BSGN Advanced Materials Accelerator

Your route for new materials development in space

Key theme: Nanomaterials

Nanomaterials consist of a wide range of organic, inorganic, and polymeric materials. This diverse range of materials share common properties in their size and shape. These impart desirable properties which can be used in applications such as: energy storage, energy generation, mechanical reinforcement, and catalysts. The wide scope of nanomaterials means they will be both disruptive and enabling technologies across a range of industries.

Microgravity provides a unique environment for studying the formation and growth of nanomaterials such as porous networks, low defect crystals and very high aspect ratio materials.

The need for extended space missions has created a demand for new enabling nanotechnologies particularly for gas and energy storage. The ambitions of both NASA, and the burgeoning asteroid mining sector, for this decade demand that these materials be manufactured in space.

Combined, the microgravity environment provides the opportunity to advance existing Earth based technologies through fundamental R&D, develop new materials for in-space applications, and develop new processes for the in-space manufacture of nanomaterials.

Applications:

- thermal management
- vibration isolation
- sensors
- radiation/EM shielding
- energy storage
- electronics
- gas storage and separation
- catalysts

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Opportunity 1 (Click here for more info)
Both NASA and ESA have identified the need for new **nano-porous materials** covering a range of applications including vibration isolation, shielding, insulation and gas storage. For example, aerogels are of interest for their thermally insulating properties whereas metal organic frameworks are of interest in gas storage and separation.

Opportunity 2 (Click here for more info)
Extended space missions will require materials to be renewed or replaced in-space for applications such as energy storage, energy generation and the production of dust and microbe resistance surfaces. The clear trend toward longer space missions and extra-terrestrial mining creates a demand for **in space or Lunar nanomaterial production.** Atomic Layer Deposition equipment has already been miniaturised and demonstrated in microgravity. The demand for in space manufacturing including miniaturised, safe, or lower power equipment is expected to grow.

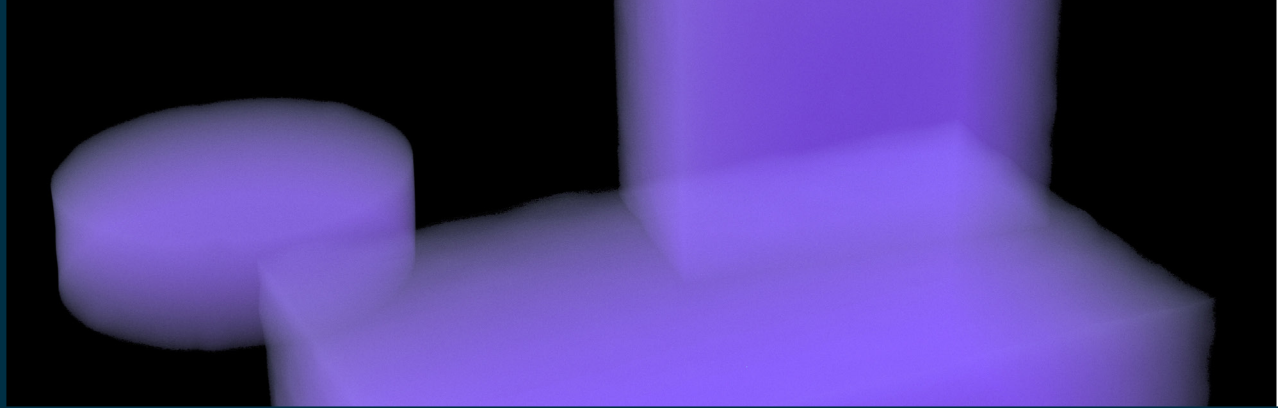
Opportunity 3 (Click here for more info)
Nanodiamonds are a promising materials set for energy generation for long life and high safety energy generation. These are of particular interest in space applications where nanodiamonds can impart stability to batteries which will be subjected to the harsh and unstable environment of space over long periods of time.

When added to lithium batteries nanodiamonds can suppress dendrite growth which result in a loss of capacity and ultimately complete cell failure or even fires. This makes nanodiamonds an enabling technology for safe high-capacity batteries such as lithium metal.

Nanodiamonds are also of interest for low-power, long-life energy sources such as 'nuclear batteries' where diamonds are used to form a semiconductor junction in order to generate electrical current from beta particles.

Nanomaterials Opportunities:

1. In-space production of nano porous materials



1. Market opportunity

The need for porous material for space is well defined by both NASA and ESA with a range of application areas covering areas as diverse as thermal management and gas storage. The opportunities for porous materials in space can be approximately divided into two. In the first case they are used to manage the significant environmental risks of extended space missions and improve the comfort of astronauts. In the second case they are needed for the production or storage or fuels in space to sustain extended missions.

