Project Administration Data Sheet

Project No.: A-3504

Contract Director: Dr. B. R. Livesay

Sponsor: Lockheed-Georgia Co.

Agreement: GTRI Standard Research Project Agreement & P. O. #CA-20733

Funded Period: From 3/22/83 To 6/5/83 (Performance) 7/5/83 (Reports)

Cost Sharing No.: Sharing Amount: $9,034

Cost Sharing No.: Cost Sharing No.

Fabrication Methods for Capacitor Probes

Administrative Data

Sponsor Technical Contact:
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Defense Priority Rating: NA

Military Security Classification:
(or) Company/Industrial Proprietary:

Restrictions

Attached Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval — Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with none proposed

Remarks:

Copies To:

Research Administrative Network
Research Property Management
Procurement/EES Supply Services

Research Security Services
Reports Coordinator (OCA)
GTRI
Library

Research Communications (2)
Project Files
Other

Other

Original

4/14/83

Frank Huff

2) Sponsor Admin/Contractual Matters:

NA

NA

NA
Date: February 29, 1984

Project No. A-3504

Subproject No.(s)

Director(s) Dr. Livesay
GTRI / GML

For Lockheed Georgia Co.

"Fabrication Methods for Capacitor Probes"

Effective Completion Date: 9/15/83 (Performance) 10/15/83 (Reports)

Contract Closeout Actions Remaining:

☒ None
☐ Final Invoice
☐ Closing Documents
☐ Final Report of Inventions
☐ Govt. Property Inventory & Related Certificate
☐ Classified Material Certificate
☒ Other: Final Report sent directly to sponsor

Sends Project No. Continued by Project No.

TO:

Director
Research Administrative Network
Research Property Management
Accounting
Procurement/EES Supply Services
Research Security Services
Research Coordinator (OCA)
OCA 60:1028

Library
GTRI
Research Communications (2)
Project File
Other
INVESTIGATIONS OF VAPOR DEPOSITION METHODS
FOR THE MANUFACTURE OF CAPACITANCE
HOLE PROBES

FINAL REPORT
PROJECT A-3504

For
Lockheed-Georgia Company
Marietta, Georgia 30063

By
G. N. Hill and B. R. Livesay
Engineering Experiment Station
 Electromagnetics Laboratory
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EXPERIMENTS were carried out in the Microelectronics Laboratory at the Georgia Institute of Technology to explore some of the technical problems involved with the manufacture of the Lockheed hole probe using vapor deposition methods. The hole probe is a cylindrical structure with an array of insulated metal electrodes distributed around the surface. The contour of the hole probe is precisely the intended shape of the holes drilled in aircraft parts. When inserted into the hole, each electrode on the probe thus becomes one member of a cylindrical parallel plate capacitor with the inner surface of the drilled metal hole comprising the other member. Nominal diameters of the hole probes range from 1/8 inch to 1/2 inch. Eight conductor segments are distributed around the circumference of the cylinder with five segments along the axis. Each of these forty segments must be electrically insulated from each other while each segment is ultimately bonded to a cable connector. In this manner, the electrical capacity of each of the forty capacitors can be measured to determine if the inner surface of the drilled hole matches the contour of the probe.

We had been asked if vapor deposition offered production advantages over the current fabrication methods which involve cumbersome silk screening techniques. An evaluation of potential
film deposition techniques led to the suggestion that R. F. sputtering offered the best possibility since it is necessary to deposit both conductors and insulators in successive steps. The deposition should be done during a single pumpdown for production efficiency. A precision masking arrangement therefore becomes necessary in order to define the forty segments and their electrical extensions to the connector. The cylinder must be continuously rotated during deposition in order to coat all side uniformly. Two concentric masks would be programmed to extend over each end of the cylindrical substrate and moved back and forth to define the alternate conducting and insulating layers which form the five bands along the axis of the cylinder. In addition, there must be provision for water cooling the cylinder due to the heat which builds up during deposition. The fabrication of such a remote controlled masking arrangement obviously involves precision machining and the installation of carefully designed rotational and positioning motors along with rotary cooling water fixtures which can operate within the vacuum chamber. The design and fabrication of this apparatus would involve considerable time and expense.

A particularly difficult problem remains. It does not appear feasible to mask the very narrow and long gaps required to divide the eight segments around the circumference of the cylinder. The widths of these gaps range from about 0.015 inch on the 1/8 inch diameter probe to about 0.060 inch on the 1/2 inch diameter probe. We examined several possible methods to accomplish this
task and concluded that it might be possible to mechanically saw through the ten alternating conductor-insulator layers (using a diamond wafering saw) and then chemically etch away edge debris which would tend to form shorts between the metal layers.

