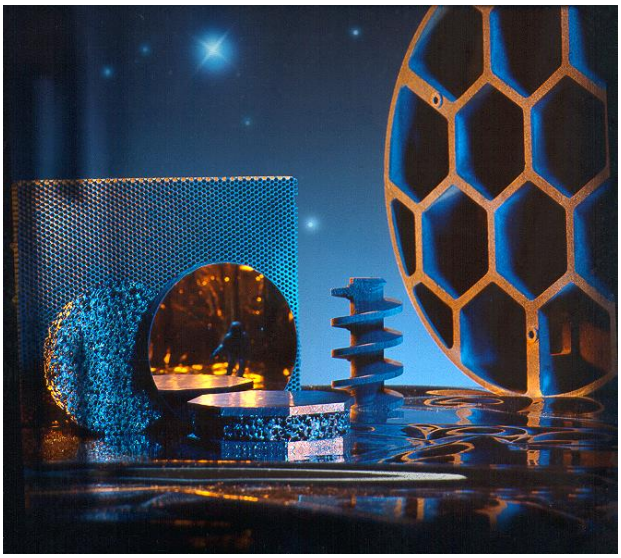
Category: Materials, Coatings & Processes

Reference: TD-DE-1023

Cesic® – carbon fibre reinforced silicon carbide – light-weight mirror technology



Cesic®'s material properties and advantages were demonstrated in numerous test and validation projects in cooperation with international space-system suppliers and space agencies. For instance, during the ESA-funded JWST NIRSpec program, a flight-representative 1,0 m x 0,6 m optical bench was manufactured, which was qualified for cryo- and mechanical stability under space standards.

Cesic® is a „space-qualified" ceramic material; and the Cesic® manufacturing processes are qualified according to the valid quality guidelines of DIN ISO 9001:2000 and ECSS standards.

A flight telescope structure with two integrated mirrors, all made entirely out of Cesic®, was manufactured and were successful integrated on the satellites. Two satellites are now in operation with an "All Cesic telescope" after their launch with an Ariane 5 on February 2009 from Kourou.
Description:

Cesic® is a ceramic matrix composite. It is characterized by high stiffness and mechanical strength, high thermal conductivity, low CTE, and quick, relatively inexpensive manufacturing times. These characteristics make Cesic® an ideal material at reasonable cost for large high-precision space optical and structural applications.

The starting material in the manufacturing of Cesic® is a short, chopped, randomly oriented carbon fiber material, consisting of both pitch-based and other fibers. The fibers are mixed with a phenolic resin and molded into a blank, which then is heat-treated under vacuum. The result is a light-weight, porous, relatively brittle C/C greenbody. At the present time circular blanks are available in sizes up to 1.6 m, with a thickness up to 200 mm. In the near future greenbody blocks up to 2 m in size or even larger will become available as circular or square blocks.

A large CNC controlled milling machine of 2.5 m x 1.75 m allows manufacture large, light-weighted, monolithic structures, such as mirrors and components for optical benches. For example, in the manufacture of optical mirrors, curved face sheets (including off-axis designs) can be machined with reinforcing ribs as thin as 1 mm and of any geometry, including ribs with light-weighting holes or of T-shape for increased stiffness.
Upon machining, the greenbody is infiltrated under vacuum conditions with liquid silicon at temperatures above 1600 °C. Capillary forces wick the silicon throughout the porous greenbody, where it reacts with the carbon matrix and the surfaces of the carbon fibers to form carbon-fiber reinforced SiC - Cesic®. The density of the infiltrated Cesic® composite is between 2.70 and 2.98 g/cm³ depending on the material type.

After controlled cool-down, the Cesic® structure is carefully examined visually and by other NDT methods, such as dye penetrant tests. The structure is then micro-machined with suitable diamond tools or by EDM

machining to achieve the required surface figure and interface geometry (e.g., mirror adaptation and mounting). EDM machining is possible because of Cesic®'s good electrical conductivity. This machining method is fast compared to grinding, it is relatively inexpensive, and it yields a surface and location accuracy (e. g., for screw holes and mounts) of about 10 µm tolerance over a large area.

Manufacturing times of Cesic® mirrors and other structures are typically only a few weeks, upon procurement of the C/C raw material, which is much shorter than the manufacturing times of other ceramic or glass structures. Highly complex and large projects take somewhat longer, e.g., mirrors with closed backs, meter-plus-class mirrors that require precision joining of greenbody or infiltrated segments, and large multi-segmented optical benches.

The maximum size of Cesic® components is only limited by the size of the Si-infiltration furnaces. The current largest furnace has a useable diameter of 2.4 m with up to three levels, each of height 1.2 m.

Innovative Aspects:

Cesic® is a versatile material that distinguishes itself by the following characteristics:

- low specific weight,
- high stability and stiffness,
- excellent fracture toughness,
- low CTE from room to cryo temperatures
- quick, cost-effective and near-net-shape manufacturing.

These properties make Cesic® an ideal material for high performance applications.

Application Areas:

The Cesic® technology with its projecting opto-mechanical performance is usable in the field of astronomy, opto-electronics, laser technologies and solar power plants, e. g. for

- telescopes
- structures
- antennas
- reflectors
- optical benches.

Cooperation:

The technology provider is interested in selling Cesic® products designed for individual and specific demands.