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# The Microstructure Of Ceramic Materials Formed By Combustion Synthesis And The Effect Of Reactant Compositions

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## ABSTRACT

There are some superior mechanical properties such as high modulus, high hardness, high high melting point, and great resistance to corrosion that can be created by using ceramic materials, ceramic materials have been attractive as revolutionary materials for high temperature applications and usage. Ttitanium carbide and aluminide have developed as two of the most fascinating ceramics. It has high strength and durability and also less expensive to be produced. TiC-Al2O3 can be manufactured from a less expensive material (TiO2) than it is to produce it from its constituent powders. The combustion synthesis (CS) technology has significant advantages for synthesizing TiC-Al2O3 since it produces a powerful exothermic reaction and has a shorter reaction time. The goal of this study was to assess the combustion synthesis of TiC-Al2O3 as well as the effect of reactant proportions on the burning process and the morphology of synthesized samples. In an air combustion chamber, the combustion technique was carried out. To start the CS, an arc flame was employed as the igniting mechanism. The micro - structural properties of synthetic items have been studied. This study's findings might be utilized to develop a high-performance ceramic material created from low-cost materials utilizing an efficient method.

**Keywords: Ceramics, Combustion, Microstructure, Synthesis**

## I. INTRODUCTION

Ceramic materials such as TiC, TiB2, WC, SiC, and Al2O3 have sparked a lot of interest as tough protective coatings in a variety of industrial applications due to its high mechanical properties and durability.. [1] [2] [3] [4]. Because of its high modulus, high hardness, high melting point, and strong corrosion resistance, titanium carbide has arisen as the most intriguing ceramic for high temperature applications. [3]. Single phase ceramics, on the other hand, are limited in their use at high temperatures due to their low fracture toughness. As a result, the TiC particles has received extensive research as a possible reinforcing utilized for a wide range of nanocomposites, including metallic composite material [5], intermetallic matrix composites [6,], and ceramic matrix composites .

Because of their great hardness and low density, alumina ceramic materials such as TiC–Al2O3 are most often used in high temperature applications. [7]. Binary TiC–Al2O3 ceramic composites were also discovered as having the potential to increase the fracture resistance of single TiC or Al2O3 ceramic materials. [8]. According to additional study, the fracture toughness of ternary ceramic composites is larger than binary ceramic materials [9]. The addition of 10% ZrO2 to Al2O3–TiC synthesized from TiO2, Al, and C by combustion synthesized and hot pressing increased the toughness of Al2O3–TiC–10 wt.% ZrO2 by roughly 20% compared to Al2O3–TiC composite. [10].

## II. LITERATURE STUDY

This research includes a few references from the literature. These are research projects on ceramic composites and combust synthesizing. By its higher strength, wear resistance, high melting point, and excellent corrosion resistance, titanium carbide has emerged as the most exciting ceramic for high temperature applications. A green compact, or simply a green, is work that has been compacted but has not yet been completely processed.

The reactant is shown as a swarm of dense, spherical granules. Limiting the gravitational effects throughout synthesis helps to prevent the separation of denser phases. Certain testing in Lear jet planes have been conducted in thermite-type systems to create thick ceramic and metal composites materials (e.g., TiC-$Al_2O_3$-A1,T iB2-Al2O3-A1Z, rB2-$Al_2O_3$-A1,B4C$Al_2O_3$-A1).

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*A. Ceramics*

Ceramics are inorganic, nonmetallic solids that are made and/or utilized at high temperatures [11]. Oxides, carbides, and nitrides are the most prevalent ceramic materials. It is also made with silicicides, borides, phosphides, tellurides, and selenides. The ceramics materials that are made at extreme temps, it results heat resistant materials.

Ceramics are created by heating natural clays to high temps. The two most common varieties of ceramic clay are red clay, which includes predominantly $SiO_2$ and iron oxide, and kaolin clay, which contains mostly aluminum oxide and very little iron oxide. Because it includes more iron, red clay has a rusty brown tint that ranges from light tan to dark brown, whereas pure kaolin clay is white.

