals, it was used to investigate the irradiation samples in more detail. [4]. In DTA, the temperature difference between the sample reference material before and after irradiation is recorded and the corresponding data obtained from the thermograms generated is used in interpreting the thermophysical changes taking place in the sample [5]. The SDT Q600 TA Instrument (USA) was used to carry out the thermal analysis. It is a composite device that provides output for differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA) data in addition to the DTA results. All of these are plotted on a more comprehensive thermogram (Fig. 1), for quicker analysis and convenience. The measurement error for SDT Q600 TA is: $Q = \pm 1.8$ %, $T = 0.1\ ^{\circ}C$, $m = 10^{-4}$ mg.

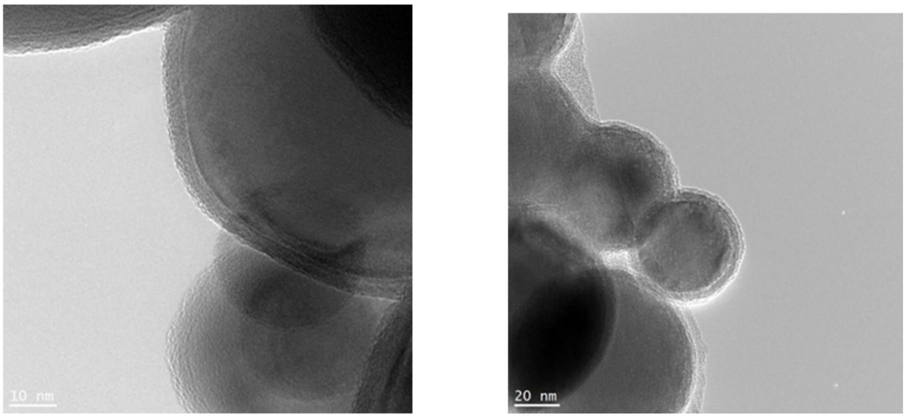

Fig. 1. Microscopy of aluminum a and iron b nanoparticles

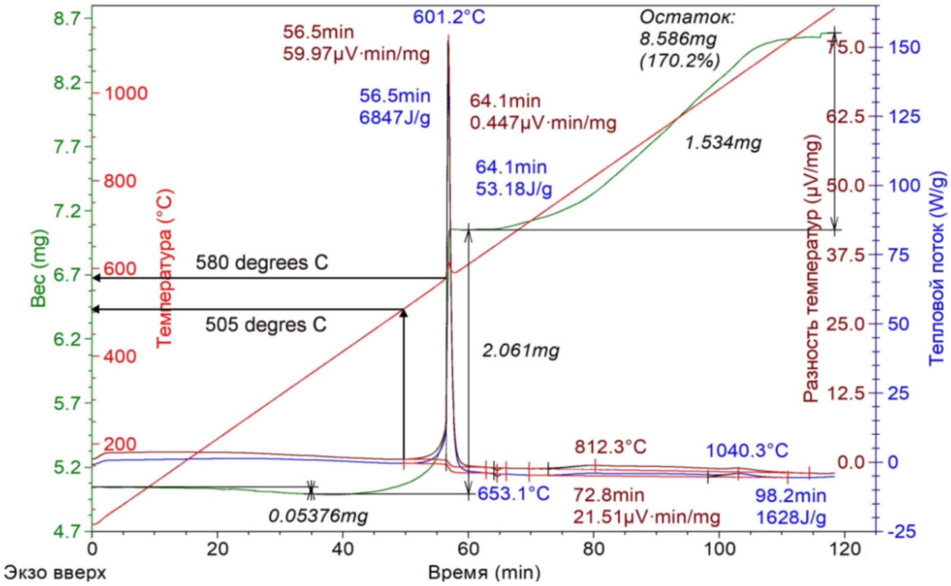

Fig. 2. A thermogram of aluminum nanopowder before irradiation

3. Result and discussion

The acquired experimental results suggest that metal nanopowders are ionized by the action of an electron beam, which also contributes to electron emission and charge adjustment through the sorbed water from the air. The same process of particle surface charge following irradiation and the development of active centers on their surface was observed after exposure to synchrotron radiation [6]. Because micropowders have a lower surface area to volume ratio than nanopowders, this effect is less noticeable. In Fe nanopowders, the amount of desorbed water essentially decreases as the irradiation dose increases (0.49 %). On the other hand, as the irradiation dose increases, the mass change following the desorption of impurities in aluminum nanopowder exhibits greater values (1.97 %). In addition, the values of the 1st stage of oxidation in the Fe nanopowders have higher values of thermal effect. While the spread of values for iron is 1225, it is 1104 J/g for aluminum. Changes in the temperature and heat of the onset of oxidation, which may be promising for the creation of information accumulation systems in the form of long-lived defects in the structures, indicate the effect of electrons in introducing defects in the crystal structure.

4. Conclusion

It was discovered during this research that irradiating metal nanopowders with electron beams affects not only the heat of oxidation, but also the temperature and heat of melting (aluminum).

Based on this, electron irradiation at 360 keV is suggested for altering the structure and properties of metal powders. This can be used in 3D printing to reduce the sintering temperature of products, resulting in lower energy consumption and production costs.

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СТРУКТУРА ПОТОКА ВОЗДУХА В ЗОНЕ ДЕЙСТВИЯ ГАЗОВОГО ИНФРАКРАСНОГО ИЗЛУЧАТЕЛЯ

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Использование газовых инфракрасных излучателей (ГИИ) имеет ряд преимуществ относительно традиционных систем отопления вследствие возможности создания локальных тепловых зон в крупногабаритных производственных помещениях [1–4].

Формирование полей температуры и скоростей воздуха осуществляется в результате нескольких взаимосвязанных процессов, образующихся в результате работы ГИИ: перенос теплоты излучением от излучающей поверхности ГИИ к поверхностям ограждающих конструкций и оборудования, смешанная конвекция в неравномерно прогретом воздухе.

Использование ГИИ в условиях крупных габаритов помещения с относительно малыми площадями, в которых находится работающий, влечет положительный экономический эффект из-за уменьшения капитальных затрат, связанных с проектированием системы отопления, и эксплуатационных за счет меньшей инерции нагрева необходимой области [5, 6].

Целью работы заключается в определении скорости и направления передвижения масс воздуха в локальной рабочей зоне.

Экспериментальные исследования проводились в помещении с размерами 4,4×5×10 м с наличием двух вентиляционных шахт: приточной и вытяжной. Использовались газовый инфракрасный излучатель светлого типа мощностью 5 кВт и горизонтальная панель, имитирующей рабочее пространство, размерами 1,2×0,6×0,05 м. Центр панели совмещен с проекцией