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Sealant Research for SOFC

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Conference Title:

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DISCLAIMER

MSOFC Development Status

CONTRACT INFORMATION

Program Title	MSOFC Technology Advancement For Coal-Based Power Generation
Contract Number	DE-AC-21-89MC26006
Contractor	Allied-Signal Aerospace Company AiResearch Los Angeles Division 2525 West 190th Street Torrance, CA 90509
Contractor Project Manager	Dr. Richard A. Gibson
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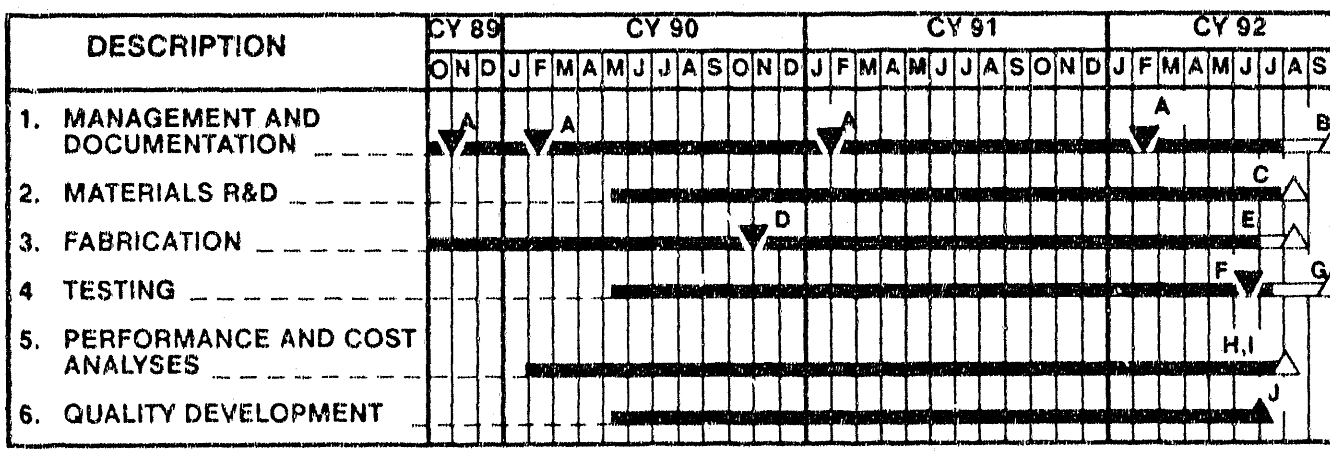
METC Project Manager	Ms. Diane Hooie
Period of Performance	September 27, 1989 to September 27, 1992

Schedule and Milestones



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MILESTONES

- A PROGRAM MANAGEMENT PLAN
- B FINAL REPORT
- C INTERIM SPECIFICATION, INTERCONNECT
- D PRELIMINARY SPECIFICATION, MATERIALS AND PROCESSES
- E DEMONSTRATION, 10-W STACK FABRICATION
- F DEMONSTRATION, MSOFC LIFE TEST
- G DEMONSTRATION, 10-W STACK OPERATION
- H UPDATED MANUFACTURING COST
- I TOPICAL REPORT, SYSTEM CONFIGURATION, AND MARKET ASSESSMENT
- J NDE METHODS REPORT

Program Schedule

OBJECTIVES

The overall objective of this program is to advance materials and fabrication methodologies to develop a monolithic solid oxide fuel cell (MSOFC) system capable of meeting performance, life, and cost goals for coal-derived fuel applications. The technical effort of this program is aimed at creating a technology base that will be used to extend MSOFC development from proof of concept toward practical application.

BACKGROUND INFORMATION

The MSOFC is an all-ceramic structure in which cell components are configured in a compact, corrugated array. The MSOFC produces a direct current by electrochemically combining fuel and oxidant across the zirconia solid electrolyte at an operating temperature of about 1000°C. There are two versions of the monolithic fuel cell, coflow (Figure 1) and crossflow (Figure 2). The crossflow approach is used in this program because it is more straightforward to manifold and fabricate. As can be seen from the figures, the MSOFC is made of two types of multilayer structures, each composed of three ceramics—anode/electrode/cathode and anode/interconnect/cathode. The anode/electrolyte/cathode composite represents a single cell. The function of the anode/interconnect/cathode composite is to connect the cells in electrical series to build voltage. In the MSOFC, the anode and cathode layers must be porous to allow gas transport to the reaction sites, while the electrolyte and interconnect layers must be dense to prevent gas mixing. Design goals for layer thicknesses and cell-to-cell distance are 25 to 100 μm and 1 to 2 mm, respectively. The MSOFC design eliminates inactive structural support, increases active surface areas, and lowers voltage losses due to internal electrical resistances. The monolithic fuel cell, thus, has high efficiency, excellent performance, and high power density. The MSOFC can be integrated with coal gasification plants and is expected to have high overall efficiency in the conversion of the chemical energy of coal to electrical energy.

