Additively Manufactured, Thermally Stable Telescope Mirror Substrates

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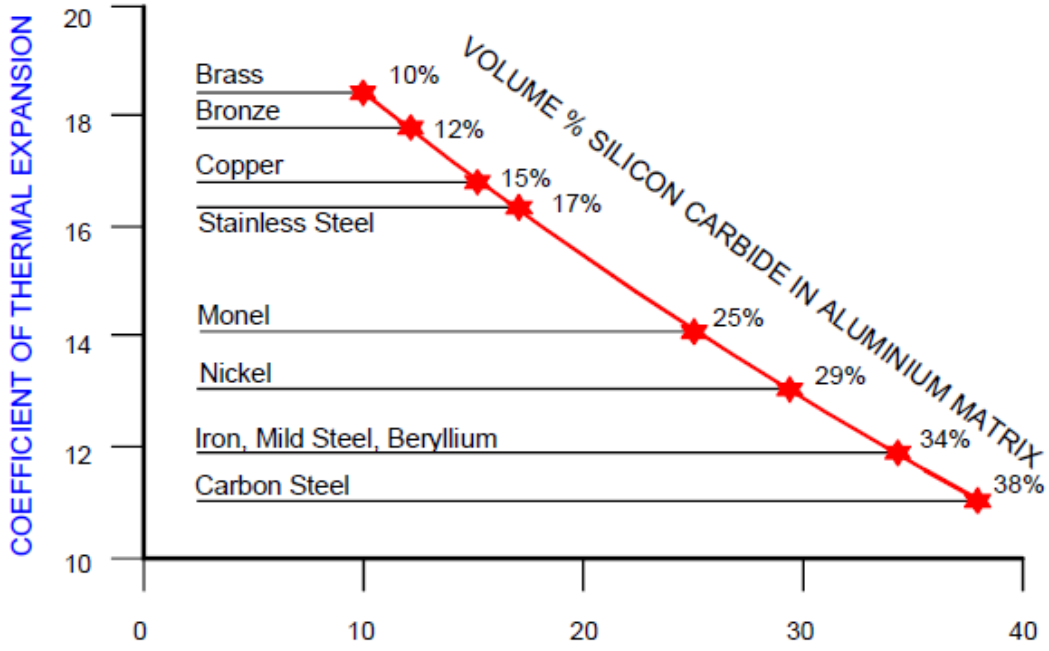
ASTS :Tony Harrison, Stephen Cooke, Joe Sims

Plasma Processes, LLC: Michael Renfro

NASA / MSFC: Ron Eng

Introduction / Why Bother?

- **SiC - AlSI10Mg metal matrix composite (SiC-AMC) is known to have different CTE based upon SiC content**



Ref. - TALAT Lecture 1501, Aluminum: Physical Properties, Characteristics and Alloys prepared by Ron Cobden, Alcan, Banbury, 1994

TALAT Training in Aluminium Application Technologies	Thermal Expansion Matching Using MMCs	1501.02.11

Introduction / Why Bother?

SiC-AMC can have mechanical properties which can compete with other materials from a strength-to-weight ratio standpoint

	Specific Strength (GPa.cm3/g) - Yield	
Beryllium	130	Wrought
30% SiC-AMC[2]	104	SLM modelled
AlSi10Mg[1]	93	SLM
100% SiC	79	Sintered

[1] Ref: Mechanical properties of AlSi10Mg produced by SLM; K. Kempena, , L.Thijsb , J. Van Humbeeckb and J.-P. Krutha 2012

[2] Ref: Particle Reinforcement of Ductile Matrices Against Plastic Flow and Creep; G. Bao, J.W. Hutchinson, and R.M. McMeeking; 1991

Phase I SOW

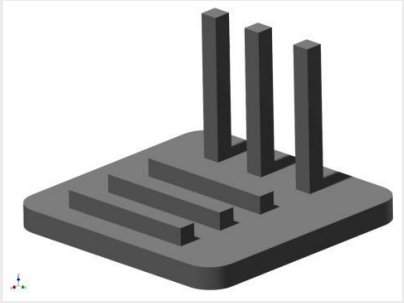
Phase I SBIR

Task 1: Optimize SLM parameters for pure AlSi10Mg; Provide Plasma Processes AlSi10Mg to encapsulate SiC into a spheroid SiC-AMC powder

