Diafilm™ EP

A solid solution for sanitising and electrochemical processing

elementsix™
DE BEERS GROUP

Our Diafilm™ EP has been specifically engineered as a solid, free standing CVD diamond electrode material, eliminating common problems associated with thin-film diamond coating such as coating delamination. Combined with its extremely wide solvent window, this is the material of choice for demanding electrochemistry applications, delivering longer life, lower process costs and enabling new types of processes to be developed.

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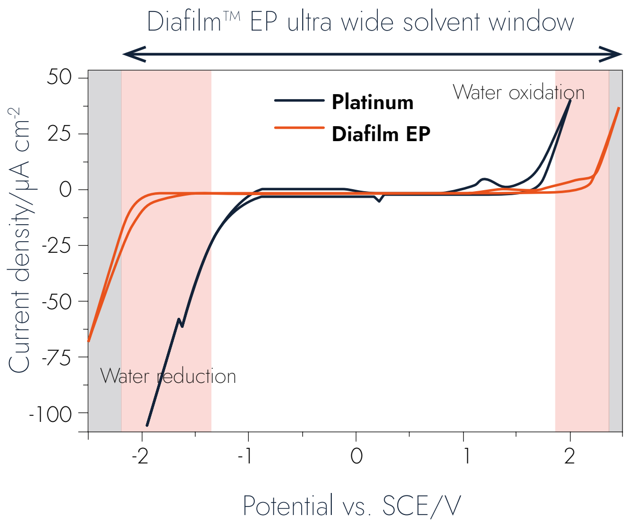
CVD diamond for high current density applications

Extremely wide solvent window

Diafilm™ EP is a solid, free-standing form of polycrystalline boron doped diamond (BDD). It has been specifically developed to operate at very high current densities (above 10 000 A m^{-2}) and has an extremely wide solvent window that enables the application of ultra high electropotentials in ionic solvents. In water, boron doped diamond electrodes are able to generate short-lived, strongly oxidizing species such as the hydroxyl radical at the anode surface and high concentrations of species in solution such as ozone.

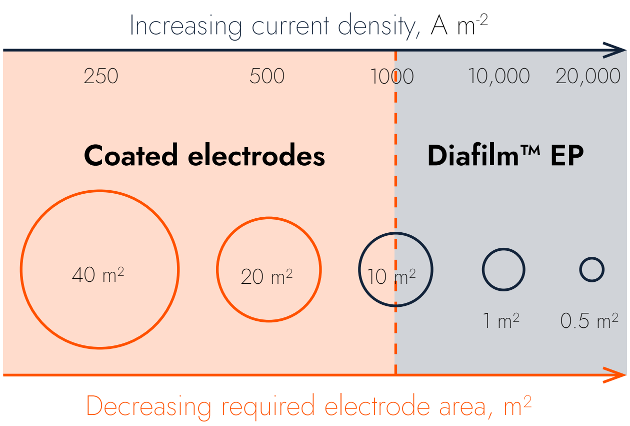


New opportunities in chemical processing

Diafilm™ EP offers the capability to undertake chemical processes that would otherwise be expensive, hazardous or prohibitive by other means. Tangible benefits include the reduction in consumable usage, increasing productivity and driving efficiency gains. Significant environmental benefits include reductions in the volume of hazardous waste and overall disposal costs.

Smaller, more compact electrochemical cells

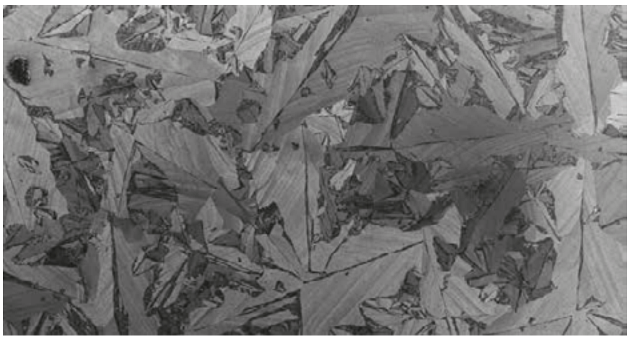
In an electrochemical process, the work done is proportional to the total charge flowing through the cell. Thin film diamond electrodes typically operate at current densities in the range of 300 to 1000 A m^{-2}. Depending on the process, Diafilm™ EP can operate in a range up to 20 000 A m^{-2}. The diagram below illustrates the equivalent area of coated electrodes compared to Diafilm™ EP to achieve the same level of processing output.



Diafilm™ EP enables very high current density operation, so for a given processing requirement, it enables a significantly smaller, more compact electrochemical cell to be used.

Delamination elimination

Diafilm™ EP eliminates substrate delamination, the common cause of premature failure with diamond coated electrodes. This means that it can be operated at extremely high current densities for many thousands of hours, dramatically increasing the lifetime of the diamond electrode compared to other diamond coated electrode materials. The success of Diafilm™ EP is also based on its superior dimensional stability during electrolysis. This allows extended periods of operation, and reductions in maintenance and downtime, thereby increasing productivity and efficiency.



