BSGN Advanced Materials Accelerator

Your route for new materials development in space

Key theme: Alloys

High-entropy alloys (HEAs) are a novel class of metal alloys, composed of five or more elements in near equal proportions. No single element dominates as opposed to traditional alloys. Bulk Metallic Glass (BMGs) are a type of unique metal alloy that form non-crystalline glass-like structures when cooled rapidly from a liquid to a solid.

Applications:

- propulsion systems
- hydrogen storage
- defence
- spacecraft structures
- hypersonic flights
- nuclear reactors
- structural engineering
- debris shielding.
- turbine blades
- accident tolerant fuel cladding
- deployable structures

Opportunity 1 (Click here for more info)
High-entropy alloys (HEAs) offer great potential both structurally (unprecedented strength and fracture toughness) as well as functionally (extreme thermal resistance and anti-corrosion/radiation). Microgravity leverages containerless processing to minimise impurities and the lack of buoyancy will afford uniform alloy compositions.

Opportunity 2 (Click here for more info)
Bulk Metallic Glasses (BMGs) can store much more mechanical energy when compared with steel and other traditional materials. This combination of high strength and high elasticity allows for extreme light-weight designs as well as for use in ultra-cold conditions. Processing in microgravity and the space environment offers the opportunity to manufacture higher-performance Bulk Metallic Glasses (BMGs) that suffer from reduced quality due to the impacts of convection, sedimentation, contamination and oxidation in the manufacturing process.

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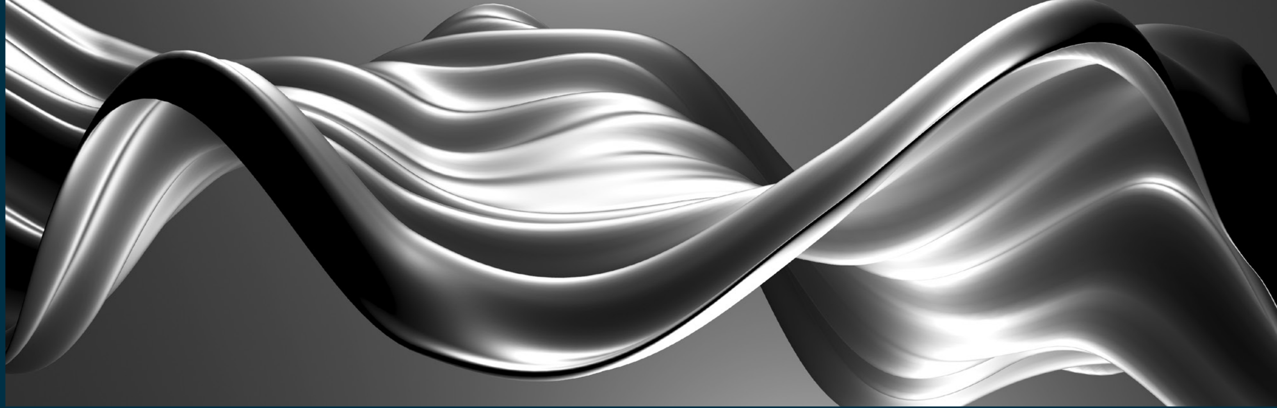
Alloys Opportunities:

1. High Entropy Alloys (HEAs): Microstructure investigations under microgravity conditions



1. Market opportunity

High Entropy Alloys (HEAs) elicit compositional freedom, presenting a unique opportunity for advanced material applications, particularly for applications where current engineering alloys fall short. HEAs exhibit excellent creep resistance and have the ability to maintain mechanical properties at either very high or very low temperatures.

Some HEAs have proven to have higher fracture toughness, strength-to-weight ratios, irradiation and corrosion resistance than many existing metal alloys, such as aluminium alloys and steels.

Due to the large number of possible compositions, processing routes, and potential microstructures in HEAs, there is a need for development of fundamental composition processing and correlation of microstructural properties to harness and exploit the attractive properties of HEAs.

