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R & D STATUS REPORT

ARPA ORDER NO: 8100 **PROGRAM CODE NO: DO-C9**

CONTRACTOR: David Sarnoff Research Center

CONTRACT NO.: N00014-91-C-0216 **CONTRACT AMOUNT:** $1,585,150

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SHORT TITLE OF WORK: High Performance YBCO Films

REPORTING PERIOD: Period 12/1/93 to 2/25/94

1 The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the Defense Advance Research Projects Agency of the U.S. Government.

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February 28, 1994

Director, Advanced Research Project Agency
Virginia Square Plaza
3701 N. Fairfax Drive
Arlington, Virginia 22203-1714

Attention: Frank Patten
Program Manager

Subject: Contract N00014-91-C-0216
Quarterly R&D Status Report #9
(12/1/93 - 2/25/94)

Gentlemen:

In accordance with the terms of the contract, enclosed are two (2) copies of the subject report.

Very truly yours,

Tawney DeBlasio
Contract Specialist

F-15427

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SUMMARY

• A program plan for Phase III of the contract was submitted and approved. It incorporates a silver capping layer and a glass/metal handle for support of a thin YBCO/magnesium fluoride microstrip structure. The basic technology can be applied to MCM's as well as millimeter wave circuit needs.

• A silver capping layer of thickness 5 microns was found to be compatible with glass and able to withstand processing temperatures of 550C used for firing and annealing of the glass. However, after subjecting the silver/glass combination to 700C (to simulate the effect of depositing a subsequent YBCO signal layer in the complete MCM structure), there was some degradation in the silver's conductivity as measured using the dielectric resonator technique. A thicker silver layer is apparently needed to adjust for the interfacial reaction between the silver and the glass.

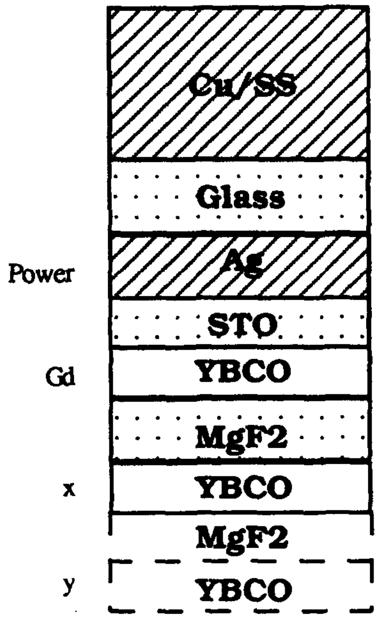
• Silver was deposited on both STO and YBCO-covered samples with excellent adhesion. After heating the samples to 750C in flowing nitrogen, the adhesion of the silver remained excellent when tested with scotch tape.

I. Introduction

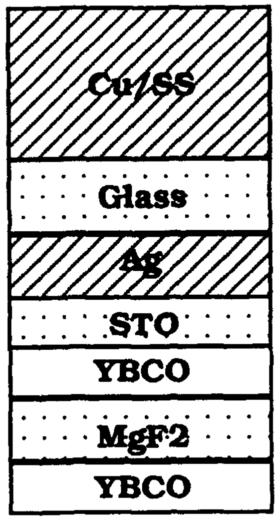
During Phase II of this contract, Sarnoff pursued an alternate approach to the MCM interconnect problem using YBCO/bulk magnesium fluoride that is based on glass bonding to a metal substrate. Compared with the originally proposed MCM program structure of growing multiple epitaxial layers of dielectrics and YBCO films grown on a base single crystal substrate such as YSZ, our alternate approach has the following benefits:

- It gives superior heatsinking through a metal base.
- Allows the use of a high quality single crystal dielectric for the YBCO film deposition.
- Provides an optional choice for the power plane of the MCM structure to be a thick normal metal instead of YBCO.

Phase II work demonstrated a structurally compatible material system for bonding a YBCO/ substrate sample to a glass/metal handle and also demonstrated thinning and polishing of magnesium fluoride to 10 microns. However, the use of capping layers consisting of yttrium oxide/Ti/Pt/Cu used to shield the glass from the YBCO was not fully successful since these cap layers chemically react with the YBCO when heated to temperatures required for glass bonding to the metal handle. We believe that the Ti and copper interact with YBCO and cause changes in the YBCO stoichiometry. In Phase III, Sarnoff is pursuing a new approach that will ultimately result in the high quality structure shown in Figure 1 that provides low circuit loss at high frequencies for microwave/ millimeter wave circuitry. This structure also provides heatsinking and a low dielectric constant substrate for MCM applications, accelerating ARPA's effort toward its overall MCM program goals.



Goal structure for the entire MCM effort.



Goal structure for this proposed effort.

