Defence Science Journal, Vol. 56, No. 1, January 2006, pp. 87–91

Qualification Methodologies for ICs and MMICs for Aerospace Industry

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ABSTRACT

The ICs/MMICs attained importance in the field of microelectronics as these play a major role in the aerospace industry. The reliability of the ICs/MMICs becomes the critical issue because of complex material properties. A methodology has to be adopted which encompasses the qualification of ICs/MMICs for their use in the areas of strategic importance. A three-step procedure, which includes the process qualification, product qualification, and product acceptance is followed. The process qualification outlines a procedure that the foundry should follow to assure the quality, uniformity, and reproducibility from a specific process. Product qualification involves a set of simulations and measurements to establish the electrical, thermal, and reliability characteristics of a particular circuit design. Lastly, product acceptance is a series of tests performed on the deliverables.

Keywords: MMIC, design verification, qualification testing, wafer-level testing, thermal characterisation, process characterisation

1. INTRODUCTION

For any application, the user wants an assurance that the device must continue to function as per the required specifications over a given time period, and under certain specified environmental conditions. Each user has different expectations of reliability as it becomes application-oriented. The reliability expectations are very high for products having applications in strategic areas. The long-term failure of ICs/MMICs is usually determined by the physical and the chemical properties associated with the technology, design, material used in the product, and most importantly, the total strength of the environmental stresses imposed during actual application. Coincidently, semiconductor ICs/MMICs are also manufactured using physical and chemical changes in the surface layers of the material, rather than having a structure of complete crystallisation or solidification. The long time failure mechanisms of these products cannot be assured predictable because of the complicated process and material properties. Moreover, advancement of the technology in terms of small feature size, ie, of the order of submicron, and density has made it further critical. The presence of both active and passive elements on a single substrate makes the subject more complex for MMICs.

2. METHODOLOGIES

The qualification methodologies proposed include the process and the product qualification and acceptance to ensure that the technology, the fabrication process,

Received 04 October 2005

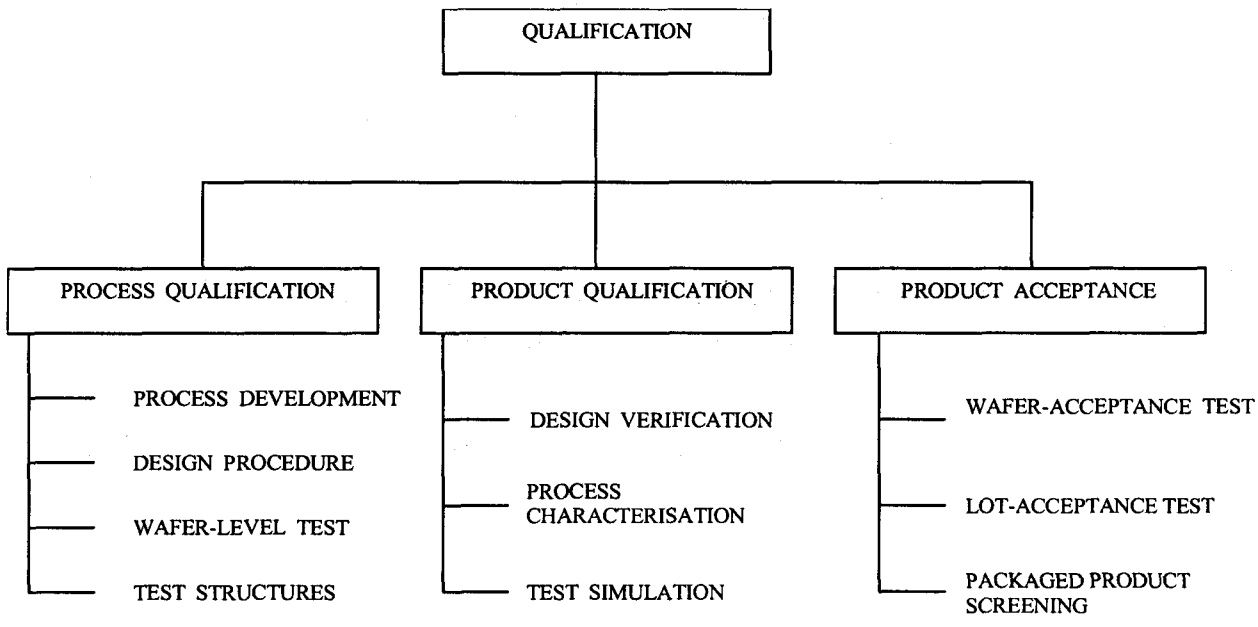

Figure 1. Different types of qualification methodologies adopted to meet expected level of quality and reliability

and the performance, meet the expected level of quality and reliability. Figure 1 shows the different types of qualification methodologies adopted for this purpose.

2.1 Process Qualification

A foundry which has standardised the production on a particular technology attempts to demonstrate that the entire process of designing and fabricating ICs/MMICs using the stated technology is under its control. In addition, it establishes electrical performance and reliability baseline for the fabrication of all components using the process. The first step in the procedure is to define process used for the wafer fabrication. The definition should cover the various aspects, mentioning all the critical steps.

