Certificate

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Herewith we certify that the papers with the title

"**On the role of aluminum powder on production copper foam by turning chips** "
A. Babakhani, A. Moloodi, M. Haddad Sabzevar

and

"**An investigation of production Al-Al2O3 composite foam via SHS**"
A. Babakhani, A. Moloodi, M. Haddad Sabzevar

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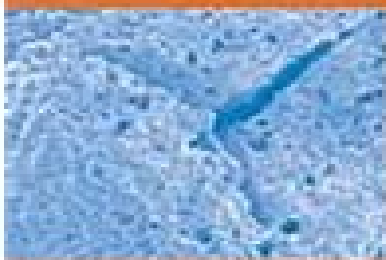

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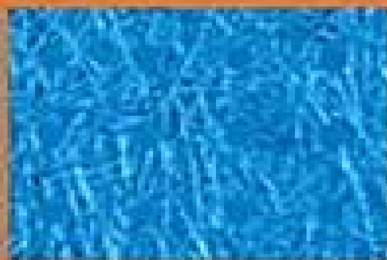

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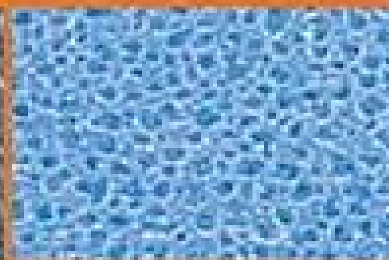

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B23
B – Manufacturing

Polyamid/EVOH Blend Nano Cellular Structure

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Cellular structure polymer has been most popular in many chemical processes. The polymer performance and property control are main subject of technical research. Energy consumption, cleaning, weight are most important criteria in the polymer design. In this research role of polymer blending process and thermodynamic in the cellular structure and performance control was studied. Polyamide modified EVOH, based cellular blend was prepared and performance was optimized during a thermodynamic control process.

B24
B – Manufacturing

An investigation of production Al-Al_2O_3 composite foam via SHS

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This article describes Self-propagating High-temperature Synthesis (SHS) process for manufacturing open cell aluminum composite foam. Porous Al composite was fabricated by the reactions between Al and $NaNo_3$ powders. The gas released during these reactions and also the initial porosity of the green powder compact was suggested to be the sources of the produced pores. The effect of extra Al content on the porosity of the SHS product was determined. Optical microscopy and compressive properties were utilized to characterize the porous samples.

An investigation of production $Al\text{-}Al_2O_3$ composite foam via SHS

This article describes Self-propagating High-temperature Synthesis (SHS) process for manufacturing open cell aluminum composite foam. Porous Al composite was fabricated by the reactions between Al and $NaNO_3$ powders.

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Introduction

Metal foams have many interesting properties, such as low density, high stiffness in conjunction with very low specific weight and high gas permeability combined with high thermal conductivity [1, 2]. However, since these materials find more applications in the industry nowadays, they need to be studied extensively to characterize all these properties [3].
Many different methods have been used to manufacture metal foams, among which, the methods that use metal powders are the most widely used. These methods have a good control over the cell shape, cell size and porosity distribution [4,5]. Some investigators have used the Self propagating High-temperature Synthesis (SHS) to manufacture the metal based foams [6-8]. In general, the chemical reactions that synthesize intermetallics or ceramics generate large amounts of heat of reaction [9-12]. SHS is a process that utilizes these strong exothermic reactions. Once the reaction occurs at the heated zone, the generated heat raises the temperature of the neighboring zone and triggers the reaction again. Hence, the reaction spontaneously propagates throughout the specimen, and results in the formation of bulk intermetallics or ceramics [13], which are generally porous [14]. Intermetallic foams that had an application in surgical implants were successfully manufactured by utilizing the SHS process [15, 16]. Under adiabatic conditions, the heat generated by the reaction increases the temperature of the products to a value usually termed as “adiabatic temperature” (Tad). If the heat that is released locally during the reaction is capable of activating the adjacent particles, then the combustion wave would be stable [17]. Merzhanov [18] presented the empirical criterion Tad ≥ 1800 K for combustion wave stability and Munir et al. [17] proposed an adiabatic temperature of 2000 K as the empirical criterion for a successful SHS reaction. It was also noted that raising the adiabatic temperature would facilitate the SHS reaction. However, only a few stable SHS systems that operate with a Tad of less than 1800 K have been reported in the literature [19].
In the present study, the SHS process was adopted to produce aluminum-alumina composite foams. In addition, optical and pressure test were employed to evaluate the effects of the different blending ratios X as well as the porosity content and morphology of the final product and the phases formed during the reaction.
Aluminum-Alumina composite can be produced by the SHS method by mixing $NaNO_3$ and Al powders and triggering the reaction by heating it with an external heat source (see Fig. 1):

