Production and Verification of RFID MM2 Microchip with Bump and On-Chip Antenna

A B Hassan1 and I S A Ali2

1Electrical, Electronic and Automation Section, Universiti Kuala Lumpur Malaysian Spanish Institute (UniKL – MSI), Kulim High Technology Park, 09000, Kulim, Kedah.

2Programme Director, Malaysian Industry-Group For High Technology (MIGHT), MIGHT Partnership Hub, Jalan Impact, 63000, Cyberjaya, Selangor.

Corresponding author*: azmi.hassan@unikl.edu.my

Abstract. This paper describes the special steps taken for the mass production of the Radio Frequency Identification (RFID) MM2 microchip. Since the MM2 is the unique semiconductor product with special on-chip antenna, it requires special production steps that might be quite different from ordinary electronics processes. In order to start the volume production, several preparation steps have to be taken in advance. These tasks are usually not included in the research and development stage. At the initial stage of the production, the production scheduling and quality management are the most important works. Since the availability of the production line varies by the demands, the production sometimes becomes very tight and it will cause the delivery shortage that is critical for customers. In this paper, the steps for the production preparation and production process are described. In order to confirm the proper operation against the process variation by lot, at least three lots (equivalent to 1 million microchips) of the wafers were produced. Very limited number of the microchips were used for the reliability test and the rest were used as the pre-production sample purposes. The uniqueness of the production steps compare to other chip production is the on-chip antenna (OCA) process i.e. build-up very small antenna coil with specified carrier frequency on top of the chips.

1. Introduction
The Radio Frequency Identification (RFID) MM2 microchip has been developed in collaboration with Government of Malaysia with FEC Co. Ltd, Japan. This RFID MM2 microchip is important as it can be embedded in paper [1] for various applications when integrated with the multi-band antenna IC chip [2]. Since the research and development stage of MM2 chip was officially completed in 2008, the mass production of the chip for pilot and full commercial had started. The government incorporated Senstech Sdn. Bhd. to spearhead the applications of the MM2 chip on various RFID systems [3] in the public and private sectors. In this paper, the authors would share the experience carried out by Senstech Sdn Bhd and their partners i.e. Torex Semiconductor Ltd, Japan and Zixsys Inc., Japan in preparing the initial mass production work of the chips.
2. Production Setup

In order to achieve a stable production, it is very important to maintain the quality of the products. The quality of the products is ensured by the careful design, evaluation of the chip and detailed preparation for the production process. The production preparation activities can be divided into two categories that are: (1) Quality assurance and (2) Setups of the production.

2.1 Quality Assurance

The quality of the products is assured by the various factors such as:

- Design quality (adequate design or margins in parameters)
- Reliability tests for backup data collection
- Tests performance
- Seamless production process control

A reliability tests performed in advance to the production is one of important factors for the quality assurance. In this category, the following works have to be performed:

- Pilot lots production
- Pilot lots evaluations
- Reliability tests

The reliability tests to be performed on the MM2 chip are listed. For the AQL purposes, 22 pieces each from 3 production lots shall be tested in each test category. These lots were produced as the first step of the series of works in this category [4].

- HTST (High Temperature Storage Test): Leave the chip in 125°C environment for 1000 hours.
- HTBT (High Temperature Bias Test): Leave the chip with operating power fed in 125°C environment for 1000 hours.
- HHBT (High Temperature High Humidity Bias Test): Leave the chip with operating power fed in 85°C and 85% humidity environment for 1000 hours.
- HAST (High Temperature High Humidity Acceleration Test): Leave the chip with operating power fed in 125°C, 85% humidity and a pressure of 2 atmospheres environment for 300 hours.
- Temperature Cycles: Cycle the temperature in 30 minutes each between -55°C and 125°C for total 300 hours.
- ESD (Electric Static Discharge): Feed the electric static discharge to the chip of ceramic package.

2.2 Setup of the Production

In order to produce the chip in volume, the production line has to be fully prepared. Although parts of the conventional production line for general semiconductor chips can be used for MM2 production, it still...
require equipment that are specially designed and build for MM2 chip especially at testing routine. Main works in this category are to build the customized test system for the MM2 chip. Very limited Tester in the world can be used for the RFID chip testing. The Testers for the RFID are very expensive and the performance of those Testers is not sufficient for the MM2 chip testing, since the MM2 employs the original air protocol. Therefore, the testing system shall be a custom design. TOREX and ZIXSYS have designed and build the test board and install it into the production line. Major tasks in this category are listed as follows:

- Design the base Reader/Writer for the testing system
- Design the test board and assembly.
- Build the test board and install between normal Tester and Prober
- Confirm the testing operation
- Install the test board in the production line and make a trial run
- Design of UID numbering application (software on tester)
- Design of Mapping information generator software

