THE MIMIC PROGRAM--KEY TO AFFORDABLE MMICs FOR DoD SYSTEMS

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ABSTRACT

The Microwave/Millimeter Wave Monolithic Integrated Circuits (MIMIC) program is a seven year, $0.5 billion program initiated by the Department of Defense (DoD) in 1986 to provide affordable, available and reliable microwave and millimeter wave circuits for use in military electronic systems. This paper describes the program, its objectives, organization, plans, and current status.

INTRODUCTION

In late 1986, the Department of Defense (DoD) launched the Microwave/Millimeter Wave Monolithic Integrated Circuits (MIMIC) program in recognition of the fact that monolithic format hardware is essential for the cost-effective deployment of many types of DoD electronic systems including smart weapons, decoys, and phased array radars. The program is centrally managed within the Office of the Secretary of Defense but enjoys full Army, Navy, and Air Force participation with each service having a resident program office, director and staff. By the conclusion of the program in 1994, a comprehensive microwave and millimeter wave monolithic technology base will be established. Manufacturing and design facilities will be in place to provide sufficient quantities of existing MIMIC designs and to rapidly and inexpensively produce new MIMICs for all DoD contractors. The benefits of MIMIC use will have already been demonstrated in a number of system applications, giving military system designers the assurance that this technology approach will work for their applications.

PROGRAM STRUCTURE AND FUNDING

The MIMIC program started with a one year program definition phase which was conducted between January, 1987 and January, 1988. This will be followed by two consecutive three year hardware development phases, the first of which will begin in 1988. Parallel efforts are also planned to provide needed technology support in areas such as lithographic and test equipment development, computer aided design tasks and packaging. Overall program responsibility is vested in Mr. E. D. Maynard, Jr., Director of Computer and Electronics Technology in the Office of the Under Secretary of Defense for Acquisition and the author. Service program directors are C. G. Thornton, Army Electronic Technology and Devices Laboratory; D. McCoy, Office of the Assistant Secretary of the Navy for Research, Engineering and Systems and W. J. Edwards, Air Force Wright-Aeronautical Laboratories. Many other DoD organizations including Naval Air Systems Command, Naval Research Laboratory and Rome Air Development Center are playing active roles in the program. In addition, representatives of the Strategic Defense Initiative Office, National Security Agency and Defense Advanced Research Projects Agency regularly participate in program activities. The

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overall program budget is approximately $500 million dollars. In the current year, $46 million has been appropriated.

PROGRAM OBJECTIVES

The primary objective of the MIMIC program is to make reliable microwave and millimeter wave monolithic circuits readily available for military use at affordable cost levels. To reach this goal, a number of supporting tasks must be carried out. These include: extending the research and development results already achieved in the laboratory; developing an adequate supply of wafers which possess the needed electrical characteristics; substantially improving computer aided design models and tools; successfully integrating results of the design process with the manufacturing process; selecting the chips and chip design approaches that will be most effective for addressing a wide range of military applications; assuring reliability of MIMICs and MIMIC modules; providing appropriate packages that will not degrade performance; assessing and assuring product reliability; extending automated test procedures, both in terms of frequency range of operation and types of circuits that can be evaluated, to reduce both cost and production time; and, finally, putting into place pilot production facilities which can produce MIMIC products at high yield and reasonable cost, thus, establishing the framework for high volume MIMIC production.

MIMIC contractors are required to prepare a business plan which is updated on a regular basis and includes a comprehensive market analysis for MIMIC products, an assessment of which MIMICs are needed for insertion into military subsystems, plans for effecting these insertions with the lowest possible risks, cost analyses and approaches to making MIMIC chips/modules available to all other prospective DoD buyers. Each contractor must also establish an additional independent source of supply for the chips that it manufactures.

Several types of data bases will be generated as part of the program. In addition to the normal program reviews and reports, an electronic data base is being implemented by personnel from Naval Ocean Systems Center to link all participating contractors and Government agencies. All contractors will also establish a manufacturing data base which will integrate cost models, process control information, computer aided design, testing, manufacturing and environmental factors. Strong emphasis will be placed upon cooperation between contractor teams to accomplish the required program objectives.