Some of these opportunities are highlighted below:

- Improved thermal management for re-entry shields, space suits, and cryogenics.
- The deceleration and capture of fast-moving objects such as space debris.
- Radiation and EM shielding materials
- Gas storage and separation, particularly for hydrogen storage.
- Catalytic applications such as the splitting of water into hydrogen and oxygen.

There is also an opportunity for porous material R&D in microgravity environments both for Earth and space as microgravity has been shown to produce porous structures that are larger with fewer defects.

2. Why space is of benefit

Microgravity has been shown to allow larger area porous materials with fewer defects to be produced as buoyancy effects are removed.

3. Previous experiments in space/successful case studies

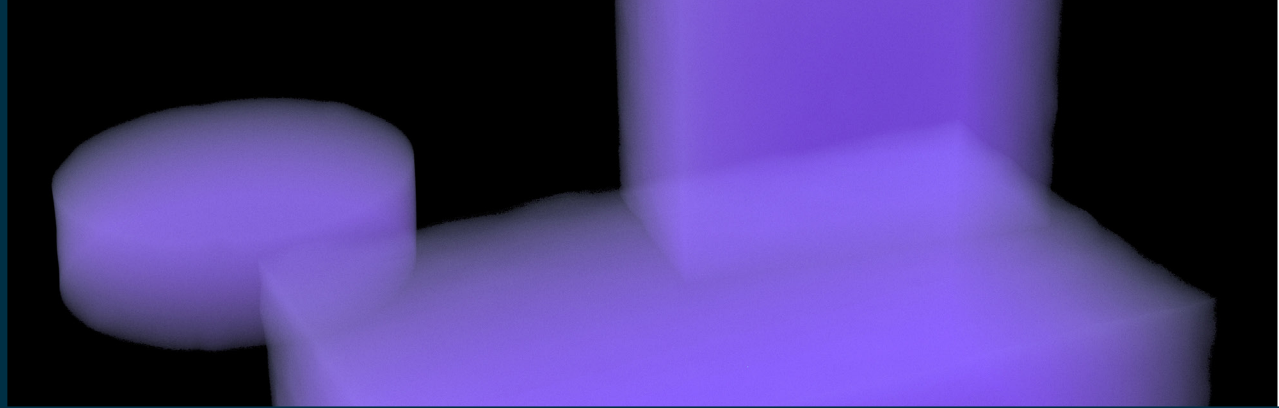
- Silica aerogels have already been used on Mars rovers for thermal protection (Aerogel insulation could provide habitable regions on Mars, Physics World, 18 July 2019)

- Aerogels have been used to sample the local environment around the International Space Station by allowing them to decelerate. (Advances in Materials Science and Engineering January 1, 2013).

4. Applications

- Collection of space debris to prevent damage to space vessels
- Thermal management for spacecraft, space suits and gas containers
- Radiation and EM shielding
- Vibration isolation.

Nanomaterials Opportunities:



2. In-space fabrication of nanomaterials for extended space missions

1. Market opportunity

For extended space missions there is a need to produce materials such as propellants or structural composites and to renew materials such as functional coatings or catalysts. To enable this the production of nanomaterials in space will be necessary. In order to do this low power, miniaturised and safe process equipment will be required, and the processes adapted for operating without buoyancy.

The NASA Nanomaterials Roadmap (2015) identified the following market opportunities for nanomaterials:

• Engineering and structured materials which include light weighting, self-healing systems, and adhesives and coating for thermal protection.
• Energy storage, power generation, and power distribution.
• Propulsion: Propellants, propulsion components and in space propulsion
• Sensors and Electronics: sensors, nanoelectronics and miniature components.

As these materials cannot all be carried as cargo from Earth, NASA has set a target date to produce materials from minerals mined from the Lunar surface by 2028.

Such a diverse range of materials will require different production processes to be developed suitable for use in space. Atomic Layer Deposition equipment has already been developed for use in space and demonstrated in microgravity where it is anticipated to be of use in reapplying protective coatings for space suits and in the development of telescope mirrors.

2. Why space is of benefit

Longer space missions will require in-situ resource (waste and feedstock) utilisation, fuel generation, production of antimicrobials and catalytic materials all of which use nanomaterials as an enabling technology.