3. Production Process
Once the preparation for the production completes, the volume production started. In order to understand the requirements for the production control, it is very important to know the semiconductor production process. Therefore, the explanation of the semiconductor production process is briefly described in this section. The production flow differs depending on form of the chip, either the Bumped die (for external antenna assembly) or the On-Chip Antenna (OCA). The bumped dies are attached on the plastic film and shipped. The back surface of wafer is ground to specified thickness and cut to die size. The production process of the bumped die and On-Chip Antenna is as shown in Figure 1.
The following Table 1 indicates the schedule of the works in the typical condition. The schedule might change depending on the uncontrollable factors such as process time, etc.
Table 1. Schedule of production works

| 1st month | 2nd | 3rd | 4th | 5th | 6th | 7th |
|-----------|-----|-----|-----|-----|-----|-----|
| Wafer production | | | | | | |
| Build Bump | Wafer Pre-test | BG. Dicing | Ceramic Packaging | Develop Test Tools for Ceramic Sample | Reliability Test | |
| OCA Re-design | Wafer Pre-test | | | | | |
| Make Masks for OCA | OCA Processing | BG, Dicing | Develop Test Tools for Ceramic Sample | Reliability Test | |
| Test Result Evaluation | | | | | | |
4. Work flow of reliability tests

The following steps have to be taken to complete the reliability tests. The descriptions below are based on chip level testing.

4.1 Order of minimum three production lots to the wafer foundry for AQL

In order to confirm the proper operation against the process variation by lot, at least three lots of the wafers shall be produced. Very limited number of the chips will be used for the reliability test and the rest can be used as the pre-production sample purpose.

4.2 Preparation of the R/W for the reliability tests

In order to perform the reliability test, the customized Reader/Writer (R/W) to confirm the chip operation shall be prepared in advance. The normal R/W communicates with the chip via RF. However, some tests will be made on the encapsulate chip in ceramic package, thus it requires the special interface which operates with ceramic package. Some of the tests are executed with the RF power fed into the chip and the chip has to be put into the oven thus the customized structure of the R/W is needed. These R/W’s were developed by ZIXSYS [5] and one sample is shown below in Figure 2.

![R/W image used for reliability tests](image1)

**Figure 2.** Reader/Writer module for MM2 Chip.

4.3 Building the chip into the ceramic package for test

MM2 chip has an access only through the RF input pads via an antenna. Since there is no method to access to the bare die of MM2 chip without antenna connection, the chip was built into the ceramic package to execute the reliability tests. 22 pieces each from three lots for each test were built into the ceramic packages. Total number of the ceramic samples becomes 396 pieces to cover all six test categories. Samples of the dies capsulated in ceramic package are shown in Figure 3.

![MM2 Chip capsulated in ceramic package](image2)

**Figure 3.** MM2 Chip capsulated in ceramic package
4.4 Execution of the reliability tests
Several equipment are required to execute the reliability tests.

- Heat Chamber to generate high and low temperature
- Heat Chamber equipped with temperature and humidity control
- Heat Shock Chamber with rapid temperature change function
- High voltage electro-static generator for ESD

The longest test will take 1000 hours to complete thus the required duration to complete the tests is estimated around three months. These tests was performed at facilities in TOREX and ZIXSYS.

4.5 Tests result verification
The test results were evaluated and the final reliability specification was defined. The rests of the chips produced for the reliability tests might be supplied in the production stage to the customers.

5. Reliability tests for OCA version
Another reliability test was performed on the OCA, since the OCA was formed on wafer in another process. The reliability tests executed on the OCA were basically the same with those for the chip. The reliability tests on the OCA shown in Figures 4(a) and (b) were conducted separately by Fujikura and ZIXSYS. The equipment used for the OCA reliability tests were the same with the ones used for the chip, therefore most of the resources provided for the chip reliability tests were reused for the OCA reliability tests. Thus, the uniformity of the reliability levels on both chip and OCA will be ensured. Figure 5 shows the brief setup for the MM2 chip OCA testing. The tester have the function to automatically execute the command transmission and response reception by the integrated microchip firmware as shown in Figure 6. The tester has 8 channels of test signals which enable simultaneous tests on 8 chips in order to expedite the total test time. Detailed testing process and specification are not included in this paper. However the example of test program and evaluation behavior of the MM2 chip presented as shown in Figure 7.

Figure 4(a). MM2 Chip with 2.45GHz  
Figure 4(b). MM2 Chip with UHF
Figure 5. Test board connected to the Probe card and 8 channel tester board.

Figure 6. Example of test program
6. Conclusions
The production flow of MM2 chip had been presented in this paper. It were carefully prepared for the seamless operation. The production of MM2 is unique mainly on OCA process and also on the function of data encryption in data connection between tags (chips) and reader/writer module as shown in Figure 6. There are several important factors that must be consider to maintain stable productions such as required time for the process in each task, factory availability, tightness of production (changing time by time), logistic flow, improvements for further cost down, accurate forecast for the future demands and leveling of the production volume in monthly base. Since the lead time for the semiconductor products are relatively longer, sudden change of the production quantity usually cannot be accepted. Therefore the accurate production scheduling is very important.

![Final wafer of MM2 chip2 with OCA fabrication](image)

**Figure 7.** Final wafer of MM2 chip2 with OCA fabrication

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