After that, the process identification document (PID) should be generated containing details about the definition of the capability domain. This is required to ensure that design and fabrication processes are clearly defined, documented, controllable, and repeatable. The design system methodology and procedures used to implement the circuit design are clearly mentioned. The interface between design, manufacturing, inspection, and test procedures is also described. The program shall follow as in the flow chart. In case of monolithic circuit,the technology characterisation vehicle (TCV) contains passive elements, dynamic evaluation circuit (DEC is a set of active devices) and the representative integrated circuit (RIC is a fully functional circuit). The design should be carried out using the design manual guidelines and reviews. The fabrication process should be in adherence to the process being subjected for qualification, including each and every fabrication step. Figure 2 shows the sequence of the steps in process qualification.

2.2 Product Qualification

The procedure involves a set of simulation and measurement procedures to establish the electrical, thermal, and reliability characteristics of a particular product design, the rationale for and a description of the steps in the design validation, model, and layout verification. The reviews are held before the circuits are sent for mask fabrication and final characterisation. The thermal analysis is done to determine the hottest part of the device, ie, the temperature difference between the hot spot and the case. It is critical in determining the expected life of the devices. The infrared scanning techniques should be used for this purpose. Details as shown in Fig. 3.

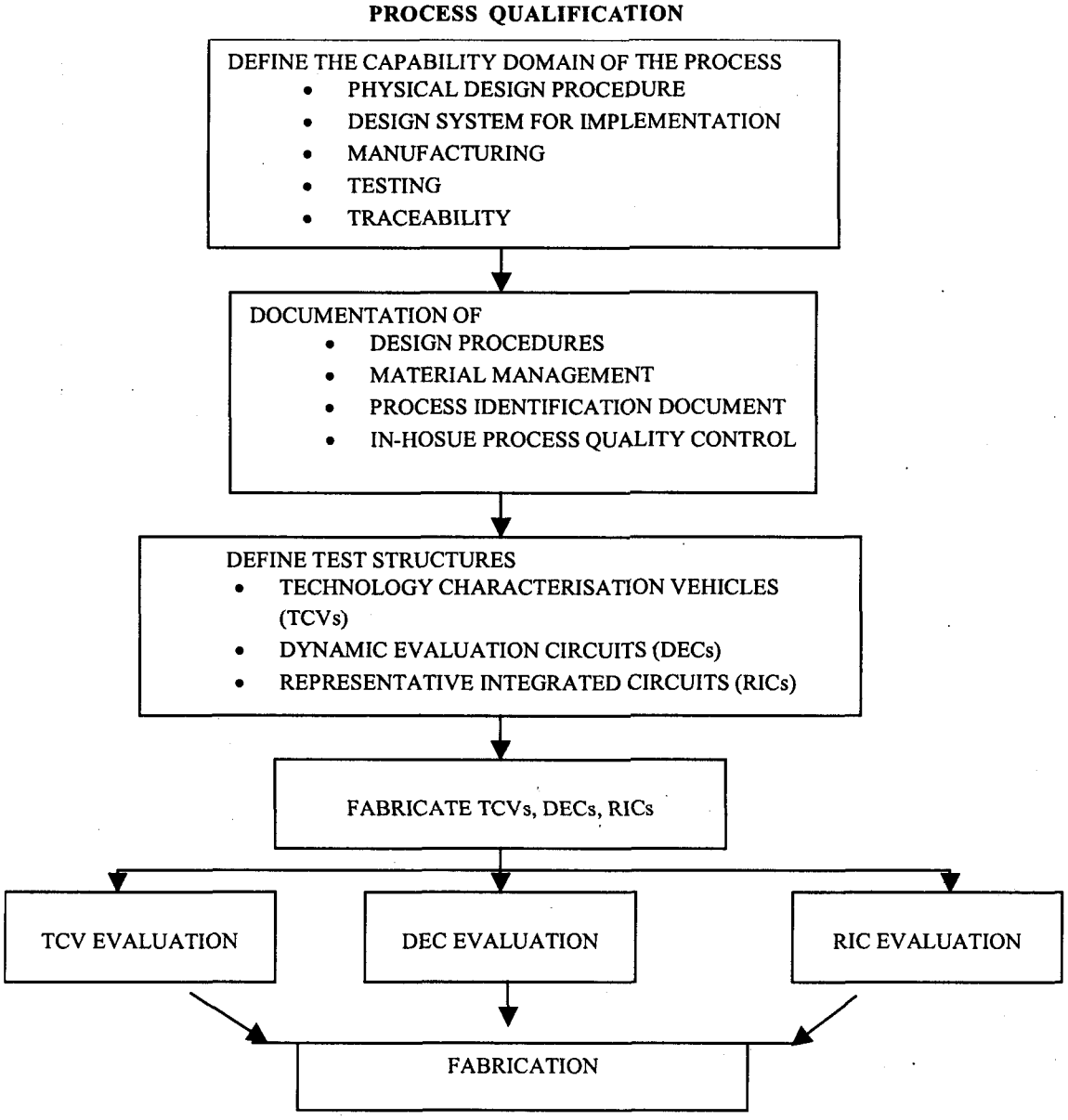

Figure 2. Flow chart for process qualification of ICs/MMICs

The ICs/MMICs are very sensitive to the electro static discharge (ESD). These can be damaged in the voltage range 20 V to 2000 V. The typical increase in gate leakage current has been observed after these are subjected to 60 V to 75 V ESD as per MIL-STD 883. The voltage ramp and high/ low-temperature tests have been found instrumental in carrying out product qualification under the normal bias conditions.

The sensitivity of ICs/MMICs design to the voltage overstress and absolute maximum ratings should be determined. The testing should be done till a catastrophic failure occurs. Data sheets should specify the highest and the lowest temperatures at which these devices should perform. High and low temperatures are defined to know the percentage changes at those temperatures.