It was suggested that we might be able to manually prepare a cylindrical hole probe by wrapping metal foils around appropriate regions of the substrate in order to form masks. The sputtering system would be opened between successive depositions in order to reposition the masks. The hole probe substrate would also have to be rotated during depositions.

Problems developed early. We therefore formulated several experiments to first demonstrate process feasibility. Multiple layered structures were prepared consisting of alternate layers of thin metallic chromium and silicon dioxide (SiO₂) about 3,000 Angstrom thick. The sputtering system was opened between each deposition in order to reposition the mask. The isolation characteristics of the metal films between conductive layers were tested by resistance and voltage breakthrough measurements. Unfortunately, all our attempts with structures prepared in this manner resulted in electrical shorts existing between successive metal layers. Examinations under optical microscopy and scanning electron microscopy indicated that the shorts were essentially pin holes. A high current between layers clearly revealed the location of pin holes but also destroyed the structure.

It is postulated that the pin holes are generated by minute dust particles which are redistributed each time the chamber is
opened to reposition the masks. These particulates then interfere with the proper deposition of the insulating material. Various thicknesses of SiO films were tried up to about 6,000 Angstroms. These attempts all resulted in shorts between layers. These results clearly showed that we were not going to be able to prepare hole probes using the proposed simple manual method where the vacuum system must be opened between the deposition of successive layers. The turbulence caused by admitting gas to the vacuum chamber stirs up metal flakes from previous depositions.

Another set of experiments was formulated to test the feasibility for mechanically sawing through multiple layered sandwich structures. In order to avoid the pin hole problem for these tests, multiple layered structures were deposited on flat glass substrates without opening the vacuum system between the deposition of successive layers. A small diamond wafering saw was used to cut through these layers. Indeed, shorting between layers was often noted at the kerf of the saw cut. However, chemical etching normally removed the shorting metal flakes. Some fracturing of the multiple layered film structure was also noted in some of the saw kerfs.

The cutting experiments essentially demonstrated that this technique for separating sectors can be made to work. However, one needs to experiment with various grades of sawing blades and with cutting parameters in order to improve this method sufficiently for reliable manufacturing purposes.

The R. F. Sputtering equipment utilized during these initial
experiments does not lend itself to easy modification without serious interruption of other work. While we were able to produce pin hole free films by not opening the vacuum chamber, there is obvious concern that installation of the motors and masks needed for remote control may generate flying debris which could again cause pin holes. In addition, our particular sputtering system required approximately 10 hours of run time to produce each multiple layered structure. It is thus clear that a more powerful R. F. sputtering system than what we have at Georgia Tech should be sought out for this type of fabrication.

Conclusions:

The vapor deposition techniques can probably be successfully employed to produce capacitance hole probes. However, the problems experienced during the course of these preliminary investigations raise a number of concerns. It is definitely going to be more difficult than it first appeared to be. The hole probes can not be economically fabricated without the complex masking-rotating-cooling arrangement discussed earlier. This will require dedicating a deposition system to hole probe fabrication for an extended time period in order to finally determined if this is an economically favorable method to manufacture the hole probes. Unfortunately, we can't do that with the equipment at Georgia Tech which is needed for a number of research programs. While the mechanical sectioning technique for separating segments was sufficiently successful, the large surface areas involved in a multiple layered hole probe assembly provides ample
opportunities for failures due to dust generated pin hole shorts. These shorts between layers are always going to be a major quality control problem using any vapor deposition technique to produce the hole probes. Careful cleaning of all fixtures within the chamber will be necessary between each run. This requirement will clearly decrease productivity.

In conclusion, it should be possible to manufacture hole probes using R.F. sputtering techniques. However, the yield may not be acceptable due to the large surface areas in multiple layers providing opportunities for a pin hole short existing somewhere in the structure. In contrast, the corresponding surface areas in microcircuits are thousands of times less. The necessary masking fixtures will need to be precision machined and will probably be expensive. It is important that mask design be such that film layers are not damaged as the masked is moved. The mask must be close to the substrate for accuracy. Finally, a large and expensive deposition system will be necessary to achieve suitable production rates. It was not possible to fabricate hole probes without shorts using the proposed manual scheme of opening the vacuum system between successive steps in order to shift mask positions. The experiments with our facilities were therefore terminated as advised earlier as not practical.