3. Previous experiments in space/successful case studies

• ISS Microgravity Science Glovebox: synthesising nanoparticles in space (Space flames and microgravity liquids: Astronauts mark 20 years with space station equipment, Space.com, July 19 2022)

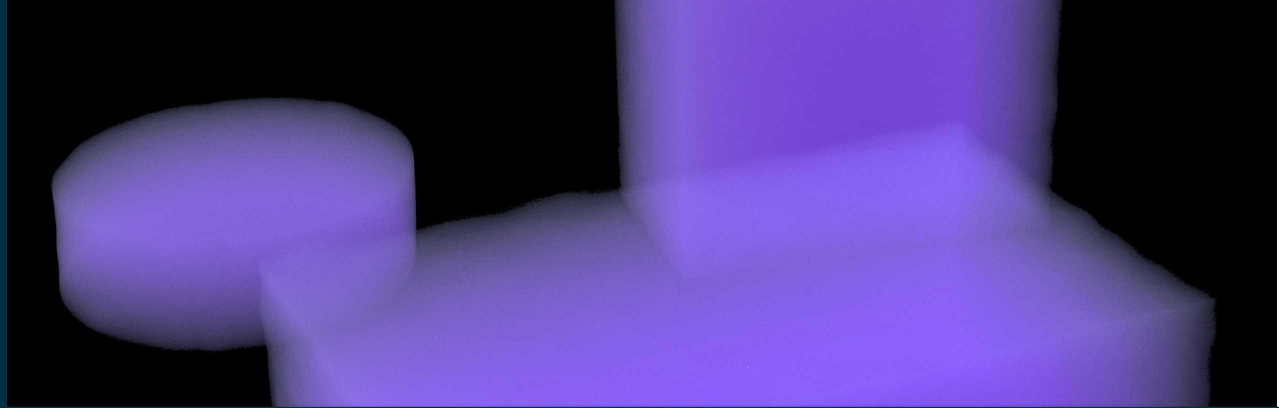
• NASA DREAM2: identifying material requirements, including nanostructured coatings, for Lunar and Meteor dust (Dust Solution Testing Initiative (Dusti), 20220001854, Karen Kathleen John, Amy M. Cassady, A. Garcia, 2022).

4. Applications

Key application for in space synthesis of nanomaterials include:
• Catalysts for energy generation (hydrogen & oxygen generation) in situ manufacture in space.
• Antimicrobial coatings and additives for extended space missions. Preventing fouling, microbial corrosion and infection of cell cultures and hydroponics
• Anti-dust coatings for Lunar and Mars materials.
• Processing of waste materials into feedstocks for other processes.
• Making use of mined materials from asteroids.

Nanomaterials Opportunities:

3. Nanodiamonds for energy generation



1. Market opportunity

The demand in battery technology is for higher capacity and stable operation. There are also niche requirements for low-energy, long life, and stable energy sources for markets such as space and medical implants.

Nanodiamonds are an emerging material that is of interest in both of these markets.

Nanodiamonds have been shown to suppress the formation of dendrites in lithium-ion batteries which are known to be detrimental to both performance and are a significant safety risk. Nanodiamonds are already used in the electroplating industry to suppress dendrite growth making them a promising candidate for high-capacity batteries such as lithium metal batteries.

For low power applications nanodiamond ‘nuclear batteries’ (beta-voltaic cells) have the potential to produce batteries that could last for 28,000 years. Bristol University have developed diamond structures which when exposed to radioactive particles generates a current. It is anticipated this could be a produced from radioactive waste. Potential applications include medical devices and power sources for space probes or vehicles where the simplicity of the cell could be beneficial in the harsh environment of space.

2. Why space is of benefit

Space vehicles and satellites are typically supported by solar power which is degraded by the extreme conditions of space (temperature, heat, dust etc).   Nanodiamond batteries have the potential to provide a stable alternatives.

3. Previous experiments in space/successful case studies

• NDB Technology

• The University of Bristol (2016) ‘Diamond-age’ of power generation as nuclear batteries developed

• Cheng et al. (2017) ‘Nanodiamonds suppress the growth of lithium dendrites’

4. Applications

• **Space:** Supporting low power devices or charging capacitors for vehicles or probes.
• **Automotive & Electronics**: Nanodiamond batteries could bring about a revolution in electric vehicles due to increased capacity, safety, and longevity.
• **Medical Technology**: Nanodiamond batteries are of interest for implantable devices such as pacemakers where low power, long life and safety is prioritised.
• **Defence**: Nanodiamond batteries can be used in surveillance systems and electronics.

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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