Figure 1. MCM/YBCO Structure Using Ag Cap Layer. *The proposed structure (right) provides low circuit loss at high frequencies for microwave/millimeter wave circuitry and* accelerates *ARPA's effort toward its overall MCM program goals (left).*

To solve the YBCO cap layer interaction problem, we are investigating Ag as a new cap layer material between the glass/metal handle and the YBCO. The use of Ag could provide, for instance, the power plane for the four layer MCM module, as shown in Fig. 1. Also, Ag on YBCO does not degrade YBCO performance as proven from previous experience at Neocera and it should not require a sticking layer such as Ti or Cr which is reactive with YBCO. We will demonstrate a cap layer plus glass/metal handle structure that is attached to a high dielectric constant material(such as STO) /YBCO/circuit substrate/YBCO combination. The circuit substrate(between the YBCO ground plane and the YBCO signal lines) could be anything suitable for the HTS MCM application. However, in our program it will be magnesium fluoride because of its very attractive low dielectric constant. Our final demonstration module will be a microstrip module using YBCO/MgF_2/YBCO/$SrTiO_3$/cap layer/glass-metal handle. Circuit evaluation will be accomplished by patterning the signal layer into the form of a meander line and measuring its unloaded Q and its performance as a delay line at microwave and millimeter wave frequencies. This effort will result in an enabling technology for millimeter wave applications as well as to help realize the MCM goals by effectively complementing the work being performed in the existing ARPA-sponsored MCM program.

II. Processing Development of MCM Structure

A. Summary of Development Plan

We have divided the fabrication and testing of the MCM/YBCO structure shown in Fig. 1 into 4 major areas of effort. The diagram showing the breakdown of the tasks is given in Fig. 2 with Tasks I and II running in parallel. Detailed descriptions of the tasks are given in the Program Plan for Phase III dated November 30, 1993, that was submitted to ARPA.

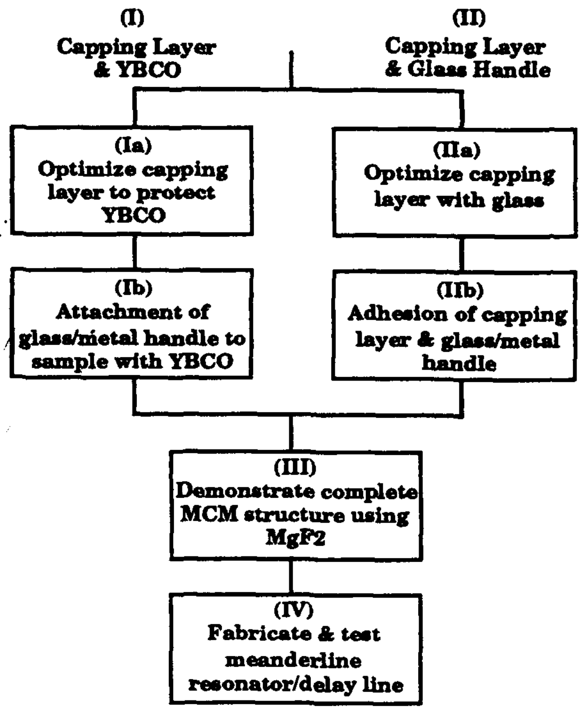


Figure 2. Breakdown of Program Tasks. *Our plan provides parallel paths for Tasks I and II reducing both risk and development time.*

B. Investigation of Silver as a Capping Layer

During this past quarter we investigated the use of silver (Ag) as a capping layer between the glass/metal handle and the YBCO. Ag was chosen because it does not degrade YBCO performance. We started with Task II (a), which is to determine the thickness of the Ag layer required to avoid complete interaction with the glass. Samples were prepared by sputtering 2 or 5 μm of Ag on polycrystalline Al_2O_3 substrates. An adhesion layer of 400Å of Ti was used in between the Al_2O_3 and the Ag. The Al_2O_3 was chosen because it is readily available and very inexpensive compared to single crystal substrates; it acts merely as a carrier for the Ag. Figure 1 shows a typical sample. After the metal depostion, Q_0 values were measured using the dielectric resonator test set to establish a baseline. The Q_0 results are shown in Table 1 for samples without glass. The glass was applied and the samples were heated to 550°C in air to fire the glass. The samples were remeasured to determine if the glass interacted with all of the Ag as determined from the observed reduction of Qo. The measurements of Q_0 for samples with and without glass are shown in Table 1.