*B. Combustion Synthesis (CS)*

Combustion syntesis (CS) is a material synthesis method that necessitates very exothermic chemical bond among metals and nonmetals, as well as exchange interaction between reactive substances or compound/mixture reactions [12].

Self-Propagating High Temperature Synthesis (SHS) and Volume Combustion Synthesis (VCS) are the two forms of combustion synthesis (VCS) can be seen in Figure 1. It illustrates the combustion synthesis process between SHS and VCS. Reactants can be compacted into a pellet, which is generally tubular in form, in either instance. To induce an exothermic, the specimens are treated by an external source (e.g., tungsten coil, laser) either locally (SHS) or evenly (VCS).

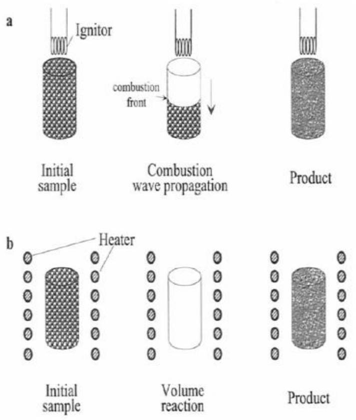


Figure 1 a) SHS Methods b) VCS Methods

*C. Ignition Techniques*

The ECAS Process is described in Figure 2. It consolidates powders or synthesizes and densifies defined products with the proper configuration and density while applying an electricity current and mechanics pressure at the same time. The transmitted electric current and mechanical load may stay constant or change during the sintering cycle, depending on the required densification stages. An automated controller, for example, may change the flow such that a particular temperature cycle is performed.

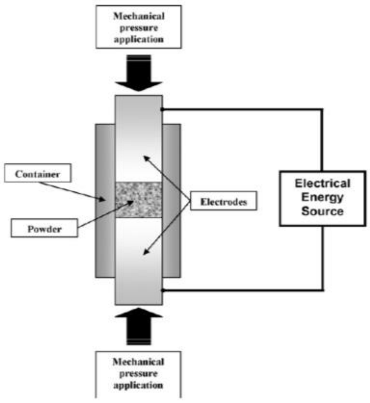


Figure 2 ECAS Process

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*D. Green Mixture Density*

A powder material combination is compressed into dies under high pressure to achieve the required form. A green compact, or simply a green, is work that has been compressed and has not yet been completely processed. [13]. The density of the section, known as the green density, is much larger than the starting mass density as a result of compression, however it is not homogeneous throughout the green density. [13]

As it passes from the primary gas stream to the pellet surface, reactant gas undertakes mass transfer. The gas must infiltrate from the interface to a firm contact between the grain and the product layer for the reaction to occur. [14].

*E.. Grain Size of Powder*

Many aspects of particulate materials are influenced by grain size, which is a useful measure of quality and performance. Powders, suspensions, emulsions, and aerosols all fall within this category. Powder size and form have an impact on flow and compaction qualities. Smaller size of particle dissolve faster than larger particles, resulting in higher suspension viscosities. To increase suspension and emulsion consistency, smaller droplet sizes and higher surface charge are typically utilized (zeta potential). The original Ti grain size is exposed in Figure 3 which magnification 100 µm.

