

An Advanced Probe System Designed For the GCT-Like Device Test

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Abstract: in recent years, with the application of power electronic techniques in power system, massive needs for high power devices occurred. Integrated Gate Commutated Thyristor (IGCT) has gained much attention in high power applications with its advantage in high blocking voltage and low conduction loss. Due to the massive quantity of segments in parallel in one single GCT chip, it is of significance to distinguish and remove the weak cells in order to achieve a better whole wafer performance. In this paper, an advanced probe system designed for GCT-like concentric device test is presented. Tested result for 4-inch device is also presented and analyzed.

1. Introduction

In recent years, with the application of power electronic techniques in power system, massive needs for high power devices occurred. However, under the restriction of material and process, each kind of device showed its own advantages in specific applications [1-3]. Integrated gate commutated Thyristor (IGCT), with the feature of high blocking voltage, high current capability and low conduction loss, has been applied in many scenarios in DC system, such as MMC converter and DC circuit breaker [4-6].

The basic structure of IGCT device mainly contains three parts, which are the GCT chip, housing package and the integrated gate drive unit, as shown in Figure 1. For the wafer part, IGCT adopts the manufacture technology of Thyristor, which arrange thousands of Thyrsitor cells in parallel in one wafer, in order to achieve a high yield and high efficiency.

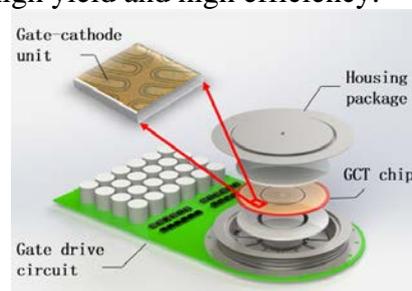


Figure 1. The basic structure of IGCT device

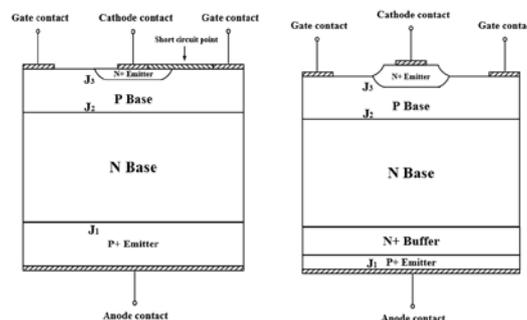


Figure 2. Basic structures of thyristor cell (left) and GCT cell (right)

However, as declared in Figure 2, there are still some differences between the structure of GCT cell and Thyristor cell. One of the differences is that, for a GCT cell, the existence of a 20um deep step in wafer surface increase the difficulty in the wet etch of aluminum contact and bring in some short circuit point between cathode contact and gate contact. Also, with the requirement of plasma extraction of cathode emitter junction, the shorted cathode structure in Thyristor structure is not applicable for GCT structure. Thus, the short circuit point between cathode contact and gate contact has to be avoided. With the restrictions of manufacture process, the short circuit point can be hardly eliminated in a GCT chip containing over 2000 segments. In this condition, an inspection and mending step is of great importance for the manufacturing process.

For high power device such as Thyristor, the inspection on contact metal quality is normally done by workers' eye measurement. However, the massive quantity of cathode segments in parallel and small short circuit point shown in Figure 3 both add to the difficulty of inspection.

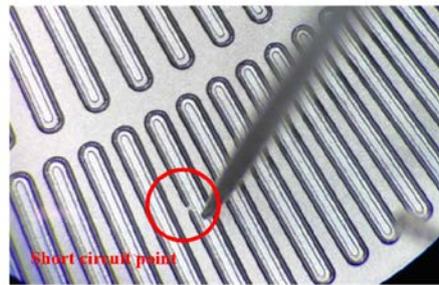
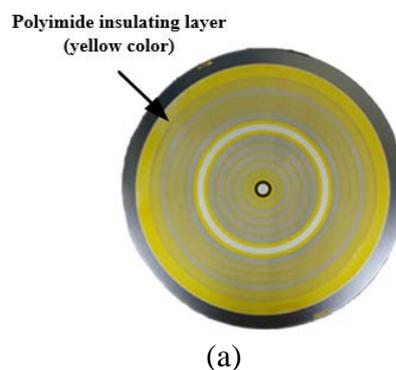


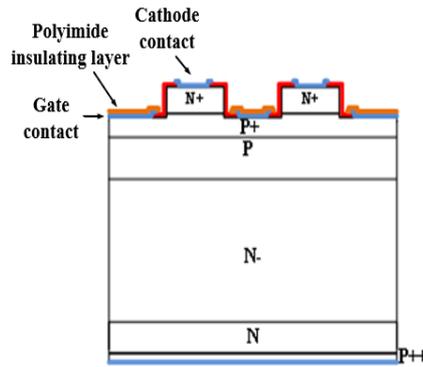
Figure 3. The illustration of short circuit point

In this paper, an approach to the measurement and positioning of short circuit point is presented, the short circuit and blocking voltage characteristics of cathode-gate junction in two GCT chips are measured on this platform. The results revealed a close relationship between manufacture process and tested feature. Furthermore, the removal of feeble segments was done, and the processed device showed a good result in the cathode-gate junction performance.