2. Why space is of benefit

Microgravity can have wide-ranging opportunities and benefits for metallic materials/ alloys:

• Minimised buoyancy and the containerless effect in this environment enables uniform dispersions of a homogenous blend of metals to form superior alloys with a thousand-fold reduction in their defects, as well as minimal impurities at the grain boundaries.

• Microgravity also has an impact on the solidification characteristics of liquid metals and alloys. Alloy parts processed in microgravity conditions possess more uniform microstructures and improved mechanical properties compared to those processed on Earth.

• Considering that equal and homogeneous distribution of alloys are of critical importance to the performance of these emerging products, they can significantly benefit from microgravity R&D and manufacturing platforms.

3. Previous experiments in space/successful case studies

• Oerlikon, a Swiss supplier of advanced materials and process for Aerospace and energy, has introduced a new HEA to additively replace super duplex stainless steels structural components, such as centrifugal pump impellers in energy applications. Oerlikon has developed this HEA for additive manufacturing in a NADEA project - a European research initiative with support of Fraunhofer IWS.

• Superior hydrogen storage in high entropy alloys.

4. Applications

There are several high value and high potential target applications for HEAs in industry, including:

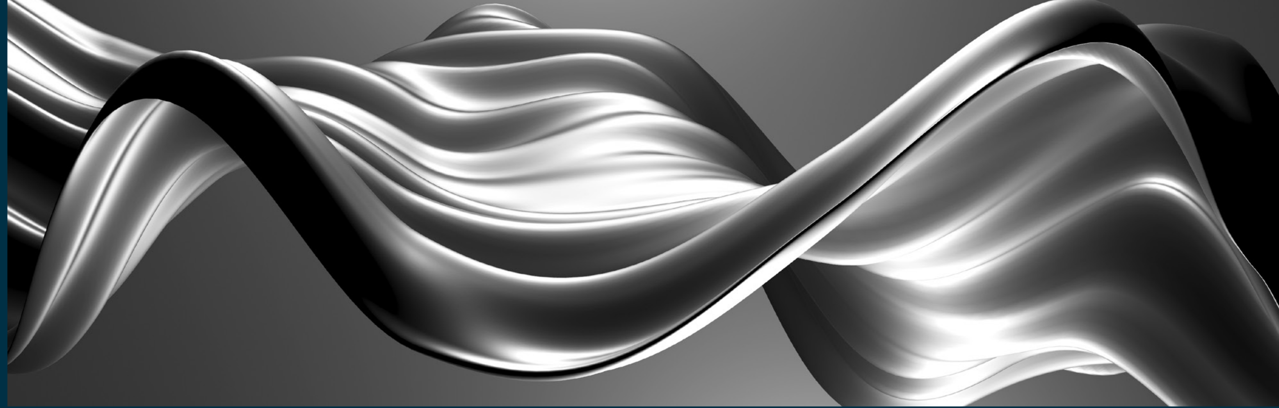
- extreme environment applications, such as ultra-high performance next generation aircraft turbine blades
- hypersonic flights
- atmospheric re-entry
- rocket/aircraft propulsion
- extreme heat exchangers in integrated power/ thermal management applications.

Hydrogen storage is a key enabling technology for the advancement of hydrogen and fuel cell technologies in applications including stationary power, portable power, and transportation. Hydrogen has the highest energy per mass of any fuel; however, its low ambient temperature density results in a low energy per unit volume, therefore requiring the development of advanced storage methods that have the potential for higher energy density. HEAs can store hydrogen, providing a potential route to viable solid-state hydrogen storage methods. HEAs can absorb much higher amounts of hydrogen than its constituents and reach an H/M (hydrogen per metal) ratio of 2.5.

HEAs offer strong value proposition for next generation nuclear fission and fusion reactors that operate under extreme radiation and temperature conditions (e.g. <1200 C). HEAs have also been considered as candidate materials for accident-tolerant fuel (ATF) cladding of reactors due to their promising oxidation and corrosion resistance as well as high mechanical strength at high temperatures.

