Statement of Work

Collaborative Nano Composite Aluminum MWCNT Alloy Development Via Powder Metallurgy for Structural Applications, Phase I

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A. PROJECT OBJECTIVE

The objective of this initial effort is to determine the effect of select process variables aimed at enhancing the properties of baseline aluminum alloy by functionalizing Multi-wall Carbon Nano-tubes (MWCN) into an aluminum alloy matrix. Several possible processes will be evaluated.

B. BACKGROUND

Carbon Nanotubes have been widely reported as having many unique and desirable properties. Functionalizing these nano tubes into light alloy systems to gain enhance properties has been of great interest and the subject of much research. There are several production methods that produce several types of carbon nanotubes including single wall and multi-wall "CNTs, and "MWCNT" for this effort MWCNT will be used.

Typically material properties regarding aluminum alloys are correlated to elemental composition, grain size, in-situ & ex-situ reinforcing particles (size, distribution, volume%).

High energy ball milling has been proven to be an effective method at tailoring elemental compositions in metallic alloys through solid state reactions. It has also been proven to disperse secondary phase particulate homogeneously within a base matrix alloy to produce effective metal matrix composites "MMCs".

Cryo-milling is essentially high energy ball milling at cryogenic temperatures and consists of a vessel filled with a grinding media, in most cases ¼" dia. stainless steel balls, a slurry of powered material in a cryogenic fluid and a mixing arm typically made out of stainless steel. As the attrition arm rotates the powdered material is subject to severe mechanical deformation, significantly reducing the microstructure and grain size as well as reducing and dispersing reinforcing particulate. Typically a PCA (Stearic Acid) is used to reduce over-agglomeration which is prominent in ball milling.

Spark Plasma Sintering "SPS' is reported as one of the fastest and most effective methods to consolidate nano-structured materials with minimal grain growth in addition to removing surface oxides and promoting inter-particulate and dissimilar material bonding. Test specimens (tensile, compression, hardness) samples can be rapidly produced from milled powders for evaluation during development steps.

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C. TEST PLAN

In this initial investigation, the feasibility of low intensity ball milling, cryogenic milling, and SPS processes as a means to functionalize MWCNT will be evaluated. The influence of process parameters on MWCNT distribution, matrix grain size will investigated and correlated to enhanced properties. The primary milling parameters are fixed during this investigation and include, equipment setup, ball size and weight, powder to ball weight ratio, attrition rpm and cryogenic fluid.

1. Approach

The experimental approach is to establish baseline "BL" 7075 properties (reported 68-78 ksi with T6/T651 H.T.) SPS condition optimization will be established with baseline powders. Once validation of consolidation and testing is confirmed. Suggested processes will be evaluated (low intensity and/or Cryogenic milling with no MWCNT addition "0%" will be evaluated and 1% vol addition of MWCN "1%" will be evaluated with same processing and testing procedures (low intensity and/or Cryogenic milling). Fracture surfaces from tensile samples tested to failure will then be analyzed by both collaborating partners to determine direction and optimization for further developments.

For initial trials, commercially available Aluminum 7075 powder will be used as it is widely characterized and used in many aircraft applications.

2. Feedstock Materials

a. Alloyed Powder: 7075 alloy, (Valimet, Stockton Ca, Gas Atomized and sieved to +270 mesh)
b. MWCNT: Bayer or American Elements, (to be determined)

3. Low Intensity Equipment

a. Vessel: Stainless steel
b. Media type: 1/4" Stainless Steel or 3/8" Carbide
c. Milling speed & time: (Optimized for every cycle, approx 80 rpm, 4 hours)

4. Cryomilling (High Energy) Equipment

d. Attritor: Union Process S-1 (modified at Cal Nano for cryogenics) ;
e. Media type: Stainless Steel 1/4" dia.
f. Milling arm: Stainless Steel

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5. Cryomilling Parameters (Fixed)

Table 1. Cryomill Parameters

Media type.	SS
Media size.	0.25 in
Media wt.	30 Kg
Powder/ball ratio	30:1
Attrition speed	180 rpm
Attrition time	6 hrs

6. Processing Parameters (DOE)

To determine the mostrequre parameters, a typical DOE is established to construe the effect of the outlined variables and their effect material properties.

D. COSTING

1. Low intensity milling

Low intensity milling will be utilized to disperse and aid in imbedding the MWCNTs into the aluminum alloy powder preventing loss of MWCNT in subsequent cryomilling.

2. Cryogenic Milling (Break-in + Milling runs)

One break-in run in necessary and critical to material cleanliness prior to material processing. Prior to a milling effort or between material systems one cleaning run is also necessary to maintain acceptable contamination standards. If several processing runs are scheduled at the same time and chemical compositions permit, processing runs can be performed back to back without subsequent clean and break-in runs increasing effectiveness.

3. Powder Morphology (SEI analysis)

In the initial DOE, it is suggested that, in addition to original powder, 3 powder samples will be taken from 3 cryomilling runs, each will be mounted on a specialized sample mounts and analyzed topographically with SEI SEM analysis. General size distribution and powder aspect ratio will be evaluated as well as MWCN distribution.