$$(10/3)\,Al + 2NaNO_3 = Na_2O + N_2 + 5/3Al_2O_3 \quad (1)$$

This reaction produces an enormous amount of heat, and the temperature of the system immediately increases to about 5400 K. In this temperature, the product of the reaction will be vaporized. Adding Aluminum powder to the powder mixture will decrease this temperature, and also produce Aluminum in final production:

$$(10/3+X)Al + 2NaNO_3 = Na_2O + N_2 + XAl + 5/3Al_2O_3 \quad (2)$$

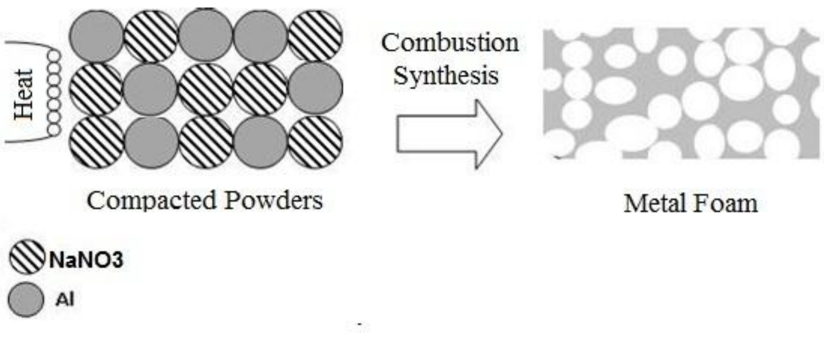

Figure 1: Schematic illustration of the combustion reaction for synthesizing porous materials

Materials and methods

Sodium nitrate ($NaNO_3$) and aluminum powders were used as the raw materials in the SHS process for the fabrication of the composite foam. First, these powders were evenly blended in a mixer at molar ratios (quantities of X in Eq. (2)) ranging from 0 to 15. The blended powder was then cold-pressed under 250MPa in a cylinder (h = 10mm, ID = 10mm) to make a precursor. Further, the top region of the precursor was heated by an oxy-acetylene flame to trigger a combustion reaction. Soon after the completion of the reaction, the cross-section of the specimen was studied using an optical microscope. The Stress-Strain curves of the Aluminum-Alumina foams that were fabricated under different conditions were measured using a uniaxial compression test method accordingly to ASTM E-9 standard. The tests were carried out at room temperature using Zoltrix Testing Machine fitted with a 160 kN load cell operating in the displacement control mode. The cross-head speed was 1 mm min^{-1}.

Results and discussion

Evaluation of the SHS reaction and appearance

The difference noted in the degrees of severity of the reactions that occurred in the different compact samples confirmed that the combustion behavior of the compact reactants varied with the content of Al in the initial powder mixture. Fig. 2a illustrates the typical SHS sequence of a compact sample wherein the molar ratio of $NaNO_3$: Al was 2 : 3.33 (X = 0). It is evident that initially upon ignition; a distinct reaction front was formed and then propagated downwards quite harshly in a self-sustaining fashion. The degree of severity of the reaction was excessively high and all the products of the reaction were vaporized. This was attributed to the generation of a high adiabatic temperature during the phase transformation.

