Synthesis of nanosize aluminum carbide powders by detonation of nanodiamond/graphite-nanoaluminum-explosive compounds

*Saeed Tavangar, Seyed Hadi Motamedalshariati,
Malek Ashtar University of Technology, Tehran, PO Box 16765-3454, Tehran, Iran , *email:tavanss@yahoo.com

Abstract: In this method, for producing Aluminum Carbide, An explosive compound is used that is consisted of 65% explosive powder (e.g. TNT, HMX or RDX), 15% Nanodiamond, with 4-6 nanometer particle size which is synthesized by detonation and graphite with 0.7 micrometer add to compounds like to diamond, 20% nanosize aluminum with 50 nanometer particle size. This compound is prepared by applying ball mill with porcelain balls in an inert liquid in a steel container for 12 hr. The products of this process were dried and were pressed by a cold unilateral compression method. The regimes were chosen so that the relative density of the charges was 0.8-.09 of maximum possible value. Charges were pressed with addition of a small amount acetone .Homogeneity of charges was studies by optical-microscopic and chemical analytic methods. Results of those studies showed that homogeneity in mixtures is very well if before mixing of explosives materials with diamond and aluminium, nano diamond deagglomerated by ultrasonic bath. The explosives charges were put into a cardboard bag and the mass was fixed at 100 gr of explosive matter. For each charge an electric no.8 initiator and a 5 gr plastic RDX booster were used. The detonation experiments were performed in an explosion chamber. Detonation products are collected in a cylindrical explosion chamber with a volume of 22 liters. The explosives have negative oxygen balance so in confined condition they produce carbon (Diamond form). Production of detonation is a solid consisted of Carbon, Iron Oxide (from explosion chamber), Aluminum Oxide and Aluminum Carbide. This composition needs a separation and purification stage that is performed by washing with an inert liquid, chemical extraction and centrifuging of the mixture. Detonation products of explosives composition are characterized by powder X-ray diffraction. The structure of powder is studied by Transmission Electron Microscopy. The explosion chamber is equipped with a vacuum system and inert gas inlet. In this paper, influence of air and argon atmosphere on the efficiency of production of Aluminum Carbide is investigated. The produced Aluminum Carbide from compound that contained nano diamond has a particle size of 10-70 nm and for compound that contained graphite efficiency is very low even with changing atmosphere. The investigation of replacing diamond with graphite is very important because graphite is very cheaper than diamond and produces in detonation that explosives have negative oxygen balance. This method is very simple to carry out. The efficiency of this method for diamond compounds is high (Seven percent of the weight of total explosive composition is converted into Al_4C_3).

1. Introduction

Carbide materials have a great potential for device applications and have been widely studied by many researchers. Aluminum carbide can be used as an abrasive in high-speed cutting tools and its particles finely dispersed in aluminum matrix lower the tendency of the material to creep, especially in combination with silicon carbide particles(1). Aluminum carbide is also used in pyrotechnics, eg. to achieve the firefly effect(2). Detonative synthesis of B_4C has been reported from mixtures that contained RDX/organoboron compounds(3). After that time detonative synthesis of inorganic compounds by shock wave loading of substrates were reported (4).In this method explosive compounds with to parts was used, first part included explosives and second part nonexplosives materials that reacted by detonation products in high pressure and high temperature in closed vessel. The famous compound that has been produced from this method was nano diamond(5), in latest works Chinese Scientifics synthesized zinc oxide by detonative method in spherical closed vessel in nano scale(6). In this work , detonative synthesis of nano aluminum carbide by detonation of explosives/nano Al/nanodiamond, explosive/nano Al/graphite, has been investigated. Adding of nanodiamond and nano aluminum and graphite to explosives separately to increase detonation performance was reported in many papers in USA(7) and Russia(8,9), but in this work we mixed three compounds together and detonated them. The powder explosives part of this compounds was TNT,RDX and HMX(min particles size 50 micrometer). Nano aluminum powder in this work had particle size 50 nm(90%actived). UDD form Nanodiamond (ultra dispersed detonation) with 4-6 nm particles size. The graphite had 800 nm particles size.

