The purpose of the innovation is to provide an enhanced stray light control capability by making a blacker surface treatment for typical stray light control components. Since baffles, stops, and tubes used in scientific observations often undergo loads such as vibration, it was critical to develop this surface treatment on structural materials. The innovation is to optimize the carbon nanotube growth for titanium, which is a strong, lightweight structural material suitable for spaceflight use.

The titanium substrate carbon nanotubes are more robust than those grown on silicon and allow for easier utilization. They are darker than current surface treatments over larger angles and larger wavelength range. The primary advantage of titanium substrate is that it is a good structural material, and not as brittle as silicon.

Three-Dimensional Porous Particles Composed of Curved, Two-Dimensional, Nano-Sized Layers for Li-Ion Batteries

A new method and materials were developed for preparing high-performance Si-based anodes for secondary Li-ion batteries.

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Building on previous knowledge acquired through research on thin-film batteries, three-dimensional (3D) porous macroscopic particles consisting of curved two-dimensional (2D) nanostructures of Si may bring unique advantages for Si anode technology. Prior work on thin Si films showed that during Li insertion, large-area Si films mostly accommodate the volume changes via variation in thickness. Therefore, the changes in the external surface area can fundamentally be minimized and thus, formation of a stable, solid electrolyte interphase (SEI) should be easier to achieve. In contrast, Si nanoparticles expand uniformly in all dimensions and thus, their outer surface area (where SEI forms) changes dramatically during insertion/extraction of Si. The low elasticity of the SEI makes it difficult to achieve the long-term stability under cycling load. Further, thin Si films have lower surface area (for the same mass), in comparison to Si nanoparticles, and better potential for achieving low irreversible capacity losses on the first and subsequent cycles.

Thin Si films coated on porous 3D particles composed of curved 2D graphene sheets have been synthesized utilizing techniques that allow for tunable properties. Since graphene exhibits specific surface area up to 100 times higher than carbon black or graphite, the deposition of the same mass of Si on graphene is much faster in comparison — a factor which is important for practical applications. In addition, the distance between graphene layers is tunable and variation in the thickness of the deposited Si film is feasible. Both of these characteristics allow for optimization of the energy and power characteristics. Thicker films will allow higher capacity, but slower rate capabilities. Thinner films will allow more rapid charging, or higher power performance.

In this innovation, uniform deposition of Si and C layers on high-surface-area graphene produced granules with specific surface area (SSA) of $\approx 5 \ m^2g^{-1}$. The over 100 times reduction in SSA of the initial graphene material is important for high Coulombic efficiencies on the first and subsequent cycles. Here, the low surface area of the composite resulted in an average Coulombic effi-
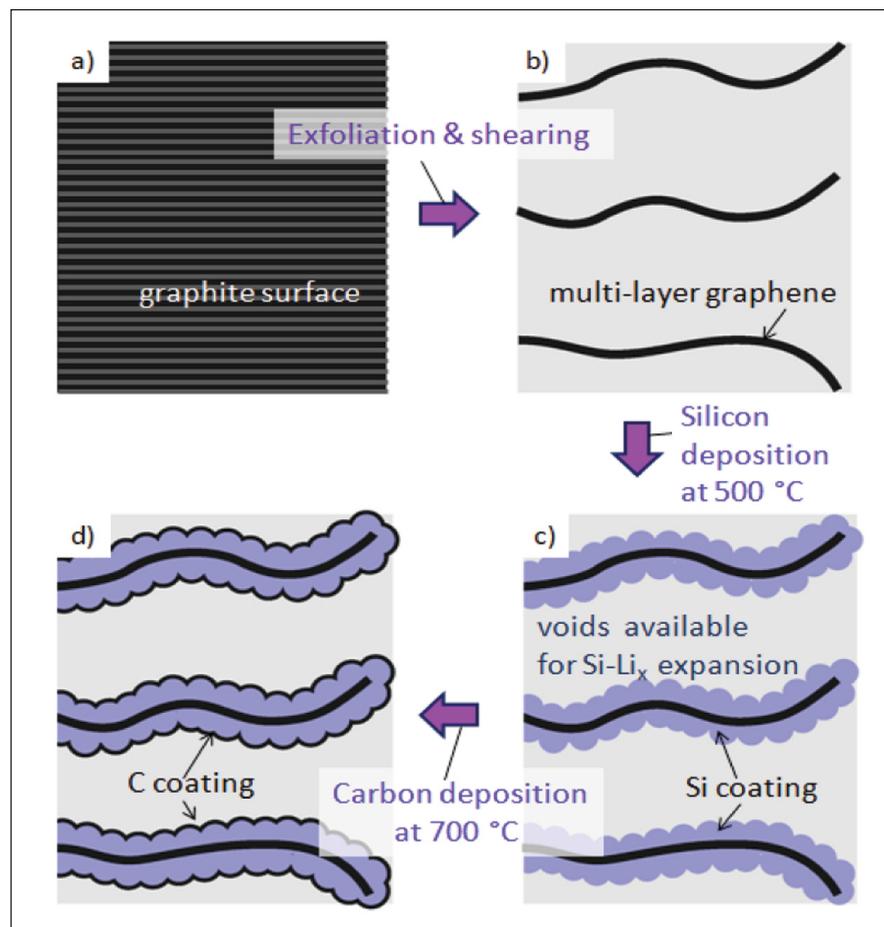
A schematic of **C-Si-Graphene Composite Formation**: (a) natural graphite is transformed to (b) graphene, and then (c) coated by Si nanoparticles and (d) a thin C layer.

