Argonne NATIONAL LABORATORY

Materials Technologies

NEW

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

2005 R&D 100 Award Winner

BENEFITS

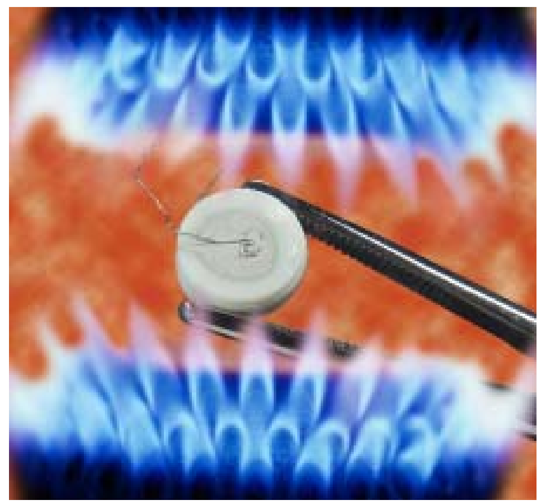
- Ability to deploy multiple oxygen sensors (due to their lower cost and smaller package size) in closer proximity to combustion sources (inside the actual combustion compartment, as opposed to inside the exhaust flue)
- Has the capability to withstand temperatures up to 1600°C
- Eliminates the need for an external supply of reference air
- Provides unsurpassed oxygen-sensing accuracy and extremely low drift
- Estimated fabrication cost of less than $200, substantially less than conventional oxygen sensors
- Helps facilities achieve significant energy savings (from 2% to 10%) by optimizing the air-fuel ratio and fuel oil viscosity

POTENTIAL APPLICATIONS

- Petrochemical industry
- Oil and gas industry
- Steel industry
- Power and steam generation
- Cement industry
- Food and beverage industry
- Pulp and paper industry
- Industrial process industries

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.



Oxygen sensor designed by Ohio State University and fabricated using Argonne National Laboratory's unique plastic deformation process.

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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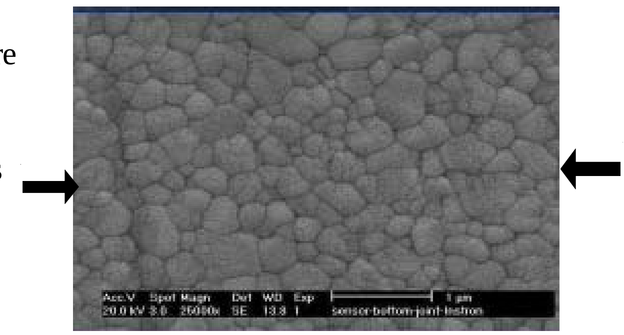
ABOUT ARGONNE TECHNOLOGY TRANSFER

Argonne National Laboratory is committed to developing and transferring new technologies that meet industry's goals of improving energy efficiency, reducing wastes and pollution, lowering production costs, and improving productivity. Argonne's industrial research program, comprising leading-edge materials research, cost-saving modeling, and unique testing and analysis facilities, is providing solutions to the challenges that face U.S. manufacturing and processing industries.

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.



The area between the arrows is the interface of two YSZ (yttria stabilized zirconia) components which comprise an oxygen sensor. The Argonne Plastic Joining Process results in a monolithic structure - note the interpenetrating grains with no porosity at the interface (shown by the arrows)

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.

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THE UNIVERSITY OF CHICAGO

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