The degree of severity of the reaction was moderated by introducing Al in the reactant mixture. When the Al content increased to 75.9 and 80.7 mol% (X = 3, 5), as depicted in Fig. 2b and C, the compact sample almost retained its original shape throughout the SHS process. This implied that the reactions generated a lesser degree of adiabatic temperature in the compact sample. On the other hand, Fig. 2d, which illustrates the combustion reaction of a mixture with 87.1 mol% Al (X =10), indicates that increasing the amount of Aluminum to X=10 in the reactant mixture caused the SHS process to terminate before its completion. It is for the reason that of lower the adiabatic temperature of system from critical temperature (T_{ad}

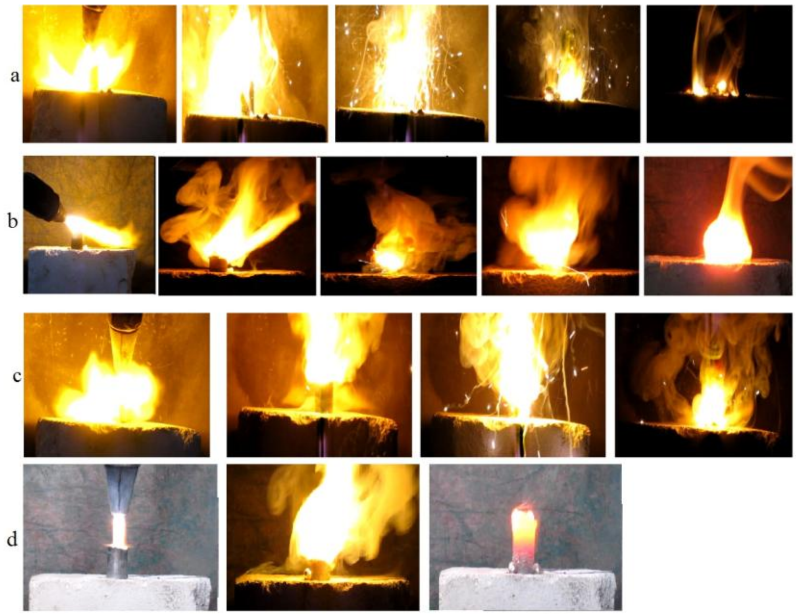

Figure 2: The recorded images of the combustion reactions of the precursors with blending ratios of (a) X = 0, (b) X = 3, (c) X = 5 and (d) X = 10.

Fig. 3 illustrates the appearance of the pores of the Al-Al_2O_3 foams synthesized by combustion under different blending ratios (X = 3, X = 5, X=10 and X = 15). This figure shows that when the Al content of the precursor was low (X = 3, Fig. 3a) the precursor deformed considerably during the SHS process whereas, a precursor with a blending ratio of X = 5 deformed much less (Fig. 3b). In addition, as the blending ratio reached to X = 10 and X =15, the combustion reaction of the compact powder was terminated (Fig. 3 c and d).

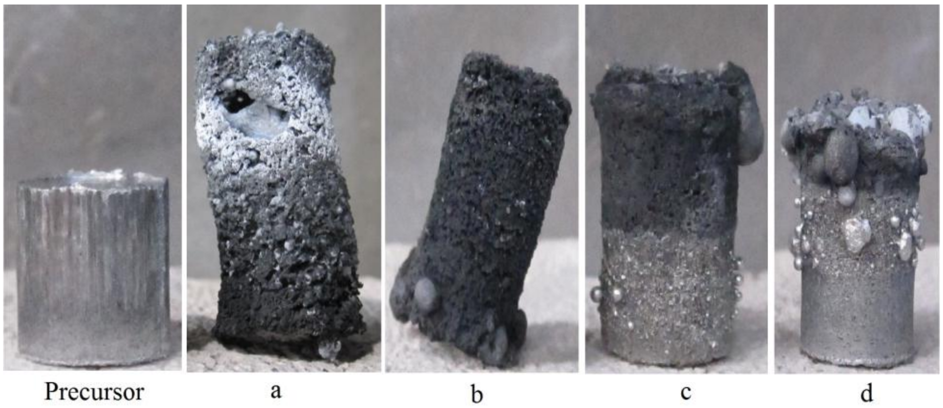

Figure 3: The appearance of the Al/Al_2O_3 composite foams synthesized by combustion under different values of blending ratios of X=3(a), X=5(b), X=10(c) and X=15(d).

