JOINING ADVANCED MATERIALS BY PLASTIC FLOW PROVIDES SOLUTION FOR OXYGEN SENSOR APPLICATIONS

The Challenge:

Industry has sought robust and less expensive sensors to more accurately monitor and control combustion processes. Improved control can be obtained by positioning the sensors closer to the combustion environment in applications such as coal-fired power plants, petrochemical plants, blast furnaces, glass processing equipment, industrial burners, and even in internal combustion engines.

Typically, operation in such environments has necessitated an external supply of conditioned air to provide a reference source necessary for the sensor to determine the constituents of the combustion process. This complexity has imposed significant cost and maintenance difficulties on conventional systems. The ideal sensor would not require an active system to supply external reference air and would be completely sealed and self-contained.

The Solution:

Recently, Argonne and Ohio State University scientists teamed to develop a high-temperature, low-cost oxygen sensing device for use inside combustion chambers, allowing monitoring at the source in real-time. This is enabled by an internal reference air chamber and therefore does not rely on an external reference gas. The sensor is sealed by Argonne’s unique deformation bonding method that joins the protective ceramic housing components without using intermediate bonding materials that typically alter the ceramic’s oxygen conductivity.

The ability to withstand temperatures up to 1600°C facilitates placing the sensor (or multiple sensors) close to the source of combustion to enable faster and more accurate monitoring and feedback. This capability also provides the opportunity to accurately map the entire combustion zone.

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Eliminating the need for external reference air and joining ceramic components without intermediate bonding materials permits the production of a very compact (millimeter-sized) oxygen sensor, having excellent oxygen conductivity through the housing, at an extremely low production cost (estimated direct cost of fabrication of less than $200), with superb stability, very low drift, and high sensitivity to changes in oxygen levels.

The information provided by the sensor is important to manufacturers, because it helps them optimize their process chemistries, or be more energy-efficient and economical in their operations by achieving energy savings by optimizing the air-to-fuel ratio. In highly optimized systems, it may even be used to optimize parameters such as fuel oil viscosity. While various sensors are available, industry has never before had a truly low-cost means of accurately determining oxygen content in the combustion process to achieve the highest possible energy savings—until now.

How Argonne’s Deformation Joining Method Operates

The Argonne plastic deformation method of joining advanced materials (ceramics, intermetallics, composites, cermets, and others) results in a monolithic structure. It provides a solution to the oxygen sensor application because it produces a strong, pore-free joint—without degrading the mechanical or electrical properties of the materials as do most conventional joining methods.

The joining technique relies on the plasticity of the components being joined. A small compressive stress is applied to the two bodies at elevated temperatures (at about ½ the melting point level). As the two bodies are compressed, grain rotation results from the principal deformation mechanism of grain sliding. As the grains rotate, they inter-penetrate, resulting in a perfect bond with a strength level equal to that of a monolith.