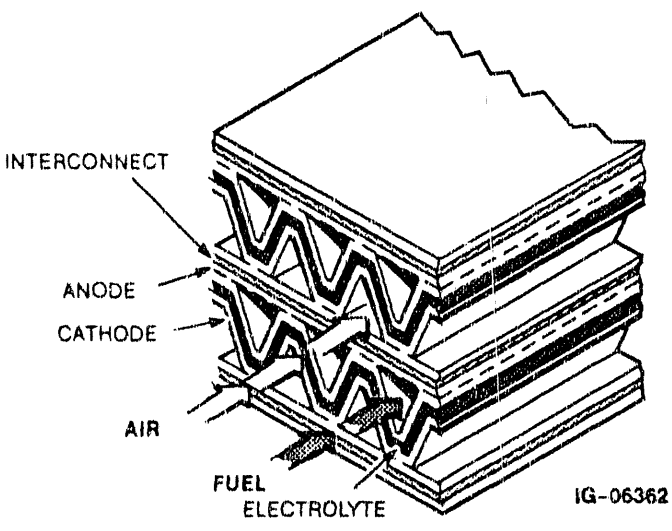


Figure 1. Coflow MSOFC

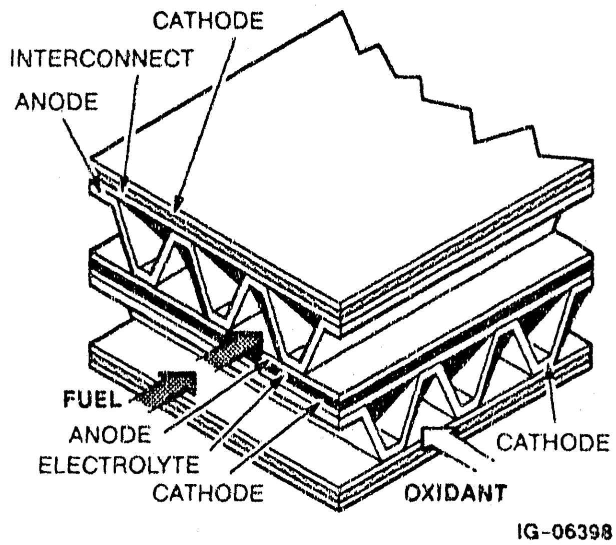


Figure 2. Crossflow MSOFC

The materials currently used for building the MSOFC are Y_2O_3-stabilized ZrO_2 for electrolytes, Ni/Y_2O_3-ZrO_2 cermet for anodes, doped $LaMnO_3$ for cathodes, and doped $LaCrO_3$ for interconnects. These materials are known to possess adequate levels of conductivity, and they are compatible and stable under cell operating conditions. The challenge is to develop ways to form the materials into thin components and to incorporate these components into the monolithic structure. A fabrication scheme for the MSOFC must incorporate each material such that none of the fabrication steps will diminish the desired material characteristics of any of the component layers. The fabrication of the MSOFC must achieve the following: (1) high-density electrolyte and interconnect, along with porous anode and cathode layers, (2) good interfacial bonding between adjacent layers, (3) insignificant reaction and interdiffusion between neighboring layers, and (4) a defect-free structure. At present, the development of suitable materials and the fabrication of the intricate structure are the main foci of the MSOFC development effort.

PROJECT DESCRIPTION

This program is performed by a team comprising the AiResearch Los Angeles Division of the Allied-Signal Aerospace Company and Argonne National Laboratory (ANL). The technical effort of the program is organized around five work tasks as follows:

(a) Materials research and development: This task concentrates on development of materials suitable for the unique MSOFC structure and environment. The work addresses several identified material issues such as interconnect sinterability, material stability and performance (especially in coal gas), and current collector materials.