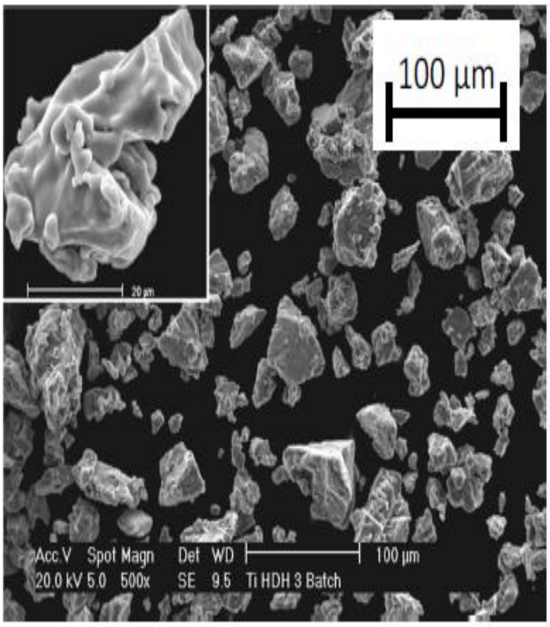


Figure 3 Ti Powder grain size

## III. METHODS

Powder was chosen as the reactant in this study because it allows for the creation of complicated product geometries and allows for "near net shape" formation, which eliminates the need for machining procedures. [15]. Titanium oxide ($TiO_2$), Aluminium (Al), carbon black (C), and alumina particles were employed in this study ($Al_2O_3$). The use of titanium dioxide ($TiO_2$) to obtain TiC indirectly is advantageous since it is less costly than using elemental Ti powder [16]. Furthermore, $TiO_2$ has a low volatile organic compound (VOC) content, allowing it to meet global environmental standards.

Eq. 1 the mass fraction reactions and calculation of each element in the chemical process to weigh the reactant powders used in the combustion synthesis.

$$3TiO_2 + 4Al + 3C \rightarrow 3TiC + 2Al_2O_3 \qquad \text{Eq (1)}$$

The mixes were then combined after being weighted according to the chemical reaction described in Eq. (1). The basic goal of mixing the powder material is to create combination that is as homogeneous as possible, because the homogeneous of the powder mixing has a substantial impact on the product's microstructure and qualities. Crushing roughly 50 grams of reactants in a ceramic mortar for around 20 minutes is used to combine the reactants.

The balancing procedure determines the weight of powder materials that will be manufactured. It was calculated using a chemical process with a total of 1 gram of reactants.

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## IV. RESULTS.

The result of this research is reported in XRD test. The results is in pure speciment without any extra addition of stoichiometric compositions is known as an XRD pure material result.

In Figure 4, There are two element found which is TiC and $Al_2O_3$. TiC is detected by XRD tests, in 45 and 80 theta with 5 and 8 in intensity, according to the XRD pattern of pure material. Meanwhile, Al2O3 is discovered as 6 spots in 2 theta, namely 31, 37, 39, 45, 60, and 85.

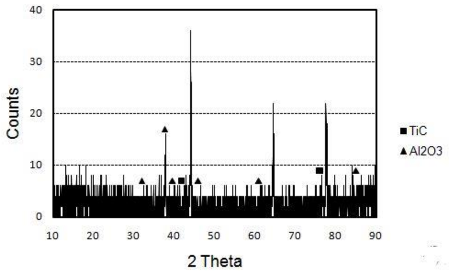


Figure 4. XRD Results 0% Excess

Meanwhile, Figure 5 shows that $Al_2O_3$ is discovered as 6 spots in 2 theta, namely 31, 37, 39, 45, 60, and 85. It is known that TiC with an additional 20 % of $TiO_2$ and C has improved and increased from one point to three, at 35, 41, and 72 theta, respectively. This sample has seven $Al_2O_3$ molecules. In 2 theta, they're at 19, 31, 37, 45, 60, 67, and 87, with intensities of 9, 5, 23, 7, 7, 4, and 7.

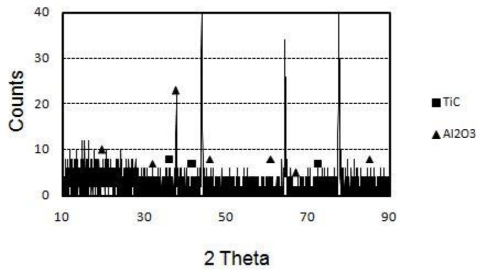


Figure 5. XRD Results with 20 % Excess

The last speciment examined by XRD can be seen in Figure 6, with a 40 percent excess of $TiO_2$ and C. The 3rd experiment has almost same theta with the 2nd experiment but it has otherl TiC found at 60 and 78 in 2 theta.

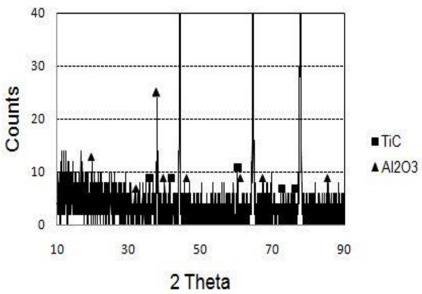


Figure 6. XRD Results With 40% Excess

**Microsructures**

The particle appears to be diverse in terms of form and size. Some particles have a denrite-like shape, whereas others have a cubic shape. Figures 7–9 show the differences in microstructures.

