Diagnostic Techniques Used to Study Chemical-Vapor-Deposited Diamond Films

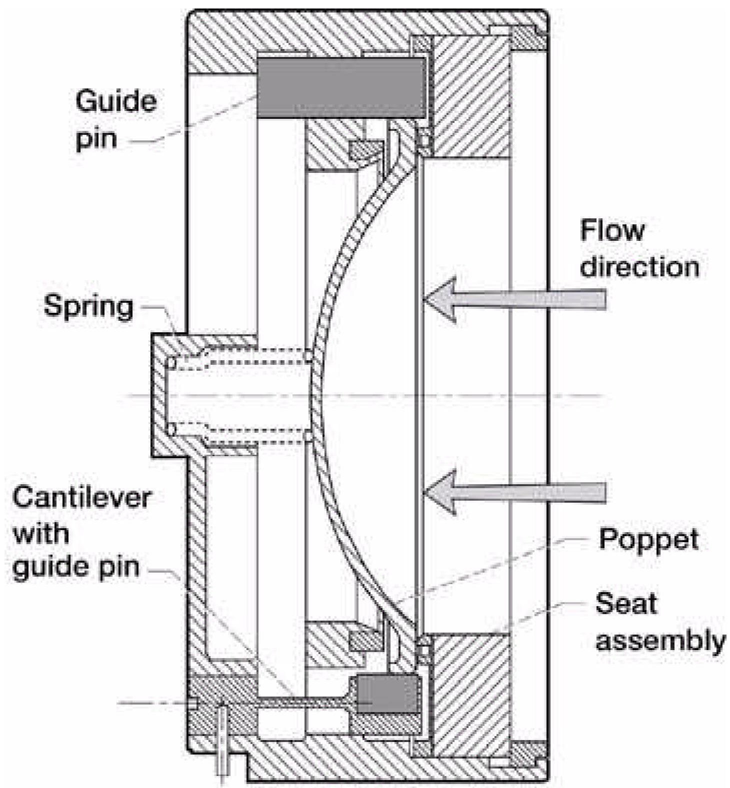
The advantages and utility of chemical-vapor-deposited (CVD) diamond as an industrial ceramic can only be realized if the price and quality are right. Until recently, this technology was of interest only to the academic and basic research community. However, interest has grown because of advances made by leading CVD diamond suppliers (ref. 1):

1. Reduction of the cost of CVD polycrystalline diamond deposition below $5/carat ($8/cm^2)

2. Installation of production capacity

3. Epitaxial growth of CVD single-crystal diamond

Thus, CVD diamond applications and business are an industrial reality. At present, CVD diamond is produced in the form of coatings or wafers. CVD diamond film technology offers a broader technological potential than do natural and high-pressure synthetic diamonds because size, geometry, and eventually cost will not be as limiting. Now that they are cost effective, diamond coatings—with their extreme properties—can be used in a variety of applications. Diamond coatings can improve many of the surface properties of engineering substrate materials, including erosion, corrosion, and wear resistance. Examples of actual and potential applications, from microelectromechanical systems to the wear parts of diamond coatings and related superhard coatings are described in reference 2. For example, diamond coatings can be used as a chemical and mechanical barrier for the space shuttles' check valves, particularly on the guide pins and seat assemblies (see the figure and ref. 3).



Potential application of CVD diamonds for valves such as the guide pins and seat assemblies in the space shuttles' check valves.

To achieve satisfactory surface and bulk properties of coatings and films, researchers must optimize deposition parameters through the study of the physical, chemical, and structural changes of coatings and films as a function of deposition parameters (ref. 4). These parameters must not only give the appropriate initial level of surface and bulk properties but must also provide durable coatings and films.

For a material to be recognized as diamond it must have all of the following characteristics (refs. 1 and 4):

1. A crystalline diamond morphology and microstructure visible by electron microscopy

2. A single-phase diamond crystalline structure detectable by x-ray or electron diffraction

3. A clear, sharp diamond peak at 1332 cm^{-1} in a Raman spectrum

4. Carbon content

5. A low equilibrium coefficient of friction (0.01 to 0.05) in air

Diagnostic techniques, including friction measurement, have been highlighted in an important case study of microwave-plasma-assisted CVD diamond films (ref. 4) at the

NASA Glenn Research Center at Lewis Field. The work focused attention primarily on the nature, character, and quality of the CVD diamond films. Diagnostic techniques included

1. Scanning electron microscopy and transmission electron microscopy to determine surface morphology, microstructure, and grain size
2. Surface profilometry and atomic force microscopy to measure surface roughness and determine surface morphology
3. Rutherford backscattering and elastic recoil spectroscopy to determine the composition (including hydrogen content)
4. Raman spectroscopy to characterize the atomic bonding state and quality
5. X-ray diffraction to determine the crystal orientation
6. Friction examination to determine the coefficient of friction and surface properties

The commercial potential of diamond films has been clearly established, and a number of applications have been identified through university, industry, and Government research studies. A combination of diagnostics techniques can provide the technical information required for understanding the characteristics and properties of diamond films, which are important to their application in specific component systems and environments (refs. 1, 4, and 5).

References

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