PROGRAM ACCOMPLISHMENTS AND TRENDS

During the program definition phase of MIMIC, which was recently completed, forty eight participating contractors on sixteen teams provided their assessments of the current technology base and of which military systems would most benefit from MIMIC technology usage. They recommended strategies to provide the most effective means of achieving both the R&D and production capability goals of the first hardware development phase of the program. The contractors' findings and recommendations can be briefly summarized as follows:

Materials: Most participants are presently using 3 inch diameter GaAs substrates grown by either low or high pressure Czochralski techniques, although some 2 inch diameter material is still in use. It is expected that 4 inch diameter substrates will be commonplace by the end of the first program phase in 1991. The approach generally adopted for active layer formation is ion implantation into substrates but epitaxial layer formation techniques are also being evaluated including molecular beam epitaxy (MBE) and metal-organic vapor phase epitaxy (MOVPE). A particularly promising new technique is metal-organic molecular beam epitaxy (MOMBE). However, equipment developments are needed to allow regular use of this approach.

The epitaxial layer approach to active layer formation is particularly important for higher frequency, higher performance devices. Considerable work is needed to consistently achieve the material properties which result in high circuit yield and improved performance characteristics.

Device Technology: There is general agreement that GaAs MESFETs with 0.5 micron gate lengths will be the primary device technology for MIMICs during the next few years. However, considerable interest and planning has been done to make MESFETs with gate lengths of 0.25 micron. In addition, there is great interest in heterojunction bipolar transistors (HBTs) because of their high efficiency, high voltage operation and in high efficiency mode transistors (HEMTs) because of their low noise and superior millimeter wave frequency performance.

Chip Design Approaches: A number of interesting approaches have been suggested including a technique in which a basic portion of a partially completed circuit can be personalized to meet a number of application requirements by changing the top metallization layer (ASMMIC--Application Specific Microwave Monolithic Integrated Circuits) (1). Other methods include the development of extensive libraries of macrocells which can be mixed and arranged in various configurations to meet performance specific needs. Many single function chips have already been demonstrated; a substantial number of multi-function chips will be developed during the next three years including several T/R modules.

CAD/CAT/CAM: It is expected that integrated computer aided design systems will evolve for MIMICs during the next three years. Most of these will make use of one of several commercially available workstations, use commercially available software packages where appropriate and include additional software to fill in the gaps particularly for non-linear and high frequency circuits. A major objective of the CAD efforts is to provide a common hardware description language so that interactions between products developed by various participants can be analyzed relatively easily. Serious attention is being given to coupling automated testing equipment and test results to the design stations and manufacturing lines.

Packages: The need for advanced packaging approaches has been recognized by many study participants both at the individual chip and module level. Many companies are interacting with packaging organizations to develop advanced packages, primarily from ceramics.

Test: Extension of wafer probing techniques to higher frequencies is already underway. A number of new companies have also expressed interest in developing equipment of this type. Within a few years, s-parameter measurements to at least 60 GHz using wafer probing should be possible.

SYSTEM CONSIDERATIONS

The primary reason for undertaking the MIMIC program was the recognition by DoD management that there is simply no other viable approach for providing the needed "front end" hardware for many electronic systems currently under development or being upgraded. Using current technology, these systems cannot be produced and procured in the quantities needed by our military forces, within acceptable budgetary bounds. The list of system candidates for MIMIC insertion includes familiar names in areas such as radar, electronic warfare, communications and smart weapons. Some of these are the new advanced multi-mode airborne radar systems under development by the Navy and Air Force, Army smart munition systems such as SADARM, MOFA and MLRS/TGW, communication systems such as the Global Positioning System (GPS), Mark XV Identification Friend or Foe (IFF) and MILSTAR. EW systems such as the Navy's GEN-X decoy and the INEWS system will also need

MIMIC technology. Combined function systems such as ICNIA will benefit as well.

CONCLUSION

The MIMIC program is well on its way to providing the necessary tools, capabilities and products for effective and widespread use of gallium arsenide microwave and millimeter wave monolithic technology in military systems. The program has enjoyed great enthusiasm from both the microwave scientific community and the Department of Defense organizations responsible for its execution and support. During the next six years an entire industry and technological capability will mature which should meet DoD needs well for many years to come.

REFERENCE

(1) C. Korgel, "Application Specific MMIC: A Unique and Affordable Approach to MMIC Development," To be presented at the IEEE 1988 Microwave and Millimeter Wave Monolithic Circuits Symposium.