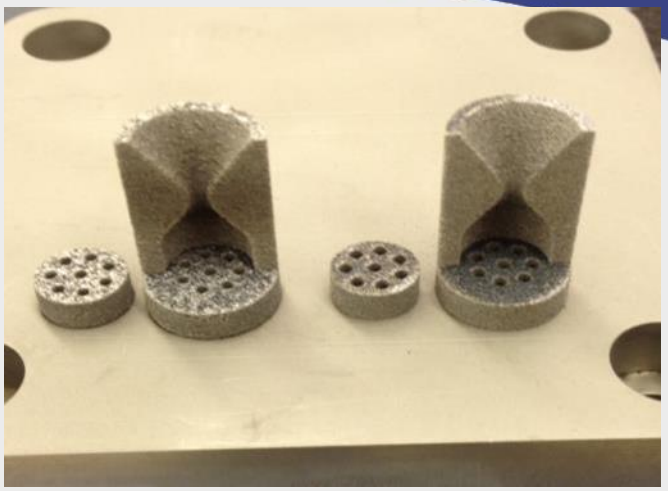
Task 2: Optimize SLM parameters for 20% SiC reinforced AlSi10Mg matrix composite (SiC-AMC); Fabricate 6 samples for CTE testing by Thermtest

Task 3: Optimize SLM parameters for 45% SiC-AMC; Fabricate 6 samples for CTE testing by Thermtest

Task 4: Analyze CTE Data and Produce Final Report



Why Need for Spheroid SiC-AMC Powder

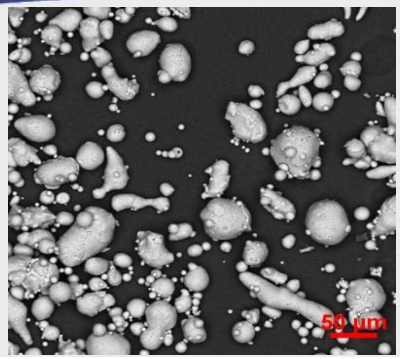


2016 NASA Phase 1 SBIR to SLM Tungsten-24%Rhenium (W-24Re) in our MLab

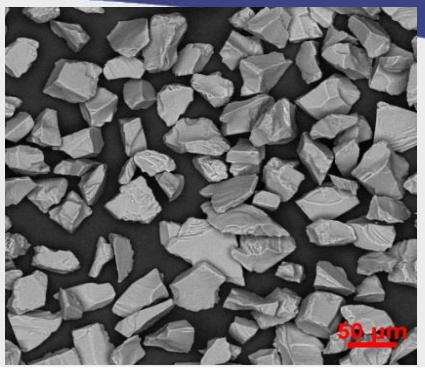
- Achieved 86% theoretical density
- Fixed powder layer thickness and laser spot size
- Experimented with various laser power, scan speeds, and assumed trace widths
- Due to irregular shaped Rhenium, even flow and distribution of layered powder was of issue

2017.2 MDA Phase II SBIR in negotiation to continue in SLM material research and development

Plasma Processes, LLC Spheroid Efforts

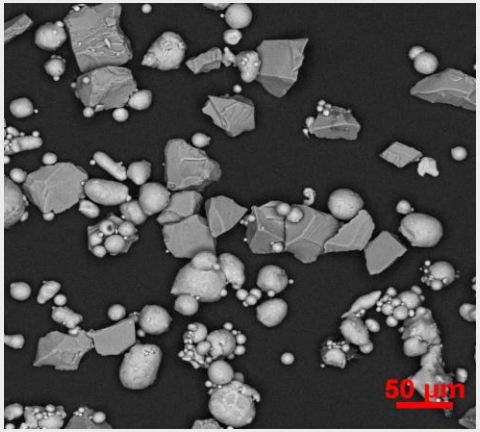


ASTS provided AlSi10Mg before processing (CL31 by Concept Laser)



PP provided SiC before processing

- AlSi10Mg & SiC size is approx. 10-45 microns (325 Mesh Sieve)
- Add AlSi10Mg to achieve 20% SiC-AMC for CTE Processing