2.Experiments and Results

The mixtures of explosives and nano particles was prepared by applying ball mill with porcelain balls with relation between weight of porcelain balls to weight of mixture equal to 10 in an inert liquid like to Hexane in a steel container and 2 liter capacity and radius speed 80 revs/min for 12 hr. The homogeneity in mixtures was investigated by SEM pictures like figure 1 and chemical analytic methods like calorimeter techniques, these pictures shown well homogeneity. In table1 mixtures compositions and conditions of test have been listed.

Mixture	Composition	Density(g/cm^3)	Atmosphere	Efficiency of production% (Al_4C_3weight/Mixture weight ,(~nanosize/microsize) Al_4C_3
RAD1	RDX/Al/Diamond(80/15/5)	1.7	Air	2.11,40
RAD2	RDX/Al/Diamond(65/20/15)	1.85	Air	4.22,60
RAD1A	RDX/Al/Diamond(80/15/5)	1.7	Argon	2.78,70
RAD2A	RDX/Al/Diamond(65/20/15)	1.85	Argon	4.81,60
TAD1	TNT/Al/Diamond(80/15/5)	1.9	Air	2.6,30
TAD2	TNT/Al/Diamond(65/20/15)	1.97	Air	2.93,40
TAD1A	TNT/Al/Diamond(80/15/5)	1.9	Argon	1.92,60
TAD2A	TNT/Al/Diamond(65/20/15)	1.97	Argon	1.99,70
HAD1	HMX/Al/Diamond(80/15/5)	2.01	Air	3.97,40
HAD2	HMX/Al/Diamond(65/20/15)	2.08	Air	6.02,60
HAD1A	HMX/Al/Diamond(80/15/5)	2.01	Argon	4.4,60
HAD2A	HMX/Al/Diamond(65/20/15)	2.08	Argon	6.98,80
RAG1	RDX/Al/Graphite(80/15/5)	1.88	Air	0.02,-
RAG2	RDX/Al/Graphite(65/20/15)	1.92	Air	0.04,-
RAG1A	RDX/Al/Graphite(65/20/15)	1.97	Argon	0.01,-
TAG1	TNT/Al/Graphite(80/15/5)	1.99	Air	0.04,-
TAG1A	TNT/Al/Graphite(65/20/15)	2.02	Argon	0.09,-
HAG1	HMX/Al/Graphite(80/15/5)	2.04	Air	0.0,-
HAG2A	HMX/Al/Graphite(65/20/15)	2.1	Argon	0.01,-

*Total weight of mixtures were 100 grams. The charges was initiated by 5 grams C-4(booster) and N-8 detonator
**Detonation products after sieving ,by washing with hexane was collected. The solid residue was subjected to chemical treatment. The solid product was extracted from solution by centrifugation. The purification of this product was not complete , because graphite particles (produced from detonation) and residual nanodiamond after detonation was mixed to this compound.
***Each shot was repeated three times

3-Conclusion

*Table 1 shows that best efficiency of reaction occurs when nanodiamond and argon atmosphere take place in reactions.
Mixtures that have been produced by RDX and TNT had lower than HMX mixtures. This is related to strength of explosives, stronger explosives like HMX generated better efficiency, in comparing between TNT and RDX ,could not be find clear relation , and only could find general in Argon atmosphere efficiency of RDX was better than TNT that it was attributed to high negative oxygen balance of TNT and effects of this on Argon atmosphere.

*The reaction between Al and C to produce is endothermic reaction in this reaction heat goes from detonation of explosives. In graphite mixtures power of reaction between graphite of detonation negative oxygen balance explosives and graphite can not satisfy conditions to produce aluminum carbide. This happen may be related to adsorption of heat from detonation productions after detonation and changed into other compounds like to CO_2 and due to this time Al particles converted to Al_2O_3.
*The compounds that had nanodiamond were best compounds. This may be related to phenomena that UDD in special conditions convert to a form of nanocarbons that name is onion like carbon(10). This compound has in together spherical structure and spherical layers of this structure have fullerene form. Fullerene carbons have more tendency to reaction with more surface area that graphite. We tried to investigate this theory in this phenomena , for doing it , we made explosive mixtures without nano Al and after detonation mixtures found small parts of onion like carbon in Argon atmosphere by detonation products Raman analysis.

