

DENSE, ISOTROPIC GRAPHITE FABRICATED BY HOT ISOSTATIC COMPACTION

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Very dense, isotropic graphite bodies have been fabricated from graphite powders by the hot-isostatic (gas-pressure) compaction process at temperatures from 1650 to 2700 C and isostatic inert-gas pressures from 680 to 2040 atm. The further densification of commercial bulk (not powder) material was also accomplished. Characterization studies of the compacted materials revealed that graphite bodies which are both very dense (2.00-2.25 g per cc) and relatively isotropic can be fabricated by this method.

In the hot-isostatic-compaction process, the powder materials may first be hydrostatically cold compacted to a specific geometry, and are then sealed in an evacuated, thin metal container, or envelope. Tantalum has been used as a container material to encapsulate the carbon-base materials because of its good fabrication characteristics and high metal-carbon eutectic temperature. The sealed containers are placed into a furnace inside a cold-wall, high-pressure autoclave. A graphite resistance heater is used to heat the components while the autoclave is pressurized with helium gas. The gas pressure is uniformly transmitted to the heated specimen through the walls of the softened metal envelope to isostatically hot-press the material.

The graphite powder materials examined in this study included relatively low-purity, naturally-occurring graphite, moderate-purity, artificial-grade graphite, and ultrahigh-purity, spectrographic-grade graphite. Various particle size mixes of the powders were examined to determine effects on the density and properties of the green and final compacts. The hot-isostatic compaction of the materials produced high-density compacts in the range of 2.00 to 2.25 g per cc (89 to 99 percent of theoretical). Densities of 2.15 g per cc were achieved from most of the high-purity materials at conditions from 1950 to 2700 C and 2040 atm to 1600 atm for 30 to 120 minutes. Moderate-purity artificial and ultrahigh-purity spectrographic-grade graphite powders were compacted to densities as high as 2.25 g per cc at 2700 C and 1600 atm. Also, commercial bulk (not powdered) materials were further densified to 2.15 g per cc at 2700 C and 890 atm. The relative tensile strengths of the various compacted powder materials were measured by the diametral loading test and varied widely for different materials from 500 to 3500 psi, as compared to a value of 2300 psi for ATJ graphite.

Isotropic characteristics of the graphite materials were determined by X-ray and neutron diffraction techniques and correlated with linear thermal expansion and electrical resistivity measurements made in two principal crystallographic directions. The degree of original powder-particle alignment and final isotropy of the compact can be controlled by varying the loading procedures for the powder materials prior to hot isostatic compaction. The dense, hot-isostatic-compacted materials achieved isotropy ratios of 0.40 to 0.99 as compared to 0.73 for ATJ-grade graphite. Microphotographs of various graphite structures investigated in this study are included.