Process Optimization to Improve Known-Good-Die (KGD) Test Accuracy and Wafer Final Yield

Yu Wang, Patrick Carroll, Jing Yao, Zach Reitmeier, Tom O'Brien, and Doug Melville

Qorvo, Inc. 7628 Thorndike Rd. Greensboro, NC 27409.
Email: yu.wang@qorvo.com Phone: (336) 678-5239

Keywords: Known-Good-Die (KGD) test, Universal Data Query (UDQ), Gold Bond Pad Clean, Oxygen Plasma Etch.

Abstract

In GaAs industry, to improve product quality, many Fabs implement wafer level test to screen out defective die. Therefore wafer test efficiency and accuracy affect production cycle time, yield, and final product quality. This paper presents a data query and analysis scheme to identify false failure in wafer level test. In particular, the authors focus on a discussion about a certain type of false failure caused by gold bond pad contamination. In addition, an oxygen-based plasma etch process was tested to improve gold bond pad clean in order to decrease test false fail rate.

INTRODUCTION

High volume production of GaAs wafers for use in highly integrated modules drives the need for appropriate wafer level test scheme to filter out defective die prior to module assembly. Accuracy and efficiency of Die Sort, so-called Known-Good-Die (KGD) test, directly impact product yield, cost, and fabrication cycle time. Over years of KGD test results analysis, we observed a variety of false failures due to KGD tester malfunctioning, flawed test scheme, or bad electric contact between test probe and die bond pad. Some false failed die can be reclaimed through retest at the cost of cycle time, labor, and probe card consumption. While unrecoverable false failure causes negative impact on wafer level yield. In this paper, we discuss a process optimization approach to improve probe/bond pad contact and decrease KGD 1st pass false failure. KGD data analysis utilizes Universal Data Query software to access test results from millions of die. [1]

Si nitride has been commonly used as GaAs wafer glassivation layer to prevent moisture penetration. To protect Si nitride from scratch, in recent years, a photoresist-based polymer coating is applied on top of Si nitride to protect nitride from any mechanical damage. Since the application of the scratch protection layer, we have surprisingly observed a significant increase in KGD 1st pass false fail from ~3.9% to ~9.4% (as shown in Fig 1). With further KGD data analysis, we found most of the 1st pass false failed die on coated wafers failed a KGD test parameter that is particularly sensitive to probe/ bond pad contact (as shown in Fig 2). When test probe first touches gold bond pad, an increased resistance caused by pad surface contamination results in lower test current. Consequently, die with contaminated bond pads fail 1st round KGD test. While during retest, all failed die (darker shaded in Fig. 2a) are retested with enhanced contact between prober and bond pad. Therefore, 1st pass false failed die can be recovered from retest (Fig. 2c). Since this type of false fail is closely related to bond pad surface condition, we suspect the root cause is related to polymer coating process that affects bond pad surface purity. Based on our observation on production wafers, we tested varied bond pad clean methods after polymer coating, and prior to KGD test. Experimental details and results are discussed in following sections.

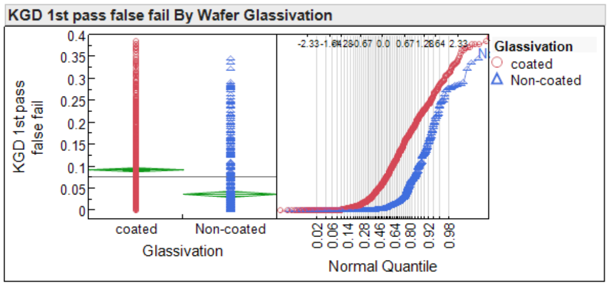

Figure 1. KGD first pass false fail rate for wafers with and without polymer coating. Quantile plot also shows significant difference between the two types of wafers.