2.3 Product Acceptance

The level of testing performed under product acceptance is the function of the form of the product deliverable. The first level of the acceptance testing,

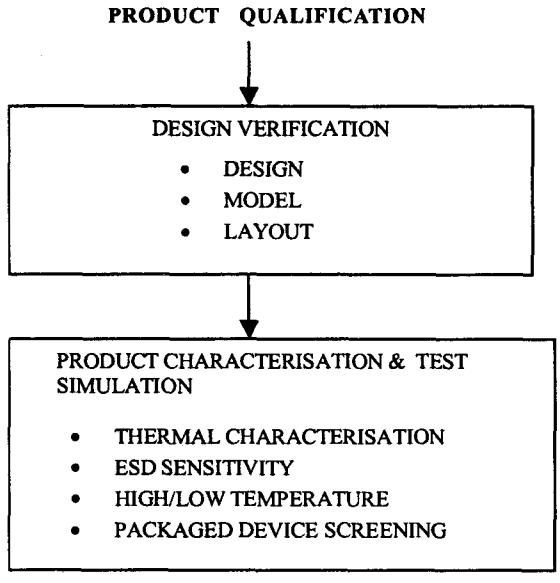

Figure 3. Flow chart of product qualification of ICs/ MMICs

called wafer-acceptance testing at wafer level, is done to assure the uniformity and reliability of the fabrication process through a wafer comparison. Lot-acceptance testing is the second level of the acceptance testing. This is the testing on sample basis that provides further reliability information. It is used if the user has requirement in die or unpackaged form. The packaged chips are tested on 100 per cent basis to give user an assurance that delivered parts are reliable and these parts do not have any adverse effect due to packaging as referred in Fig 4.

3. CONCLUSION

This paper discusses the various practical approaches for qualification of the ICs/MMICs. It describes that the level of qualification methodology differs from the point of view of the requirements. Process qualification is the required procedure for foundry qualification. This approach takes care of the process-level sensitiveness and identifies the procedure to verify the quality and reliability of the process. Different structures are fabricated for

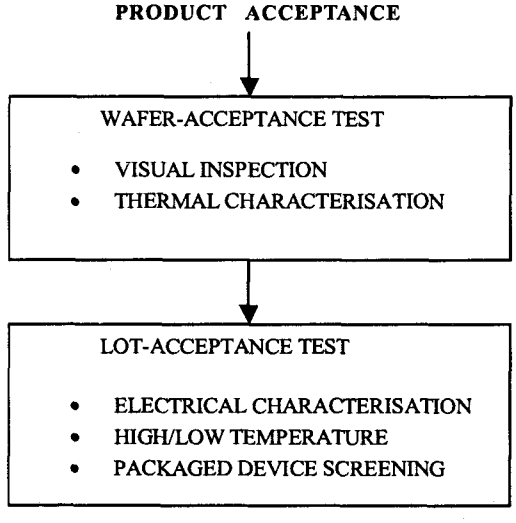

Figure 4. Flow chart of product acceptance of ICs/ MMICs

whole-process qualification. These structures cover the passive, active, and integrated components. Product qualification process encompasses the design verification, product characterisation, and test simulations, which is less in of process qualification. Product acceptance test procedure encompasses only product-level tests. These methodologies encompass the different levels of processes and products. The user has to select the methodology suitable as per the application.

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Mr Anesh K. Sharma received his BE (Electronics Engg) from the Nagpur University in 1989. He worked in the field of IC/MMIC/hybrid fabrication, assembly, testing and quality assurance for over 15 years at the Vikas Hybrids, Bhiwadi, and Semiconductor Complex Ltd, GAETEC Project, Hyderabad, and Research Centre Imarat (RCI), Hyderabad. He has also worked for foundry qualification for its Hi-rel applications like in aerospace systems. His areas of research are: Design, development, and qualification of hybrid and MMIC-based miniaturised products. He has published seveal research papers on qualification technologies.