2. Existing approaches and problems

Generally, there are two main approaches to the measurement of segments features. The first is test all the segments manually, which is often conducted by the beep mode of a multimeter together with possibly a microscope. Figure 4 shows a top view and a cross section of a GCT chip. It can be observed that the majority of gate contact is overlapped by the polyimide insulating material. When one probe is fixed on the gate contact in the center of GCT chip, the beep sound made by the multimeter when another probe sweeping across the cathode segment region indicates a short circuit point. However, this manual method, in one aspects, cannot be implanted on the chip with a poor polyimide layer quality. Because when you sweep the probe over a badly-made polyimide layer, the probe may cross over the polyimide layer and contact the gate electrode directly. In another aspect, the probe of multimeter is generally strong and hard, which means the sweeping action bring some damage to the aluminum contact and polyimide layer, causing some manmade short circuit point, as illustrated in Figure 5.





(b)

Figure 4. The top view (a) and cross section (b) of a GCT chip

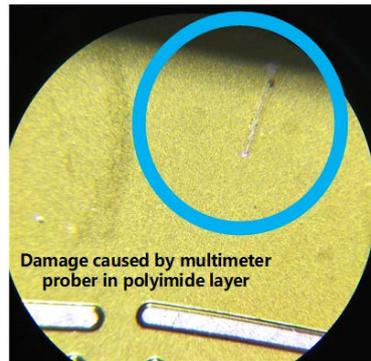


Figure 5. Damage caused by multi meter

Another approach is the automatic probe system used in the field of integrated circuit manufacture. Figure 6 illustrates the structure of an automatic probe system [7]. The inspection on integrated circuit is commonly based on the probe card, which contains many needles for the electrical connection. The precise positioning of needle and wafer is achieved by the equipment of wafer chuck. However, a standard 4-inch GCT chip contains over 2000 segments, which means it is not realistic to test all the segments at the same time. Also, though all segments are arranged in concentric circles, the pattern of all segments is not concentric. This is because the angle corresponding to a gap between two segments is different in two adjacent rings, as illustrated in Figure 7. The asymmetric structure makes it impossible to measure different regions of the wafer with identical probe card for several times. Therefore, it is essential to develop a measuring equipment suitable for the GCT-like device test, whose structure is not symmetric or repeated

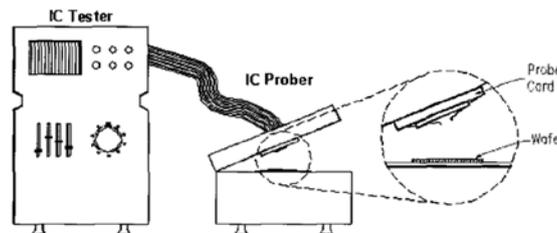


Figure 6. The basic structure of automatic probe system [7]

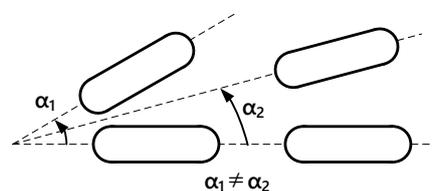


Figure 7. Illustration of included angle between two adjacent segments for different rings

3. Advanced test platform

Figure 8 shows the modified automatic probe system. The system mainly contains four different parts, which are the tester, video capture device, wafer chuck and the probe. When operating in the test mode, the device under test is mounted to the wafer chuck through a vacuum pump. The wafer chuck then calibrates its coordinate system by the symbol in the center of wafer captured by CMOS sensor, as shown in Figure 9.

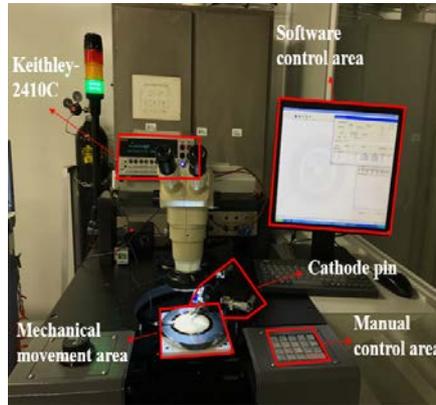


Figure 8. Modified automatic probe system

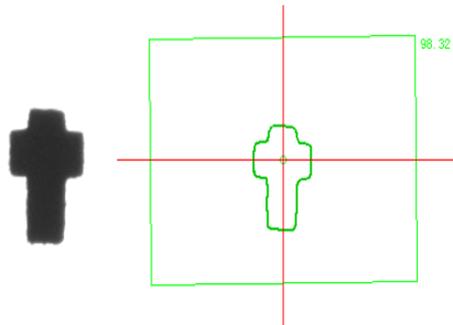


Figure 9. Marker used for coordinate calibration

Then an additional calibration step of origin probe position is needed to ensure the precise click on the aim segment. The calibration process can be done through positioning the probe to the center of wafer under test at the origin state, as shown in Figure 10.