EXPERIMENTAL

In this work, we tested both wet and dry etch in order to improve gold bond pad surface purity. As shown in table 1, after polymer was coated and cured, four bond pad clean conditions have been tested, including developer dip clean, oxygen plasma etch at varied energy, and the combination of both wet and dry surface clean methods. Mild and strong plasma etch were performed at low and high plasma power, respectively. KGD test was carried on immediately after gold bond pad clean. All wafers were tested through the same KGD tester and probe card to minimize variation caused by test equipment. KGD false fail rate is calculated from subtraction of 1st pass yield from final yield after retest. All test wafers were processed through standard fabrication process with an additional optical microscope inspection after wafer singulation to exam surface cosmetics.

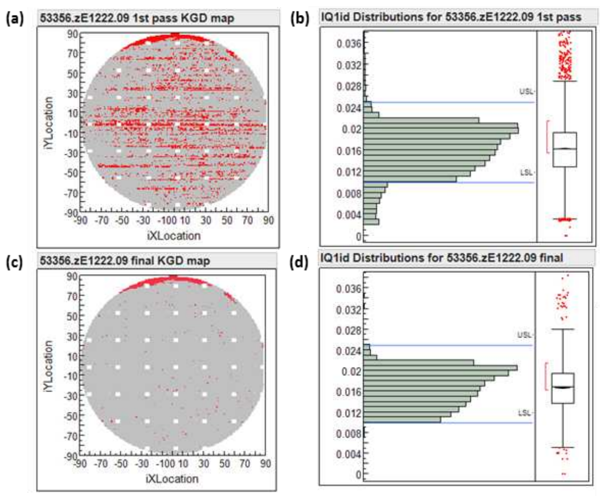

Figure 2. (a) KGD first pass map, and (c) final map after retest (darker shaded die – fail, lighter shaded die – pass). (b) and (d) are distribution of a test parameter after 1st test and retest. USL and LSL are upper and lower spec limit.

Table 1. Polymer-coated test wafer gold bond pad clean methods prior to KGD test.

Wafer #	Bond pad clean prior to KGD test	
	Wet etch	Plasma dry etch
01, 05, 09, 13	Developer dip clean	No
02, 06, 10, 14	Developer dip clean	Mild descum (low power)
03, 07, 11, 15	No	Mild descum (low power)
04, 08, 12, 16	No	Strong descum (high power)

RESULTS AND DISCUSSION

Figure 3 shows wafer maps of 16 wafers tested in this experiment. Die passed 1st round KGD test is lighter shaded, while die failed 1st KGD test but pass 2nd KGD test, e.g., recovered die, is darker shaded. White squares represent PCM (process control monitor) regions on a wafer. Successfully recovered die typically outputs test current lower than spec in 1st pass KGD test. While during retest its output current bounces back to a normal range when the die is probed deeper on bond pads. False failed die also tends to form a certain type of pattern on a wafer. For instance, false failed die due to bond pad contamination forms line pattern along moving direction of a probe card as shown by green die on wafers maps in Fig 3.

In addition, Fig. 3 shows a strong correlation between the number of false failed die on a wafer and its bond pad clean process. From direct comparison of false fail rate among test wafers, it is interesting to notice that plasma etch can effectively reduce KGD test 1st pass false failure by improving gold bond pad surface condition.