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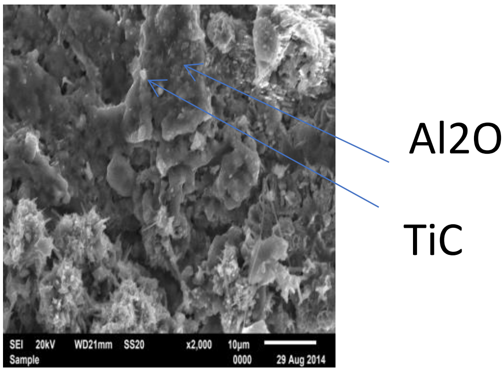


Figure 7. SEM Results With 0 % of  Excess

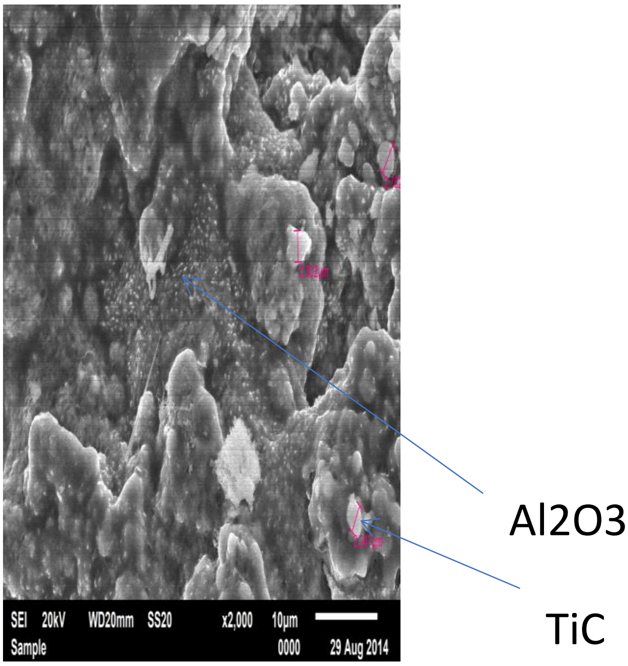


Figure 8. SEM Results of  With 20 % Excess

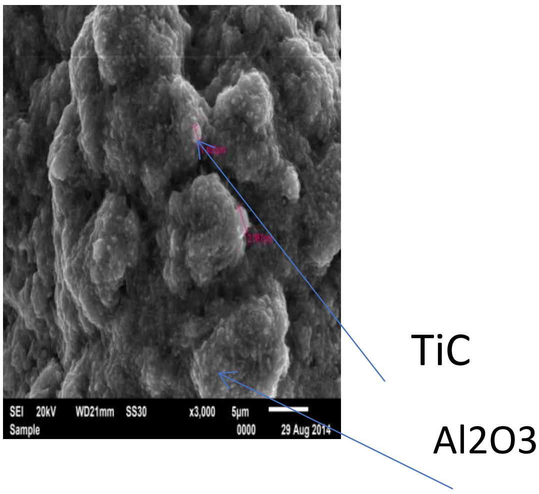


Figure 9. SEM Results of  With 40 % Excess

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## V. CONCLUSIONS

The use of combustion synthesis to produce ceramic material proved successful. The ignition and flame propagation have been modified by the reactant composition. SEM and XRD may be used to determine the phase composition of the produced product. The presence of $Al_2O_3$ can be observed clearly in the XRD graphs. However, the XRD spectra of titanium caribide (TiC), a consequence of combustion, are missing. The porosity of the reacted product reveals the influence of reactant mixture on the microstructure of the synthesized material, with larger porosity coming from a rise in TiO2 and C. The increasing TiO2 and C content is also seen in the XRD pattern. The more additional addition there is, the higher the maximum value on the XRD test. SEM testing is also recommended to ensure the composition of the synthesized product.

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