Combustion Synthesis of Mechanically-Activated Nb-Al Mixtures

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Abstract: In this work shake milling were used to mechanically activate Nb – Al powder mixtures at different relative proportions (Nb80Al, Nb65Al, Nb54Al e Nb42Al). All milling process parameters were unchanged, e.g., powders mass, ball/powder mass ratio, balls diameter, quantity and kind of process control agent. Uniaxially compacted cylindrical pellets of milled powders were vacuum reacted. After a two-step degassing treatment (290°C for 0.5 h and 400°C for 4 h), samples were heated at 30°C/min. Ignition and combustion temperatures were measured by a thermocouple inserted in a hole drilled into the pellets. The microstructure of milled powders and reacted pellets were characterized by X-ray diffraction and SEM analysis. Bulk density of the pellets was measured by water immersion (Archimedes). The results showed a decrease of both ignition and combustion temperature with mechanical activation as seen by comparison with reacted pellets of the same composition not mechanically activated (simple mixtures). By increasing the heating hate the completeness of the reactions were improved. The lower the aluminum contents the lower the ignition and combustion temperatures and also the densification. The decrease on ignition temperature was caused by a more effective dispersion (and so more activation) attained by samples with lower aluminum content.

Introduction

Among Nb-Al intermetallic compounds, $NbAl_3$ has been gained increased attention as a candidate material for airspace applications [1-3]. This came from its low density and good oxidation resistance due to its high aluminum content.

Monolithic $NbAl_3$ has been obtained by combustion synthesis from its elemental constituents [4,5], showing advantages over conventional processing like foundry or powder metal sintering.

Making a dense material by this process demands a very accurate control of the process variables. In previous papers it has been shown that it is possible to attain densities higher than 95% of theoretical value, but with significant dimensional distortion [5,6].

$NbAl_3$ combustion synthesis was verified to be severely altered by milling its elemental powder reactants, particularly by decreasing ignition temperature and dimensional distortion due to a lower (smaller) liquid phase formation during the reaction [7,8].

A good manner to have clues about the combustion of Nb75Al mixtures is to react other Nb-Al compositions and see what happens. In a previous work [9], non-milled Nb-Al mixtures (e.g. 42, 54, 65, 70, 75 and 80 a/o Al) were reacted. $NbAl_3$ was always the first phase to form. The reason for that is based on the ignition temperatures of the pellets, measured by a thermocouple placed outside the samples. They were very close together (from 850 to 860°C), at the same range of Nb75Al samples, indicating a similar event. Once aluminum is liquid at the ignition temperature, nucleation