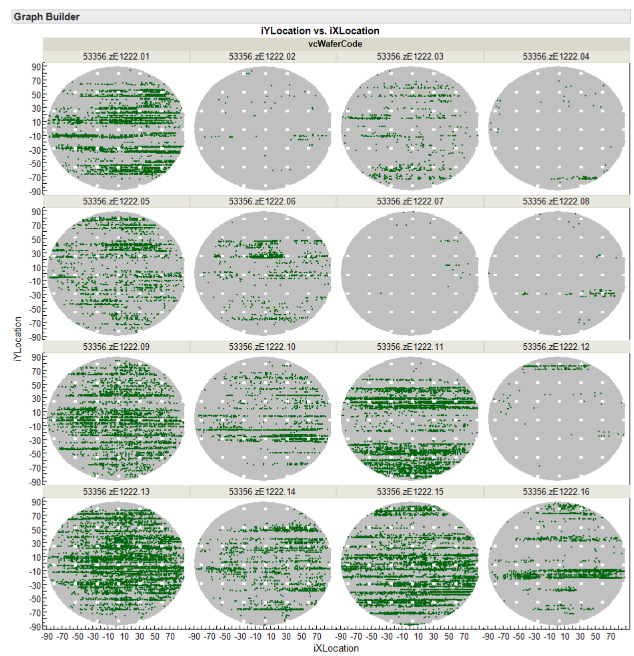

Figure 3. KGD wafer maps. Lighter shaded die pass 1st KGD test, darker shaded die fail 1st KGD test but pass retest. Wafer 1, 5, 9, and 13 were only developer cleaned, wafer 2, 6, 10, 14 were wet etched in developer followed by mild plasma dry etch; wafer 3, 7, 11, and 15 were plasma etched only at lower energy; wafer 4, 8, 12, and 16 were plasma etched only at higher energy.

Figure 4 compares false fail rate of test wafers processed through varied bond pad clean procedure prior to KGD test, including developer dip clean only, mild and strong oxygen plasma etch only, and a combination of developer dip clean and plasma etch. We observe a higher false fail rate for wafers only wet etched in developer. While wafers dry etched under a higher plasma power tend to have the lowest KGD test 1st pass false fail rate. This indicates oxygen plasma etch of bond pad improves electrical contact between KGD tester probe and gold bond pad, resulting in lower false fail rate in 1st pass KGD test.

However, after microscopic inspection on all test wafers, we observed unexpected cosmetic defect (as shown in

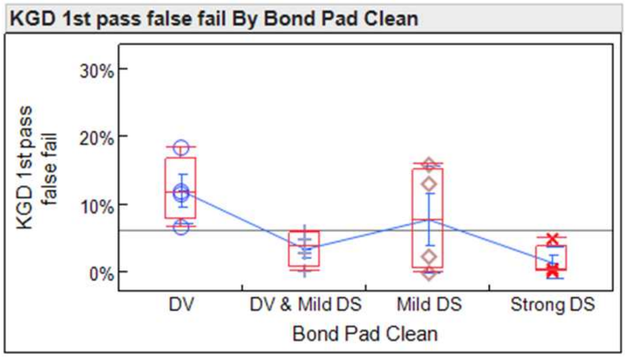

Figure 4. KGD first pass false fail rates for wafers etched only in developer (DV), wafers etched in developer followed by mild plasma etch (DV & Mild DS); wafer plasma etched only at low power (Mild DS); wafer plasma etch only at high power (Strong DS).

Fig. 5) from wafers have been plasma etched only after polymer cure. More interestingly, wafers processed through developer dip clean and followed by plasma etch do not have cosmetic defect. One hypothesis for this phenomenon is developer dip clean uniformly remove top layer of damaged polymer to smooth up polymer surface. Then additional plasma etch can only thin down the polymer coating but it cannot rough the polymer surface to cause cosmetic defect. While without developer dip clean, polymer starting surface becomes uneven, and plasma etch further roughs polymer surface and eventually cause surface defect. More experiments are carried on to test this hypotheses and other possible source of bond pad contamination.

In table 2, we summarize test wafer process condition, average KGD false fail rate for each group of wafers, as well as wafer cosmetics from microscopic optical inspection.

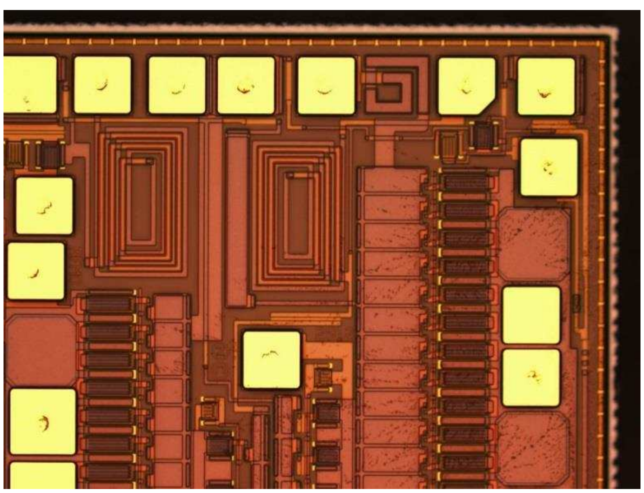

Figure 5. Optical microscopic image of wafer with surface cosmetic issue. This wafer was plasma etched at high power after polymer cure.