PP 45% SiC with AlSi10Mg before processing

ASTS 100% AlSi10Mg SLM Processing

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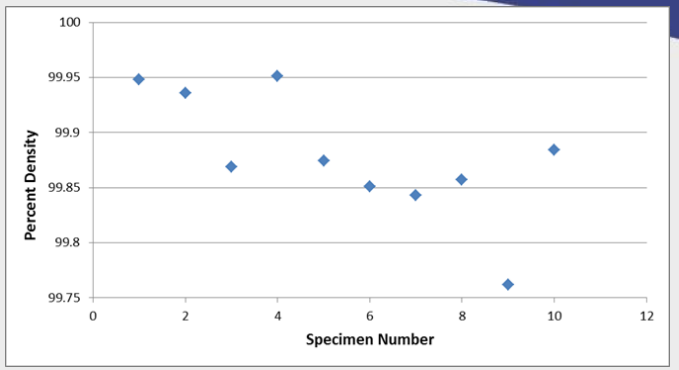
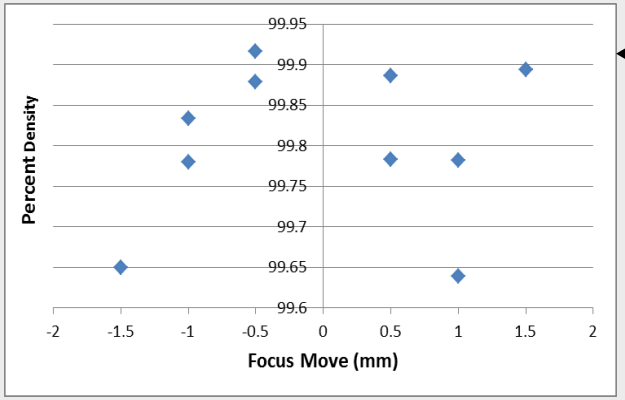
Initial SLM Parameter Assessment

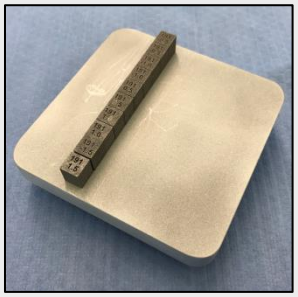
- AlSi10Mg theoretical density – 2.68g/cc
- CL SLM processing parameters used
- **Achieved 99.8+ theoretical density** with 0.015mm powder layer thickness





Optimized SLM Parameter Assessment

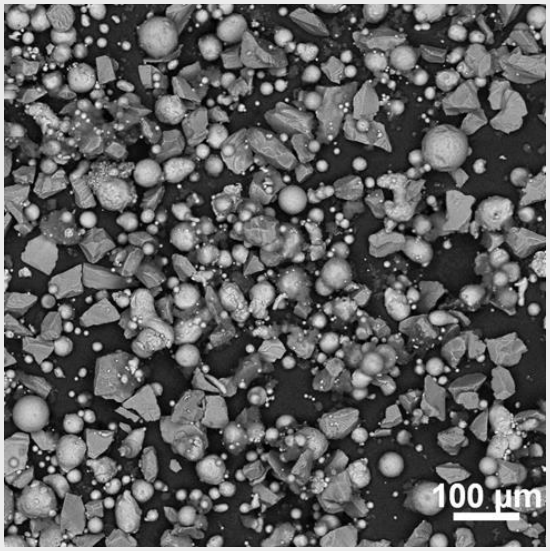
- Varied laser spot size by adj. laser focus
- No positive effect in density by changing from CL baseline