The microstructure

Fig. 4 and Fig.5 illustrate the microstructure of the polished surface of specimens synthesized by combustion, the precursors of which were produced under a blending ratio of X = 3, 5 and 10. The microstructure of cell walls consisted of nodular Al_2O_3 particles dispersed in an Al matrix. It can be seen by increasing of molar ratio of Al, the amount of Al_2O_3 in matrix decreased. Furthermore, increasing of X in equation 2, due to introduce smaller pours in metal foam. It is as a result of less gas releases from initial powders by increasing of X, in addition, the adiabatic temperature of system decreases and thus generation of gas and formation of pours become rigid.

Figure 4: The microstructures of pours in different specimens (100X magnification)

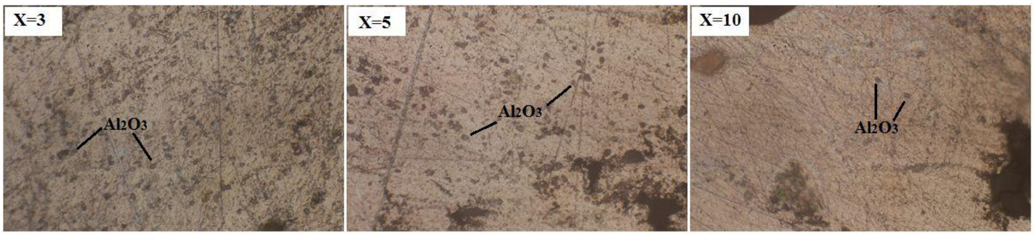

Figure 5: The Al_2O_3 dispersion in different specimens (1000X magnification)

Mechanical properties

The Stress-Strain curves of different specimens are shown in Fig. 6. It can be seen that by increasing the molar ratio of Al in initial powders the yield stress and elastic modulus increased and then unchanging thereafter. It is as of small pours in these specimens than the other ones. Decreasing the size of pores in metal foams has been conducive to increasing the strength [1-3].

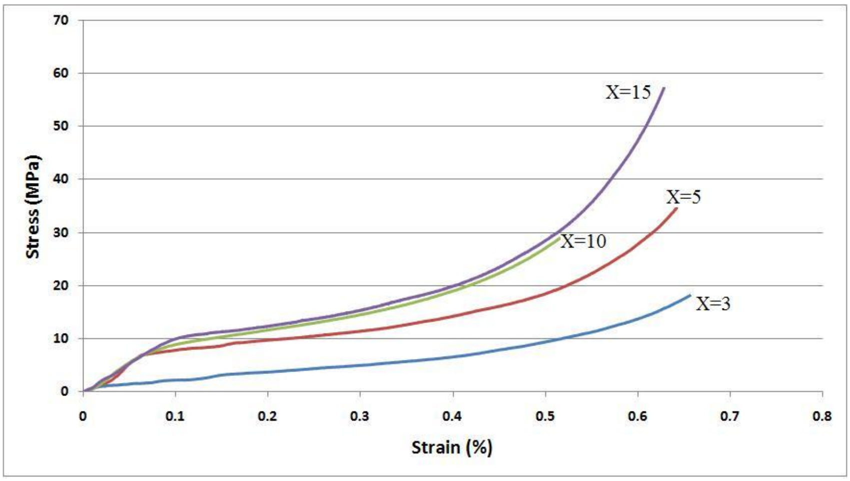

Figure 6: Compressive Stress-Strain curves for Al/Al_2O_3 foams with different molar ratio of Al in initial powders

Conclusions

Aluminum Alumina composite foams have been produced via SHS reaction using Al and $NaNO_3$ powders. The following results were obtained:

1. The molar blending ratio of the green ingredients was found to be an important parameter that controlled the behavior of the SHS reaction, the porosity content of the final product, and the morphology of the produced pores. The best molar powder ratio that produced open pores through a sustainable SHS reaction and optimum strength was found to be about $NaNO_3$: Al ≈ 2 : 10(X ≈ 6.5).
2. The critical molar ratio, below which the SHS reaction was not sustainable, was determined to be about $NaNO_3$: Al ≈ 2 : 10(X ≈ 6.5).
3. The greater the Al powders in initial powders, the lower the pour size of the final product and there for higher strength of final products.
4. It was found that by decreasing the molar ratio of Al in initial materials, the amount of Al_2O_3 in final products has been increased.

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