(b) Fabrication: This task is aimed at demonstrating MSOFC fabrication and fabrication reproducibility and reliability. The fabrication process will be scaled up to produce MSOFC stacks of increasing power output. This effort also involves definition of optimal fabrication parameters, defect analysis, development of material and process specifications, and material supplier identification.

(c) Testing: This task verifies the performance and life of the MSOFC with coal-derived fuels. MSOFC cells and stacks are tested under specified conditions, and posttest analyses are carried out to provide information for explaining observed behavior and identifying degradation mechanisms.

(d) Performance and cost analysis: This task involves performance, system, and cost analysis of the MSOFC in coal-based applications. The emphasis of performance analysis is on development of an MSOFC performance model. System and cost analysis defines MSOFC system configurations and MSOFC manufacturing and system costs.

(e) Quality development: This task concentrates on developing methods for ensuring the quality of fabricated MSOFC stacks. This effort involves evaluation of NDE methods, stress analysis, and microcrack control.

The overall program is expected to resolve several material and fabrication issues and to result in a technology base that will be used to bring the MSOFC technology toward practical application.

RESULTS

During the past year, AiResearch effort has focused on development of the requisite technology for fabricating and demonstrating multicell stack operation. This effort has generated parallel tasks as follows:

(a) Fabrication of single-cell building blocks comprising anode/electrolyte/cathode (A/E/C) trilayers cofired with top and bottom corrugated electrodes and with or without cofired top and bottom electrode plates. These building blocks are called single-cell stacks (with electrode plates) and single-cell modules, respectively (see Figure 3). Design changes suggested by a compre-