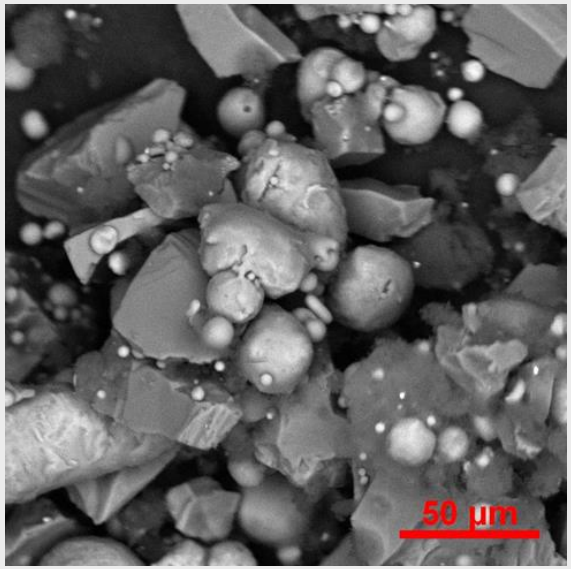


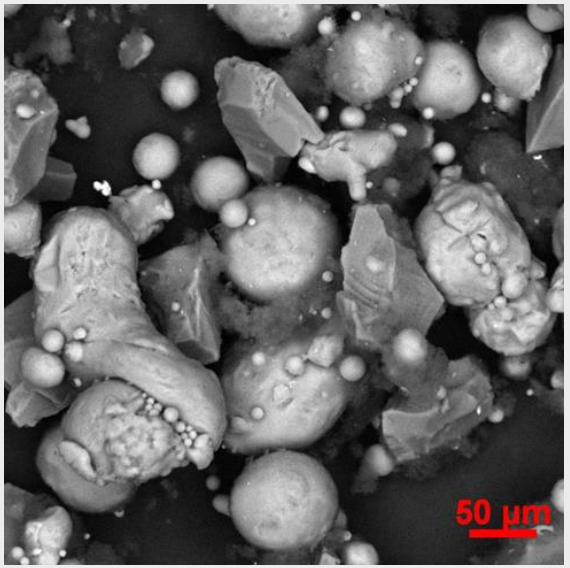
SLM of PP Spheroid Powder Results

Received from Plasma Processes, LLC. in Mid-August spheroid processed 45%SiC-AMC

- Ratio's produced by weight
- Recognized by both PP and ASTS this was a best effort process
- Blending, agglomerating and Powder Alloy and Spherodization (PAS) processing

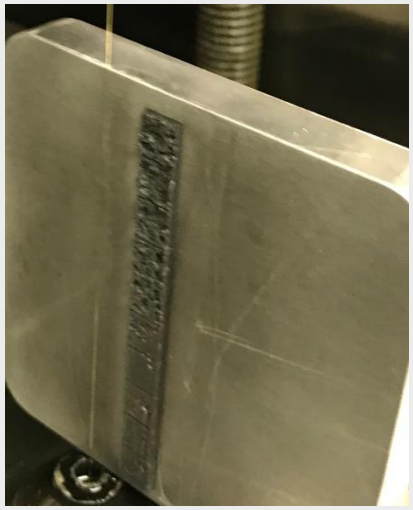


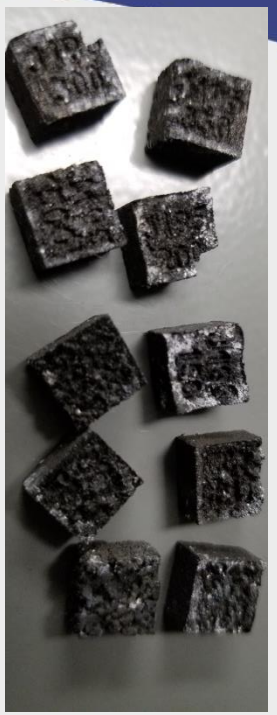




Plasma Processes, LLC. 4914 Moores Mill Rd. Huntsville, AL 35811
http://plasmapros.com/

ASTS SLM Results of PP Powder





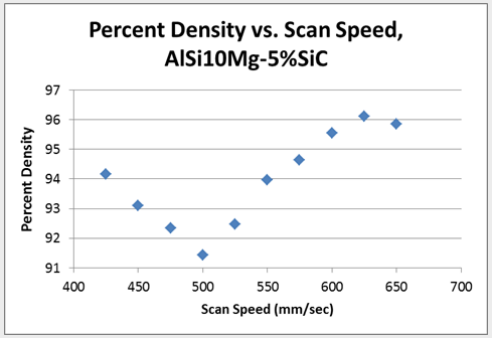
Results exemplifies need to further research SiC-AMC powder development for Additive Manufacturing use:

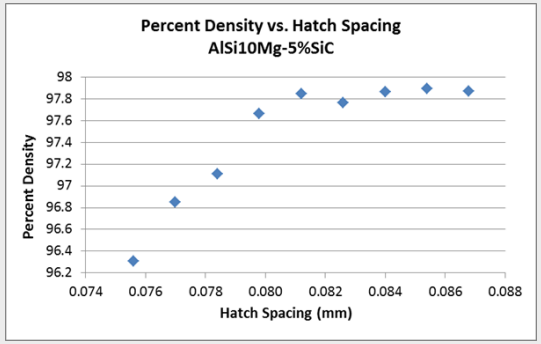
- Wettability study of aluminum to silicon carbide
- powder particle shape, size and size distributions in the powder blend for enhance encapsulation

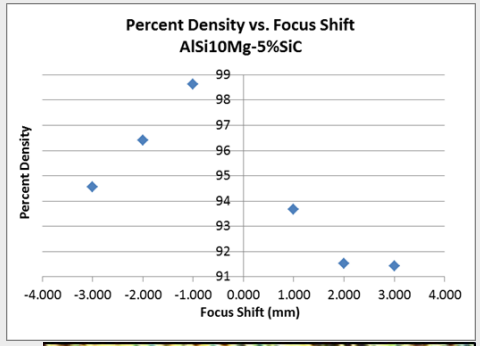
ASTS SiC-AMC Processing (Plan B)

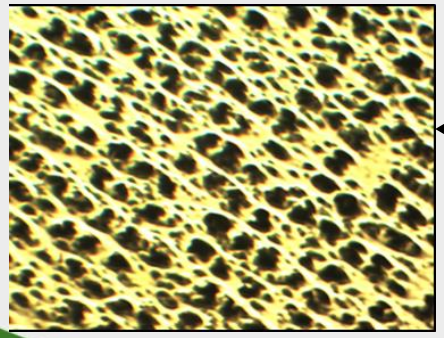
Purchased from Reade Int. Corp. 99% pure, -325 Mesh SiC Powder
Manually mixed **5%** SiC by weight with AlSi10Mg powder
SLM Parameter Development

- Constant Layer Thickness (0.015mm); Laser Power (95 W)
- Varied methodically laser scan speed, hatch spacing, and focus sift (laser spot size)



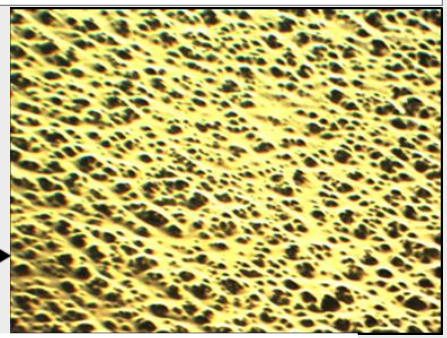






scan speed = 575 mm/sec, hatch spacing = 0.10 mm, focus shift = 0.0 mm

scan speed = 625 mm/sec, hatch spacing = 0.084 mm, focus shift = -1.0 mm

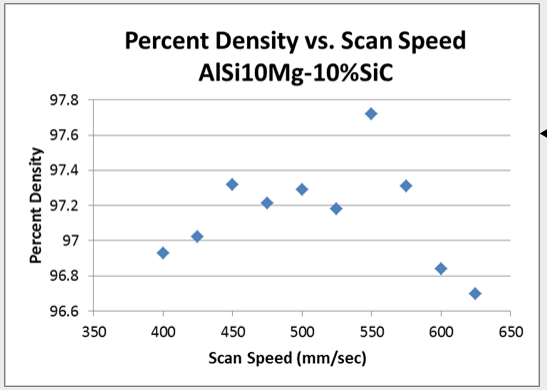


Achieved 98.6% Theoretical Density

ASTS 10% SiC-AMC SLM Results

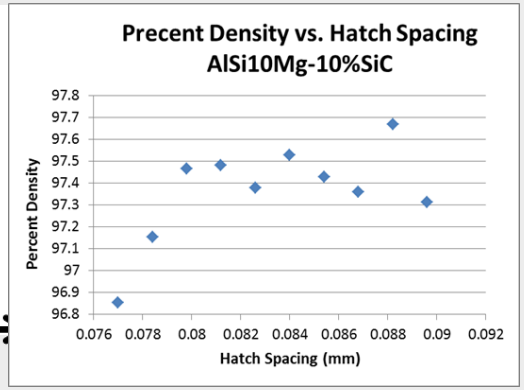
Manually mixed **10%** SiC by weight with AlSi10Mg powder
SLM Parameter Development