Due to their high mechanical strength and high energy absorption capacity, HEAs could also be used for ultra-hard ballistics applications in the defence sector, such as for use in individual protection or military/non-military armoured vehicles.

Alloys Opportunities:



2. Microgravity Processing of Bulk Metallic Glasses (BMGs) and foams

1. Market opportunity
In-space R&D and manufacturing offer the opportunity to manufacture higher-performance Bulk Metallic Glasses (BMGs) that suffer from reduced quality due to the impacts of convection, sedimentation and contamination in the manufacturing process. Investigations to deepen our knowledge of BMG formation requires convection free conditions.

By introducing gases into a mixture of molten glass and molten metal and allowing the mixture to cool without gravity separating the components, leads to the formation of a metallic glass foam. These foams possess uniform structures and an extremely high strength-to-weight ratio, with the strength of steel and the corrosion resistance of glass. These foams can be used to create more durable spacecrafts, that will require less fuel to travel long distances.

Until now, the manufacturing of even small BMG components has been quite complex and very expensive. Making large BMG components using traditional manufacturing methods, like melt spinning, casting, powder metallurgy or thermoplastic forming, is not possible. In-space additive manufacturing can overcome complex geometry challenges and produce advanced BMG components for space and earth applications.

2. Why space is of benefit
• In-space R&D and manufacturing offers the opportunity to manufacture higher-performance Bulk Metallic Glasses (BMGs) that suffer from reduced quality due to the impacts of convection, sedimentation and contamination in the manufacturing process.

• BMGs are extremely reactive when in contact with oxygen. The space environment and microgravity offer ultra-vacuum as well as a containerless platform for eliminating contamination of BMGs during their processing.

• For metallic glass foams, gravity can interfere with bubble formation, causing the bubbles to rise and the liquid to sink. This is especially true when conventional metal liquids (like aluminum or titanium) is foamed. Because the effects of buoyancy are minimised in space, more uniform foam structures with unique properties can be produced.

3. Previous experiments in space/successful case studies
• Space deployable structures operating in extreme conditions
• NASA experiment: Viscous Liquid Foam - Bulk Metallic Glass
• Fabrisonic 3D Prints Bulk Metallic Glasses to Make Wear-Resistant Surfaces
• BMGs have also found their way in Luxury watches of Omega, currently being marketed as Liquidmetal® due to their hardness and durability.

4. Applications

• BMGs are highly relevant for space innovations with applications in ultra-cold conditions and for the manufacturing of materials that need to be formed into specific shapes.

• BMGs are ideal for structural engineering applications owing to their high elastic strain limit combined with a high yield strength and fracture toughness.

• BMGs are one of the candidates for manufacturing spacecraft deployable structures as well as rovers (parts such gears, drills, and wear-resistant coatings) which need properties such as those offered by BMGs to operate in extreme environments of space.

• These types of metallic foams have great potential for future exploration applications because of their great strength and light weight. These include lighter and more durable spacecrafts, that will require less fuel to travel long, and such foams may also be very effective shields against micrometeorite and orbital debris strikes.

The BSGN Advanced Materials Accelerator Call for Proposals is now open. Apply by 30 Nov 2022.

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About the BSGN Advanced Materials Accelerator
The BSGN Advanced Materials Accelerator has been established to support innovators and enterprises developing new products, technologies, and services at the intersection of advanced materials and microgravity engineering. The accelerator promotes opportunities for engineering novel materials in microgravity, and the contract is carried out under the BSGN programme of and funded by ESA, the European Space Agency.
The accelerator is coordinated by the Satellite Applications Catapult in collaboration with Innovate UK KTN, the National Composites Centre (NCC), the Technological Institute of Plastics (AIMPLAS), the DLR Institute of Material Research (DLR) and the Centre for Process Innovation (CPI). Learn more about BSGN here.

For inquiries, please get in touch at BSGNmaterials@sa.catapult.org.uk.

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