Precision surface illustrating the heterogeneous structure of Diafilm™ EP.

Advantages of Diafilm™ EP

Extremely wide potential solvent window

- Unrivalled ability to generate and regenerate strongly oxidizing and reducing species in solution, e.g. hydroxyl radicals ozone
- Enables the treatment of recalcitrant chemicals in solution
- High potential oxidizing agents mean more efficient and rapid electrolysis, with shorter processing cycles providing benefits in terms of reduced lead times and operational costs
- Lower production costs by simplification of chemical processing, reducing or eliminating chemical consumption and minimizing disposal requirements

High current density operation

- Increased chemical processing capacity compared to metal and diamond coated electrodes
- Maximizes cost effectiveness of Diafilm™ EP
- Allows compact electrochemical processing cells

Free-standing solid diamond electrode

- Eliminates the substrate failure mechanisms experienced with coated diamond electrodes, maintaining process continuity and avoiding electrode replacement
- Increased electrode lifetime

Chemically inert and operates in corrosive environments

- Enables novel electrochemical processing techniques to be developed in highly corrosive and harsh environments e.g. solutions containing hydrofluoric acid or strong bases
- High resistance to fouling
- Able to operate for extended periods, reducing maintenance and downtime

Bi-polar operation

- Switching of polarity enables electrochemical cleaning
- Maximizes capacity, processing and efficiency

Extreme performance with solid diamond electrodes

E6 electrochemical cell

Element Six patented Diamox™ electrochemical cells incorporate Diafilm™ EP electrodes in a bipolar configuration for high current density operation in a range of water treatment applications. The technology is modular and scalable in design and can be used to incinerate low to medium volume toxic and/or biocide containing industrial effluent streams, such as spent caustic from sulphur scrubbing processes in petrochemical industries, treating pharmaceutical wastes and reject streams from membrane filtration systems for treating landfill leachate.

New and existing applications

Diafilm™ EP electrodes have been proven in the field for many years, delivering unsurpassed reliability and high current density operation. This revolutionary electrode material is used to design compact electrochemical cells for a wide variety of new and existing applications. Typical applications include:

- Waste water treatment
- Sterlization
- Electro-deposition
- Electrochemical processing
- In-situ oxidization
- Decolorization
- EDM cutting
- Industrial etching

Material of choice

In demanding applications, where the capacity of the electrode is determined by the operating current, Diafilm™ EP is the material of choice. It enables electrochemical engineers to design new and innovative products for industry, offering unparalleled electrode lifetimes and reduced cost of ownership.

Technical partnership in application development

Material availability

Diafilm™ EP is available in wafer form for electrodes up to 130 mm in diameter, and thickness typically in the range 300 to 800 µm. Electrodes can be cut to a custom defined shape with a range of surface finishes, metallization and bonding options being available.

Technical support

Element Six has more than 20 years' experience in the research, development and manufacture of CVD diamond technology for applications that range from electrochemistry to optics. Element Six is able to provide:

- Expert assistance to ensure our clients maximise their technological potential
- Co-development capability to solve application problems

Electrodes are cut from wafers to almost any shape to meet customer requirements.

Properties	Value	Comment
Electrochemical properties		
Boron doping concentration (typical)	~ 3 x 10^{20} Atoms cm^{-3}	Averaged over 0.4 mm^2
Resistivity	0.50 x 10^{-3} Ohm m	Range is 0.20 - 1.8 x 10^{-3} Ohm m
Aqueous solvent window	-2.2 to 2.3 V	0.1 M KNO_3 versus SCE
Typical current density range	1000 A m^{-2} to 20,000 A m^{-2}	
Typical erosion rate	<6 µg h^{-1} m^{-2}	Measured over 200 hours @ 5000 A m^{-2} with 1 M NaCl electrolyte
Mechanical properties		
Nucleation side fracture stress	>800 MPa	Typical thickness in range of 400 to 800 µm
Growth side fracture stress	>450 MPa	Typical thickness in range of 400 to 800 µm
Young's modulus	1050 GPa	
Fracture toughness	8 $MPam^{0.5}$	
Weibull modulus	>10	
Hardness	81 ± 18 GPa	
Thermal properties		
Thermal conductivity	~700 W m^{-1} K^{-1}	@ 300 K
Dimensional tolerance un-processed		
Thickness uniformity	±25%	Typical values
Nucleation side roughness	Ra <0.35 µm	Typical values
Growth face roughness	Ra <200 µm	Typical values
Max area available (round)	13,200 mm^2	Diameter 130 mm
Max area available (rectangle)	7150 mm^2	Rectangle 110 x 65 mm
Lateral dimensional tolerance	±0.20 mm	All edges are laser cut
Processed		
Lapped face roughness	Ra <250 nm	Typical range
Polished face roughness	Ra <30 nm	Typical range
Thickness tolerance	±0.05 mm	Typical range

Find out more

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