- Initial 5% SLM Parameters: Layer Thickness (0.015mm); Laser Power (95 W) Constant
- **Maximum theoretical density: 97.7%**



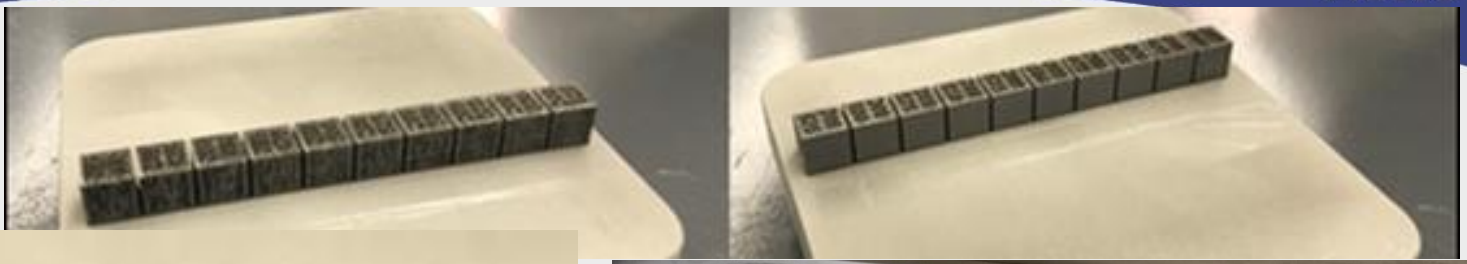
Layer Thickness=0.015,scan speed = 625 mm/sec, hatch spacing = 0.084 mm, focus shift = -1.0 mm

Layer Thickness = 0.025, scan speed = 625 mm/sec, hatch spacing = varied mm, focus shift = -1.0 mm



Regardless of layer thickness, cracks in all the specimens occurred resulting in lower theoretical density results

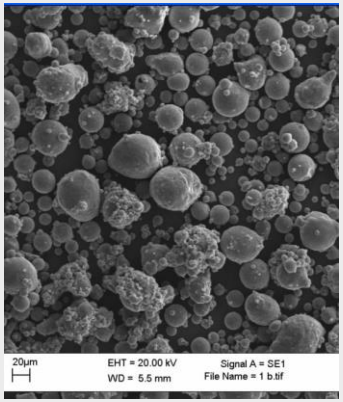
ASTS 10% SiC-AMC SLM Results (Cont.)



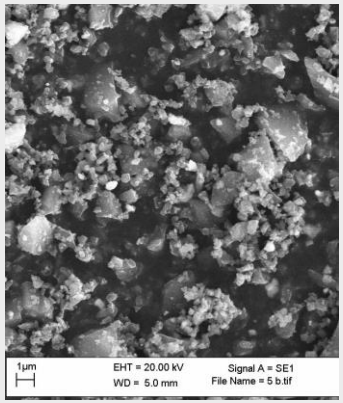
- Spherical particles are necessary for effective powder flow during blade wipe
- Particle size distribution range needs to be less than powder layer thickness

Powder Processing optimization is needed with SiC-AMC to effectively use in SLM Additive Manufacturing

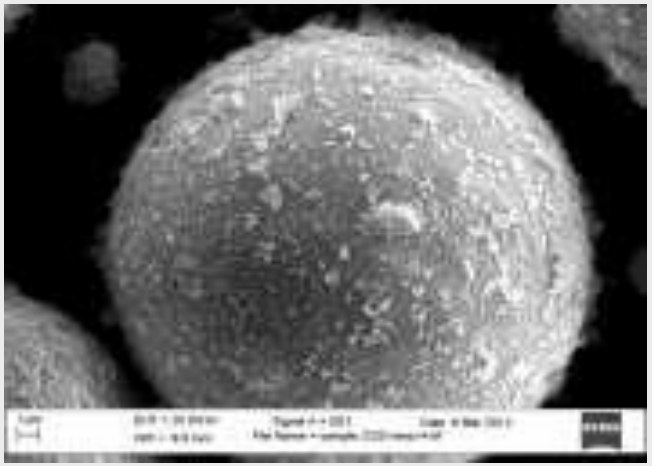
UK AlSi10Mg and SiC Powder Processing



AlSi10Mg sieved to 63 µm



SiC sieved to 1 µm



Results of 10% SiC-AMC powder processed using ZoZ Simoloyer CM1 mechanical alloying machine