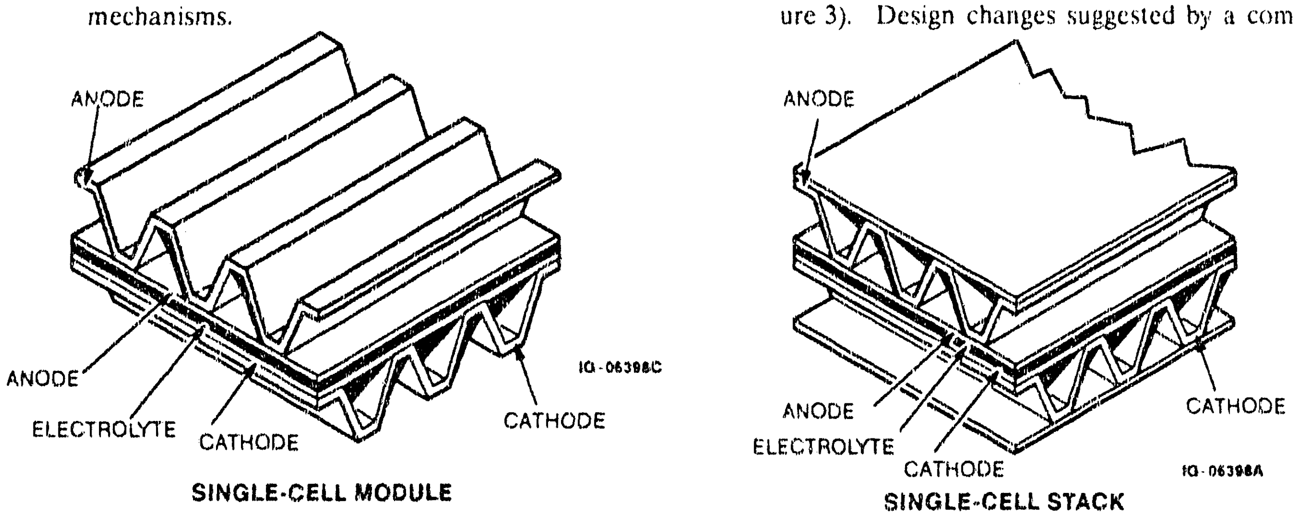


Figure 3. Clarifying MSOFC Terminology

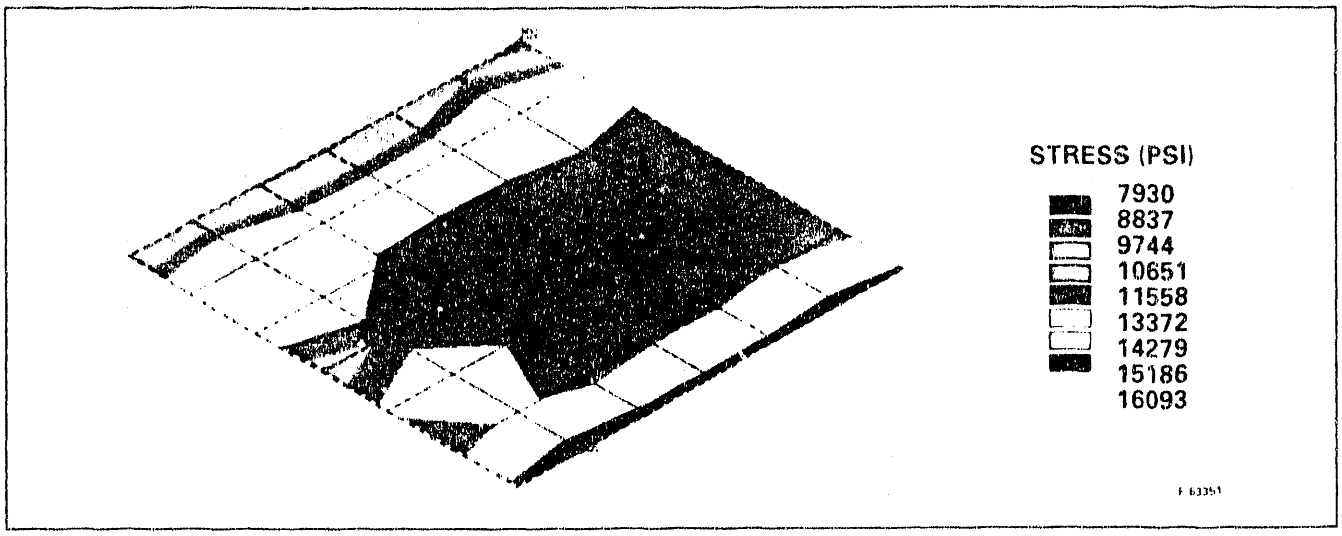
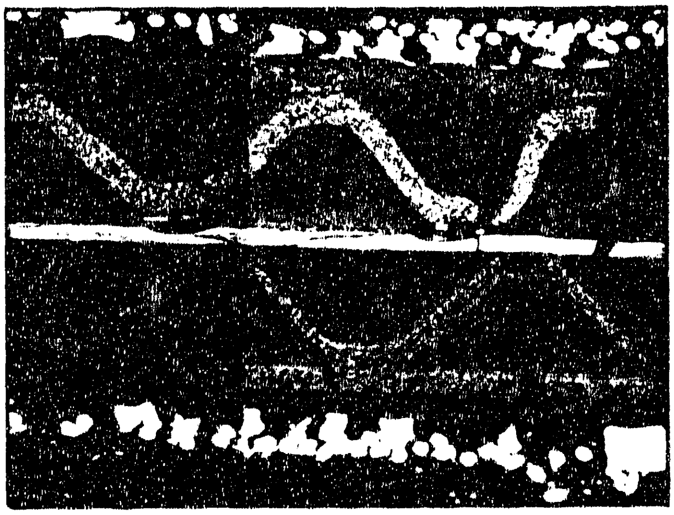


Figure 4. A Comprehensive, Detailed Stress Model Permits Three-dimensional Analysis of the Effects of Design Changes on Component Stress Levels

hensive stack stress model (Figure 4) have reduced fracturing in the building blocks (Figure 5) and improved performance (Figure 6).

(b) Development of bonding technology for forming the building blocks into multicell stacks. Because of delays in development of an interconnect technology suitable for simultaneously thermally processing all components of multicell MSOFC stacks, an alternative, two-step process has also been under development. In this process the building blocks and interconnects are fired separately, bonded, and fired again. The "second step" bonding technology has continually improved (see Figure 7).

(c) Development of multicell stacks fabricated from the bonded building blocks. Stacks have shown continually improving performance (see Figure 8). A two-cell stack has recently been tested for over 500 hours without performance degradation.



