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CVD Diamond Sensing Devices (invited)

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Abstract

CVD diamond has numerous *material* advantages for sensing applications: chemical inertness, electrode compatibility, extremely low diffusivity of other materials, electronic stablity over a very wide temperature range, good dielectric constant, ability to be doped, biological compatibility, high dielectric strength, hardness, small thermal coefficient of expansion, high thermal conductivity, light weight, low coefficient of friction, and high piezoresistivity. Diamond microstructure array detectors have broad *practical* applications to microsystems for biotech, chemical, industrial, consumer, and medical use.

The use of diamond in sensors, MEMS, and electrochemistry is a relatively new area of research that has emerged within the past decade because CVD diamond film has distinct advantages, having become a developed technology with readily available deposition systems. Furthermore, CVD diamond fabrication is well suited for use in microsystems because the technology for patterning, selective growth, and doping of CVD diamond films processed in a manner similar to conventional silicon MEMS technology has been reported.

This paper will focus on the use of CVD diamond for chemical sensing, specifically 1) diamond-based rectifying electrodes for detection of toxic and explosive chemical gas species in air and 2) diamond microelectrode array for electrochemical sensing in liquid media.

Diamond chemical gas sensor - We have developed chemically sensing rectifiers comprised of micro-electrodes on diamond layers for detection of H_2, O_2, CO, and hydrocarbon gases. High sensitivity and fast response time in seconds have been achieved over a very wide temperature range (> 600^{o}C). These sensors were demonstrated to operate at temperature, dynamic range, sensitivity, and radiation with far better performance than those based on silicon and other materials. These findings indicate further development of a selection of rugged miniature diamond rectifiers for detection of toxic and explosive chemical species in air and harsh environments can be achieved. The seriously limited temperature range (< 200^{o}C) of silicon devices has stifled exploitation with semiconductor rectifiers for gas sensing applications, particularly for detection of toxic gases from the combustion process and *in situ* emission control. Gas sensors utilizing diamond can operate at very high temperature (> 800^{o}C), with high performance and reliability, **and** low cost.

Diamond microelectrode array for electrochemical sensing- High quality and conductive diamond has been shown to possess several important and unique electrochemical properties: (i) low and stable voltammetric and amperometric background current in aqueous media, (ii) a wide working potential window in aqueous media, (iii) quasi-reversible to reversible electron transfer kinetics for several redox systems without any conventional pretreatment, and enhanced signal-to-background ratios due to the low background signal, (iv) long-term response stability, (v) morphological and microstructural stability during anodic polarization, and (vi) weak adsorption of polar molecules. The properties of a diamond electrode make it ideally suited for electroanalysis and clearly distinguish it from the more commonly used "graphitic" electrodes, such as glassy carbon. In electrochemical sensing, the superior detection figures of merit for diamond, particularly the limit of detection and sensitivity, could be further improved by decreasing the electrode geometry thereby enhancing mass transport to the interfacial reaction zone by non-planar (spherical) diffusion. This work reports on the design, fabrication and experimental evaluation of diamond microelectrode arrays for electrochemical sensing. Array parameters such as electrode geometry, electrode-electrode spacing, and array size are established through design and fabrication and their relation to electrochemical response evaluated. Experimental results have shown that the diamond ultramicroelectrode array exhibits higher sensitivity than the conventional planar diamond film. Additional experimental data of the array's geometric parameters effect on the electrochemical sensing behaviour will be presented. Diamond ultramicroelectrodes in array configurations may find utility in areas of electroanalytical chemistry, the study of fast electron transfer reactions and electrocatalysis. The microband has potential application as a sensor in flow systems, where fast scan rate is essential to detect target species flowing through the cell.

Keywords: diamond, sensors, MEMS