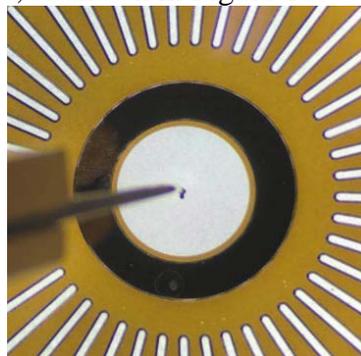


Figure 10. Calibration of origin probe position

After the configuration steps, with the inputs of radius and segment numbers of each ring, the probe system can then calculate the rectangular coordinates by (1).

$$\begin{cases} x_{ij} = R_i \cos(\theta_i + 2\pi(j-1)/N_i) \\ y_{ij} = R_i \sin(\theta_i + 2\pi(j-1)/N_i) \end{cases} \quad (1)$$

$i = 1, 2, 3, \dots, N_{ring,max} \quad j = 1, 2, 3, \dots, N_{cell,max}$

With the precise control of serve motors in x and y axis, the wafer truck can be moved to a specific position accurately. An extra pressure sensor is installed in the needle in order to ensure a close contact with the GCT chip

After connecting GCT chip with probe, the electric characteristics are measured with a tester. The tester model is Keithley-2410C, which can apply a specific current to the gate-emitter junction. The voltage of emitter-gate junction corresponding to each segment is recorded. The segments with voltage lower than the threshold voltage will be marked with different color.

4. Result

Figure 11 illustrates a typical pattern of weak points in a GCT chip (Source current set to 3uA, threshold voltage set to 20V), and Figure 12 illustrate the cathode-emitter junction voltage distribution in a chip. The low voltage points are marked with ink, as shown in Figure 13. When measured again in sweep mode of Keithley-2410C, most of the weak points show a soft V-I feature, which is identical to the analysis, as shown in Figure 14. When observing the weak points through microscope, some photolithography errors can also be easily distinguished, as illustrated above in Figure 3.

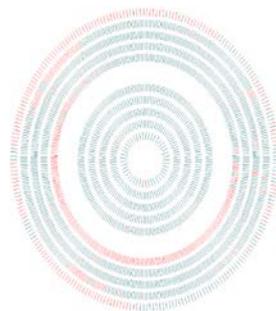


Figure 11. Typical pattern of weak points in a GCT chip

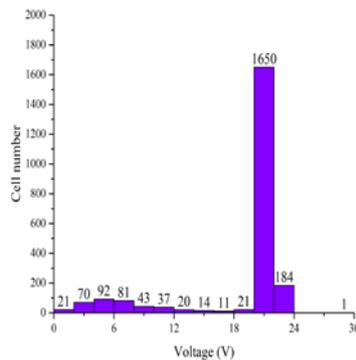


Figure 12. Segment cathode-emitter junction voltage statistics

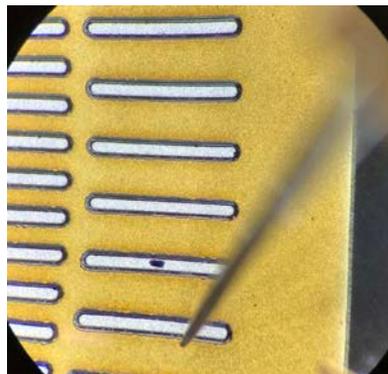


Figure 13. Ink mark indicating the weak point

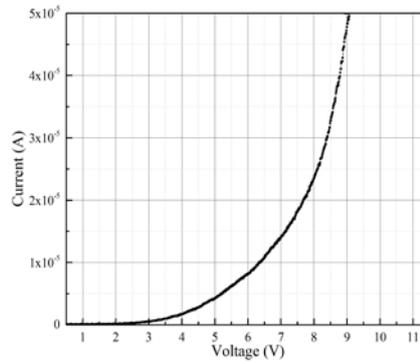


Figure 14. Typical I-V characteristic for weak point

Table 1 shows a comparison between manual method and automatic probe system method, which indicates a leap in the efficiency of inspection.

Table 1 Comparison between manual method and advanced automatic probe system

	Manual method	Automatic probe system
Efficiency	2 hours for 100 segments	100 minutes for over 2000 segments
Difficulty	Twist the knob run the test manually for each segment	Automatic test after configuration
Positioning	Observation with naked eye	High precision serve motor movement with calculated position coordinate
Marking	General camera photo record	Ink mark on weak points
Results	Discrete data points	Statistical charts and diagrams

5. Summary

In this paper, a modified probe system suitable for the GCT-like device test is analyzed and presented. The distribution of emitter-gate junction voltage and location of emitter-gate short circuit points for a 4-inch GCT chip are measured through the system. The result shows a great improvement in the efficiency and precision for the emitter-gate test when compared with the manual method.

Acknowledgment

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