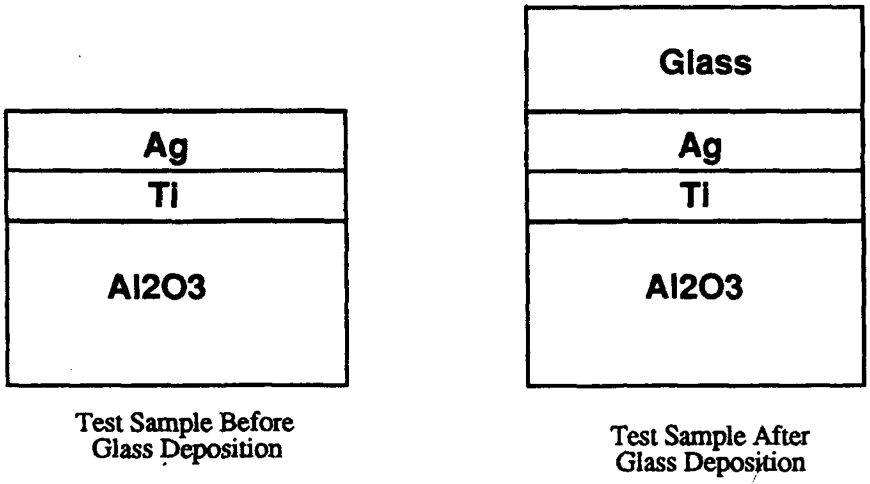


Figure 3
Glass Test Samples

Table 1

Q_0 of Samples Before and After Glass Deposition

Sample #	Ag (μm)	Glass	Side	Qo
1	2	no	front	3500
1	2	no	back	5439
1	2	yes	front	2742
1	2	yes	back	4530
2	5	no	front	3502
2	5	no	back	5446
2	5	yes	front	3863
2	5	yes	back	5802

Note: Front side - looking at the Ag or glass surface
Back side - looking at the alumina surface

It appears that the 2μm of Ag has been affected by the glass from the slightly degraded Q_0 values. However, there is little to no change for the 5μm samples. These results are very encouraging. The slightly higher Q_0 value for the 5μm sample with glass is probably due to measurement uncertainty.

The glass is fired at 550°C but the second YBCO layer will be deposited at 700°C, so the Ag must also withstand this higher temperature. The samples were heated to 700°C using a schedule similar to a YBCO deposition. The samples were quickly ramped to 700°C in 30 minutes, held at temperature for 15 minutes and then cooled to room temperature by turning off the furnace. These results are listed in Table 2. From the Q_0 numbers, it appears that firing the samples at 700°C has caused the glass to completely react with the Ag on the 2μm sample. Although there has been a reaction of the glass and Ag on the 5μm sample, it appears from the Q_0 value that some Ag remains. Work will continue in this area.

Table 2

Q_0 of Samples After 700°C Firing

Sample #	Ag (μm)	Glass	Side	Q_0
1	2	yes	front	0
1	2	yes	back	0
2	5	yes	front	1548
2	5	yes	back	2316

Our work with Ag continued with the investigation of the adhesion of Ag to STO as well as Ag to YBCO. These tests are part of Task II (b). A single crystal STO substrate and a YBCO/$LaAlO_3$ sample were used. Based on the results for the Ag/glass tests, 5μm of silver was sputter deposited on the samples. An adhesion layer was not used; only Ag was deposited. Figure 4 illustrates both samples. The adhesion of the silver to the STO and YBCO was tested with a standard scotch tape test. Scotch tape was repeatedly applied to both samples and then quickly removed. In both cases, the Ag adhered well. In addition to the scotch tape, a razor blade was used to try to lift the metal from the STO and the YBCO. In both cases the Ag adhered well. Both samples were heated to 750°C in flowing N_2. The N_2 was used to prevent the Ag from oxidizing.

For the actual circuit, the Ag will be capped with the glass. The adhesion tests were repeated for both samples with excellent results again.

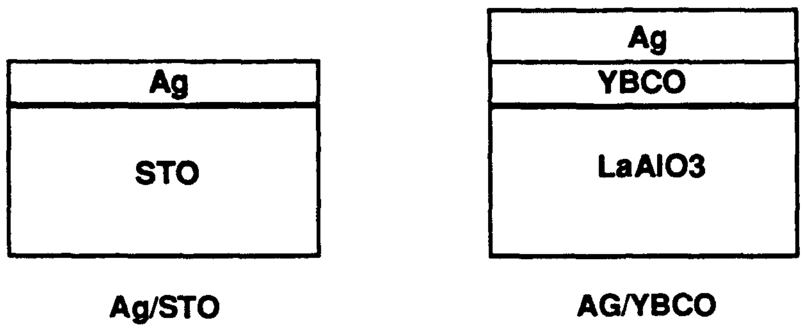


Figure 4. Adhesion Test Samples

C. Possible Problems and Solutions with Glass/Metal Handle Structure

One of the expected problems with the complete glass/metal handle MCM structure is that the ground plane YBCO layer will be sealed from getting oxygen that is needed to restore superconductivity after processing. The approach that will be taken to address this problem is to pattern the glass layer into a grid structure; this will provide grooves through which the oxygen can reach the YBCO. Ozygen is able to permeate through the remaining silver and STO layers to the YBCO. Once the oxygen gets to the YBCO through the grooves distributed over the sample area, it diffuses rather fast in the plane of the YBCO film. We will maximixe the coverage area of the glass to reduce the degradation of heat conduction from the sample. Experiments with the patterned glass/metal handle onto samples with YBCO will occur in the next quarter.

III. References

IV. Change in Key Personnel: None

V. Summary of Substantive Information Derived from Special Events: None

VI. Problems Encountered and/or Anticipated: None.

VII. Action Required by the Government: None.

VIII. Fiscal Status

1. Amount currently provided on contract: $1275K
2. Expenditures and commitments to date: $935K
3. Funds required to complete work: $1,585,085