Table 2. Summary for KGD false fail rate and polymer cosmetics for 16 test wafers with varied bond pad clean procedure.

Wafer #	Bond pad clean prior to KGD test	Wafer cosmetics	KGD false fail (average)
01, 05, 09, 13	Developer clean only	Good	12.2%
02, 06, 10, 14	Developer clean plus mild descum	Good	3.6%
03, 07, 11, 15	Mild descum only	Bad	7.9%
04, 08, 12, 16	Strong descum only	Bad	1.6%

Further optimization on gold bond pad clean is carried on through a separate experiment and presented in Fig. 6. In this plot, squares represent wafers only developer dip cleaned prior to KGD test, and triangles and circles represent wafers cleaned through both developer dip and plasma etch. The goal of this experiment is to test the effect of oxygen plasma etch power and length on KGD false fail rate. A promising trend of decreasing false fail rate with increasing plasma etch power is shown in Fig. 6. And false fail rate plats up when plasma etch power increases up to level 3.

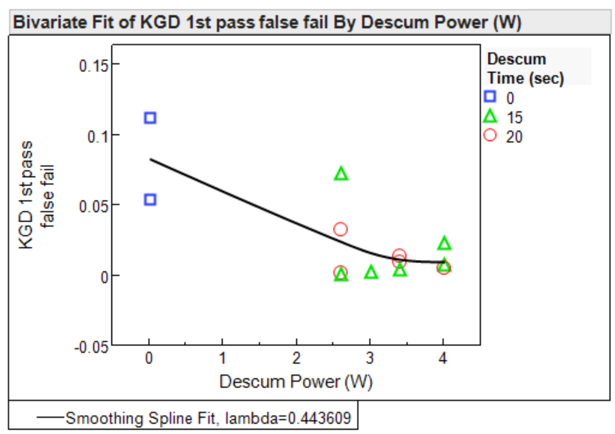

Figure 6: KGD 1st pass false fail rate vs. oxygen plasma descum power in arbitrary unit. All wafers were wet etched in developer prior to plasma dry etch.

CONCLUSIONS

In this paper, we demonstrated an approach to improve KGD test accuracy and efficiency. Massive data analysis plays a key role in our approach to identify certain type of KGD test false failure and to search for root cause and solution.

To seek for a solution, we tested both developer-based wet etch and oxygen plasma-based dry etch in order to decrease a particular type of false failure caused by bond pad surface contamination. A combination of wet etch and plasma dry etch process was developed to decrease KGD 1st pass false fail rate by ~10%.

More importantly, this joint effort on process and test improvement may lead to an increase in final yield at wafer level. Once the newly developed bond pad clean recipe is implemented into Fab POR (process of record), we will further evaluate its impact on KGD test efficiency and wafer level yield with the help of UDQ. Nevertheless, it is a continuous effort to balance test accuracy, product quality and yield. Massive data analysis always helps to recognize and fix different type of test issue that originates from test instruments, test scheme, or minor die imperfection.

ACKNOWLEDGEMENTS

The authors would like to thank Terry Tesnow, Doug Cheney, and Dwain Boyles who helped with the experiments and sample measurements. Also appreciate the support from Wafer Fab production group and management team.

REFERENCES

[1] P. Carroll et al., 2012 CSMANTECH Tech. Dig., May 2012.

ACRONYMS

KGD: Known-Good-Die
PCM: Process Control Monitor
POR: Process of Record
DV: Developer Dip Clean
DS: Plasma-based Descum