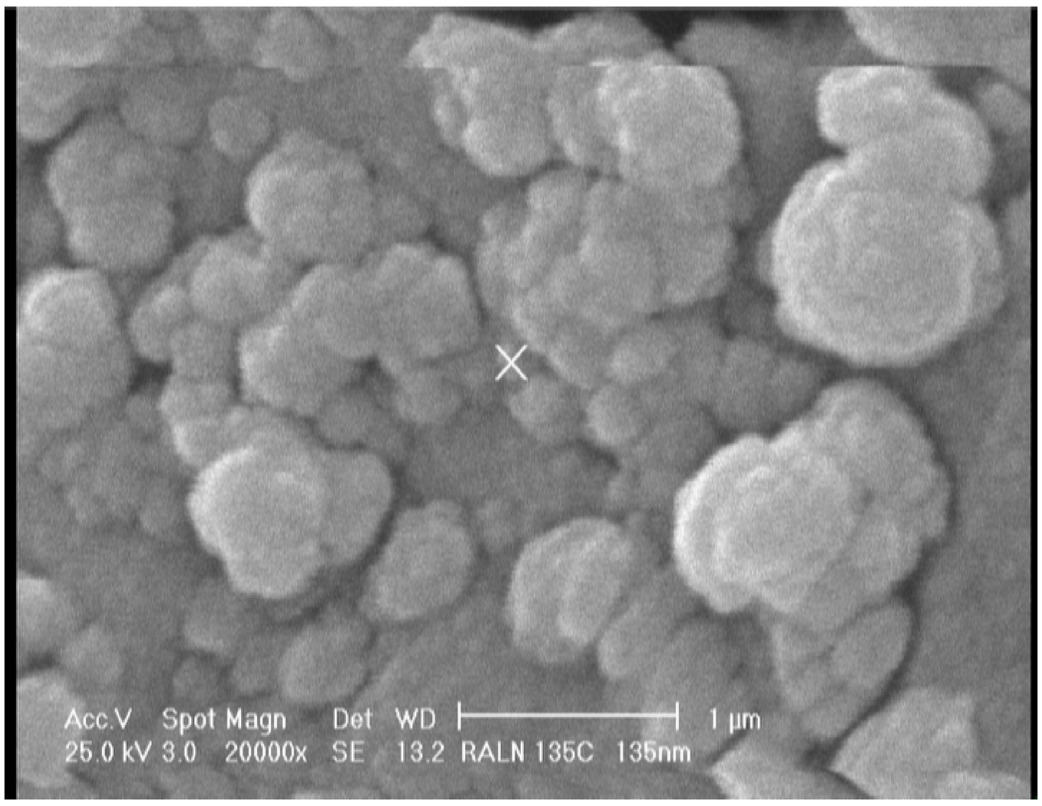

Fig.1) SEM Picture of RAD2

Fig.3) Chamber of detonation with 22 liters volume

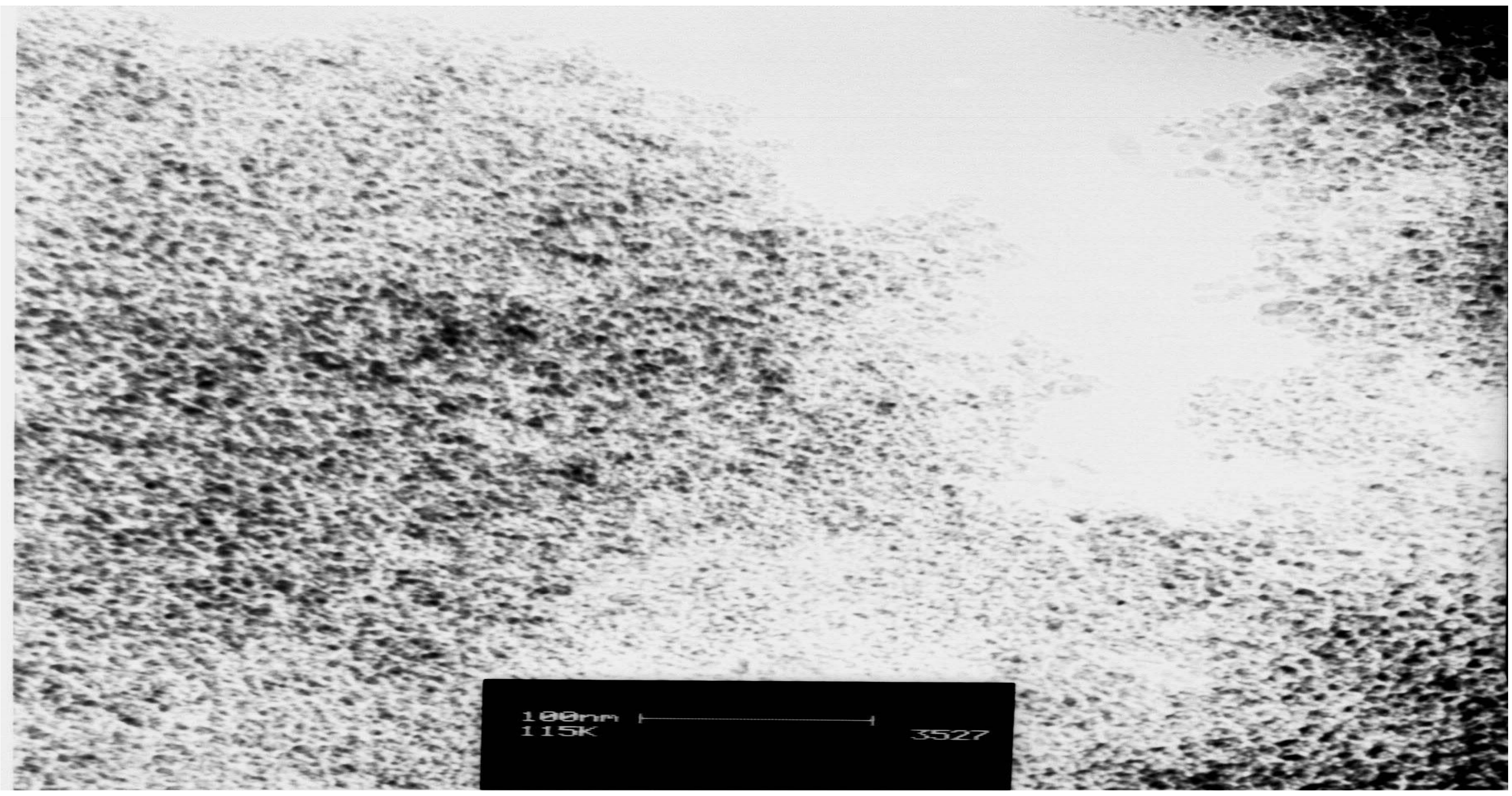

Fig.3)TEM picture from Aluminum carbide that was generated by HAD2A detonation (**scale is 100nm**)

References

1- J. Savekar, High Speed Cutting Tools,US6033789, 2000
2-Http://en.wikipedia.org/wiki/Aluminium_Carbide
3-V.I. Pepekin ,The Reactions of Boron in the Presence of an Explosives, Fizika Goreniya I Vzryva, Vol. 8, NO. 1, PP.135-138,1972
4- S.Cudzilo, A. Maranda, Detonative Synthesis of Inorganic Compounds, Journal of Materials Science Letters, 19,pp1997-2000,2000
5-V.Volkov, Synthesizing of Diamond from Carbon of Products of a Detonation of Explosives Fizika Goreniya I Vzryva, Vol. 26, 123-125,1990
6- Xinghua Xie, Detonation Synthesis of Zinc Oxide Nanometer Powders, Materials Letters, 2006
7- Doherty , R.M., Detonation Velocity f Melt-Cast ADN, ADN/Nano diamond Cylinders, Shock Compression of Condensed Matter, 2001
8- V. Pepekin, Development of High Efficiency Energetic Explosives, 27^{th} intern. Annual Confer. Of ICT,1996
9- M.N. Makhov ,A. Yu. Dolgoborodov and M. A. Brazhnikov ,Explosive Performance of Aluminised NQ-Based Compositions, 32^{th} , Intern. Annual Confer. of ICT,2001
10- V.L. Kuznetsov, Onion-like Carbon from Ultra-dispersed Diamond, Chem. Phys. Lett. 222, 343,1994