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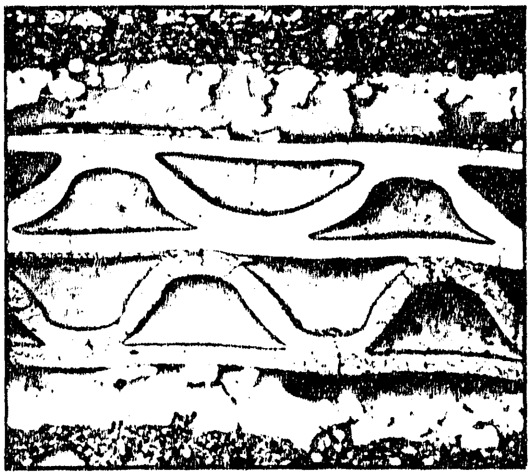

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Figure 5. Design Changes Suggested by the Stress Analysis Have Dramatically Reduced Defects

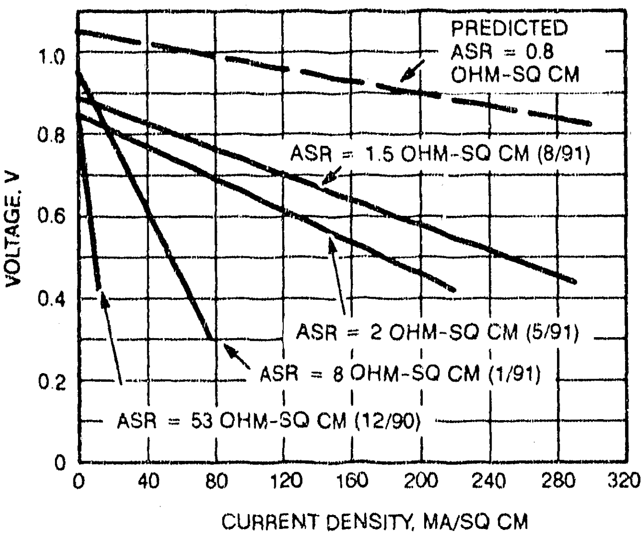


Figure 6. Reduced Structural Damage Has Significantly Improved Single-cell Stack Performance

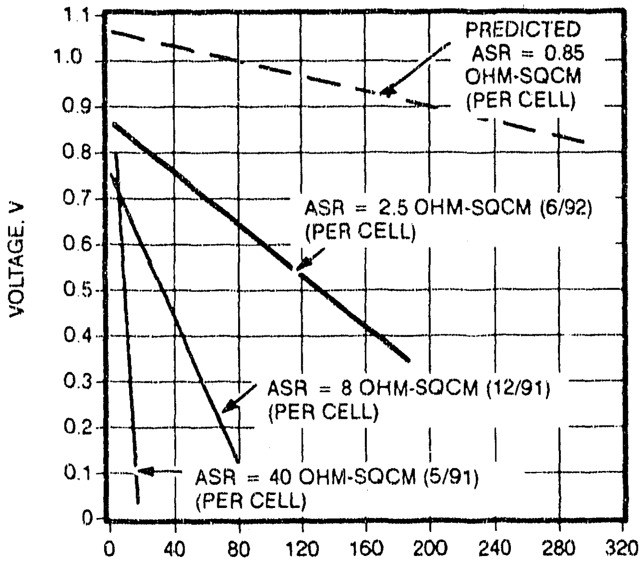
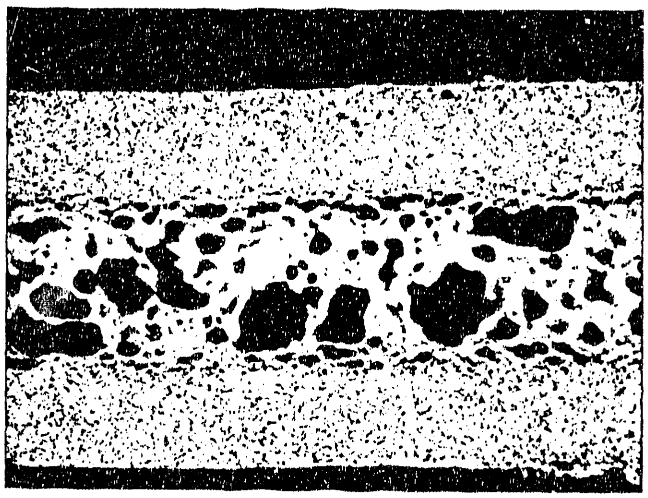
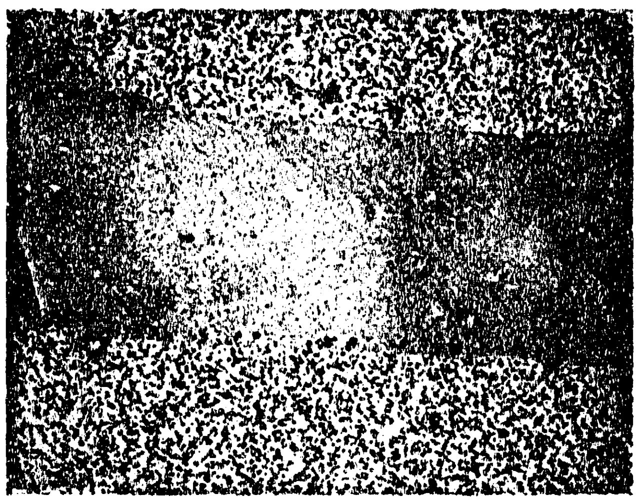