ciency in excess of 99%. The anode composed of the nanocomposite particles exhibited specific capacity in excess of 2,000 mAhg^{-1} at the current density of 140 mAg^{-1} and excellent stability for 150 cycles, significantly exceeding the theoretical capacity of graphite and graphene. While only a Si-containing composite was demonstrated, the synthesis techniques utilized are applicable for other high-capacity materials that can be conformally coated on graphene. Similarly, while only curved graphene was used as a substrate for Si deposition, other curved, thin, 2D substrates (which do not react with Si precursors) may be used for conformal coating by Si or other high-capacity materials.

This work was performed by Gleb Yushin, Kara Evanoff, and Alexander Magasinski of

Ultra-Lightweight Nanocomposite Foams and Sandwich Structures for Space Structure Applications

Marshall Space Flight Center, Alabama

Microcellular nanocomposite foams and sandwich structures have been created to have excellent electrical conductivity and radiation-resistant properties using a new method that does not involve or release any toxicity. The nanocomposite structures have been scaled up in size to 12×12 in. (30×30 cm) for components fabrication. These sandwich materials were fabricated mainly from PE, CNF, and carbon fibers. Test results indicate that they have very good compression and compression-after-impact properties, excellent electrical conductivity, and superior space environment durability.

Compression tests show that 1000 ESH (equivalent Sun hours) of UV exposure has no effect on the structural properties of the sandwich structures. The structures are considerably lighter than aluminum alloy (≈36 percent lighter), which translates to 36 percent weight savings of the electronic enclosure and its housing. The good mechanical properties of the materials may enable the electronic housing to be fabricated with a thinner structure that further reduces the weight. There was no difficulty in machining the sandwich specimens into electronic enclosure housing.

Thermally Resilient, Broadband Optical Absorber From UV to IR Derived From Carbon Nanostructures

This technology can be used in aerospace, semiconductors, antireflection coatings, optoelectronics, and communications.

NASA's Jet Propulsion Laboratory, Pasadena, California

Optical absorber coatings have been developed from carbon-based paints, metal blacks, or glassy carbon. However, such materials are not truly black and have poor absorption characteristics at longer wavelengths. The blackness of such coatings is important to increase the accuracy of calibration targets used in radiometric imaging spectrometers since blackbody cavities are prohibitively large in size. Such coatings are also useful potentially for thermal detectors, where a broadband absorber is desired. Au-black has been a commonly used broadband optical absorber, but it is very fragile and can easily be damaged by heat and mechanical vibration. An optically efficient, thermally rugged absorber could also be beneficial for thermal solar cell applications for energy harnessing, particularly in the 350–2,500 nm spectral window.

It has been demonstrated that arrays of vertically oriented carbon nanotubes (CNTs), specifically multi-walled-carbon-nanotubes (MWCNTs), are an exceptional optical absorber over a broad range of wavelengths well into the infrared (IR). The reflectance of such arrays is 100× lower compared to conventional black materials, such as Au black in the spectral window of 350–2,500 nm. Total hemispherical measurements revealed a reflectance of ≈1.7 % at λ ≈1 μm, and at longer wavelengths into the infrared (IR), the specular reflectance was ≈2.4 % at λ ≈7 μm.

The previously synthesized CNTs for optical absorber applications were formed using water-assisted thermal chemical vapor deposition (CVD), which yields CNT lengths in excess of 100's of microns. Vertical alignment, deemed to be a critical feature in enabling the high optical absorption from CNT arrays, occurs primarily via the crowding effect with thermal CVD synthesized CNTs, which is generally not effective in aligning CNTs with lengths < 10 μm. Here it has been shown that the electric field inherent in a plasma yields vertically aligned CNTs at small length scales (<10 μm), which still exhibit broadband, and high-efficiency optical absorption characteristics from the ultraviolet (UV) to IR. A thin and yet highly absorbing coating is extremely valuable for detector applications for radiometry in order to enhance sensitivity. A plasma-based process also increases