- SiC embedded into the AlSi10Mg
- Also alloyed the AMC into spheroid shape

Ref: Selective Laser Melting of Aluminium Metal Matrix Composite
Omotoyosi H. Famodimu*, Mark Stanford, Lijuan Zhang, and Chike F. Oduoza
May 2014

ASTS Powder Processing Status

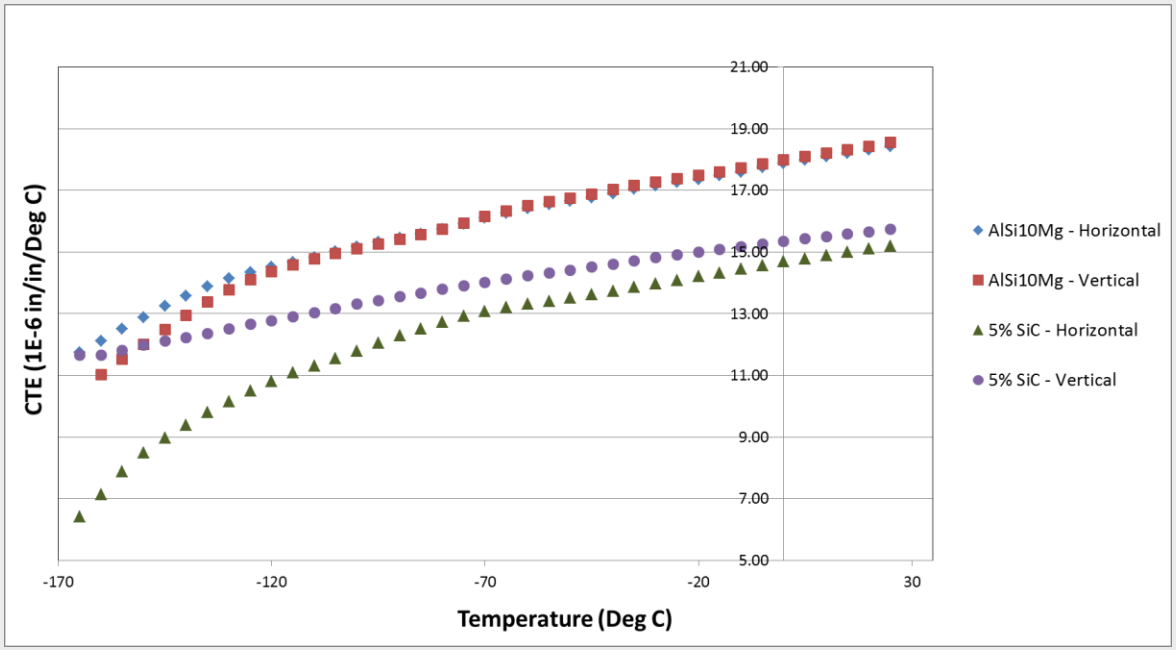
Purchased and received a Planetary Ball Mill

- Processing 10% SiC-AMC powder using existing AlSi10Mg powder and procured 1 micron SiC powder
- Perform SLM parameter processing for density evaluation and document results