Figure 8. Improvements in Flatness and Bonding Methods Have Led to Major Gains in the Performance of Multicell Stacks



OLD FORMULATION (1991)



NEW FORMULATION

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Figure 7. Second-step Bonds Have Improved Substantially

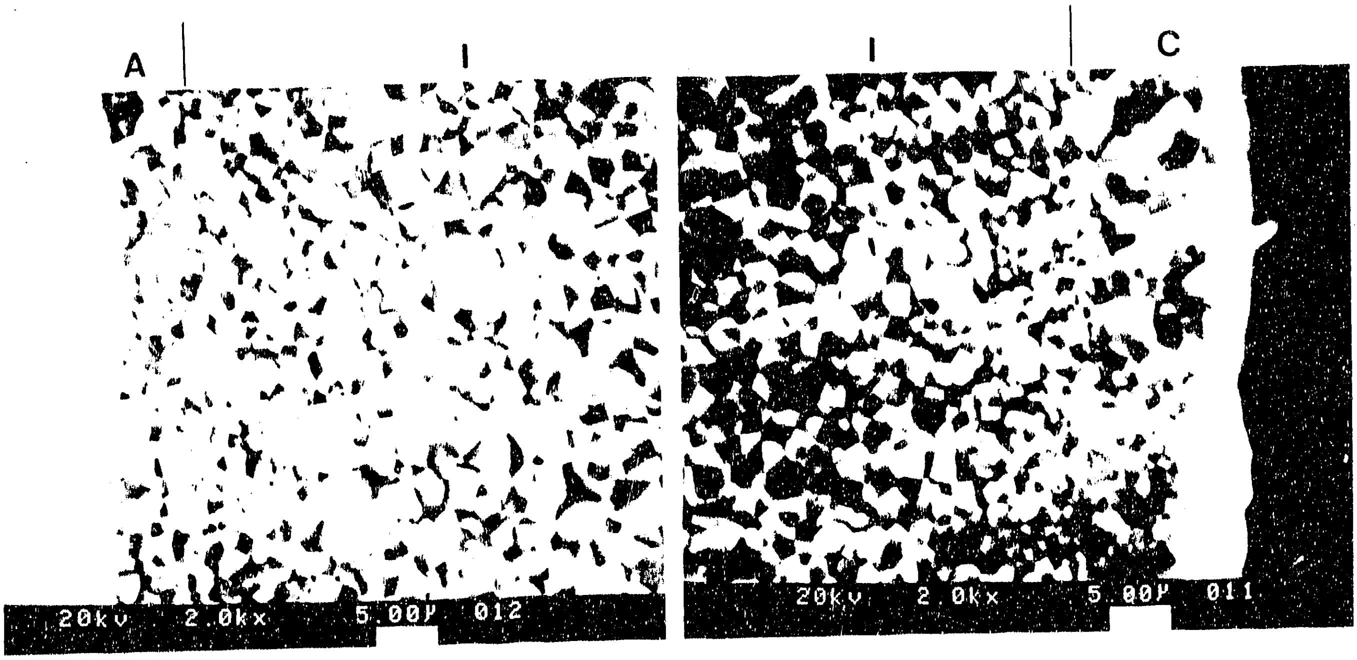

Figure 9. Dense A/I/C Trilayer Fabricated Under Thermal Processing Conditions Compatible with Balance of MSOFC

(d) Development of a dense cofired interconnect. Recently a dense interconnect has been formed and cofired with anode and cathode (Figure 9). Attempts to fabricate a cofired multicell stack are underway, and initial results are encouraging.

FUTURE WORK

Future plans include progress toward a 10-w stack via both two-step cofiring and cosintering interconnect processes. An updated assessment of the costs of producing MSOFC stacks will be performed, building on the study completed in the previous program with METC. Life testing of stacks will also be performed in the near future.

END

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