Results in these experiments will determine go forward plan in Phase II efforts

CTE Assessment Status

Performed CTE testing of the 100% AlSi10Mg and 5% SiC-AMC SLM samples



We plan to HIP 5% SiC

Downward CTE trend with SiC-AMC is occurring

ASTS Awarded NASA Phase I SBIR

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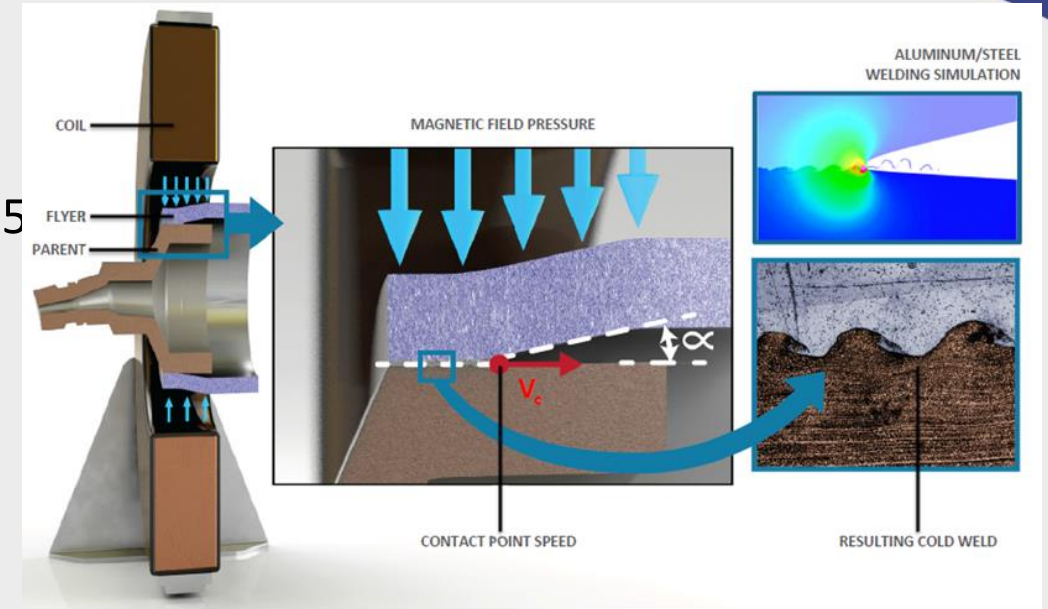
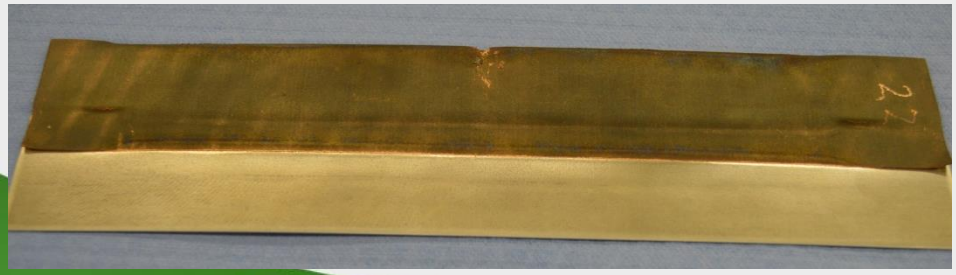
Additively Manufactured Bimetallic Combustion Chambers for Small Launch Vehicles

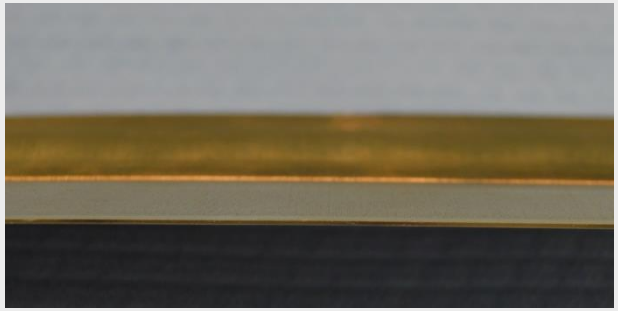
Magnetic Pulse Welding

- SLM GrCop84 with Inconel 625
- Apply to fabrication of bi-metallic combustion chambers for rocket engines



Contact point speed and contact angle are the critical parameters





Observations/Status of Conclusions

Ability to effectively fabricate parts with highly theoretical density using the SLM technique is significantly dependent on powder characteristics

- **Spheroid in shape for flowability**
- **SiC-AMC average powder particle size should be less that SLM layer thickness**

SLM processing of SiC-AMC to achieve high theoretical density is feasible

- **Verified by research in the UK for 10% SiC-AMC**
- **Further research and SLM processing development is needed in the USA**

Successful SLM development of SiC-AMC has great potential in aerospace and many other commercial applications

Thank You for Your Attention

Tony Harrison

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