U.S. Department
of Transportation

National Highway
Traffic Safety
Administration

Analysis of Electronic Control Unit and Accelerator Pedal Mechanism Components Damaged During EMC Testing

February 2011

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16. Abstract

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1.0 Introduction

During the Electro-Magnetic Compatibility (EMC) testing conducted by a team of NASA and NHTSA staff as part of the Toyota Unintended Acceleration (UA) study certain Electronic Throttle Control (ETC) system component failures were experienced. As discussed below, none of the component failures resulted in UA, nor was there any evidence that failures of this type were occurring in the field, and all the failures occurred under conditions unlikely to occur in consumers' use of the vehicle. For these reasons, the extent to which the failures were a result of EMC effects, component susceptibilities, the test setup/method employed, or a combination of these, was not fully evaluated by the team.

In one case the failed ETC component, an electronic control module (ECM) resulted in an engine stall (or a failure of the engine to start). In the other component failures, involving accelerator pedal mechanisms (APM), these caused the engine to remain at idle regardless of the accelerator pedal position. The failed components were subsequently evaluated by the component supplier, Denso Corporation and its subsidiary Denso Manufacturing Tennessee, with oversight provided by NHTSA staff. A description of the vehicles under test, the testing that was being performed when the failure occurred, and the Denso reports produced for the failed component are provided below.

2.0 ECM Failure

2.1 Vehicle Detail

Model Year (MY) 2004 Toyota Camry XLE w/V6 1MZ-FE engine (Vehicle 14C). The vehicle was the subject of NHTSA Vehicle Owner Questionnaire ODI number 10321093[1]

2.2 Description of Testing and Failure

In July 2010 the above vehicle was being tested in an anechoic EMC test chamber operating on a dynamometer between 30 and 35 mph. The test environment of interest was in the frequency range from 144 MHz to 160 MHz, and the power level was up to a maximum of 250 volts/meter[2]. During the testing the vehicle was observed to slow down and eventually stall when exposed to high radio frequency (RF) energy[3], and warning lights were noted to be illuminated on the instrument panel.

The testing was stopped and the vehicle was interrogated using a Toyota provided diagnostic tool called a TechStream Lite, a PC based device. The TechStream connects to the vehicle's diagnostic link connector (DLC) via a USB device, called a Mongoose cable, which allows the PC to communicate with the ECM and other vehicle systems. The interrogation showed that engine diagnostic trouble codes (DTCs) P0346, P0717, P2241, B2799, P0346, P0353, P0356 and ABS/VSC/TRAC DTCS C1201, C1203, C1224 had been stored.

In an attempt to collect additional information on the DTCs and engine performance issues experienced during the testing, the team elected to conduct additional EMC testing while the

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[1] A public copy of the report is available at http://www-odi.nhtsa.dot.gov/complaints/.
[2] The signal was being modulated using a 50% duty cycle square wave at 1 kHz.
[3] The vehicle speed could be modulated (slowed) gradually by adjusting the power level of the RF. A number of tests were run at various power levels to characterize this behavior, all in the 144 to 160 MHz frequency range.

TechStream device was connected to the vehicle, since this would allow various ECM data parameters to be monitored.

To accomplish this the PC was located outside of the test chamber (in a Faraday cage for EMC protection). The Mongoose cable was routed between the vehicle and the PC, and an optical USB coupling device was utilized between the Mongoose cable and the PC. The optical coupling device required power at the Mongoose cable connection to provide 5Vdc to the Mongoose cable (this power normally comes from the PC USB port). As a result of this setup the Mongoose cable, the powered end of the optical USB coupling cable, and the 5Vdc power supply wires, all of which were routed in the vehicle and test chamber, were exposed to the RF environment during conduct of the test. The Mongoose interface, the 5Vdc power supply cable, and the powered end of the optical USB coupler were all wrapped in a double layer of aluminum foil to provide shielding from the RF energy.

As the testing proceeded the TechStream began exhibiting difficulty communicating with the ECM and at some point the engine stalled and could not be restarted[4]; at this point the TechStream lost all communication with the ECM. A replacement ECM was installed in the vehicle as a test to confirm the ECM had failed. It is important to note that subsequent to this failure no other vehicles were EMC tested with a TechStream device connected to the DLC, and none of the other vehicles tested in equivalent RF environments experienced an ECM failure.

In August 2010 NHTSA staff hand carried the failed ECM to a Denso facility located in Maryville, TN for additional assessment. Through testing and component swapping, which was witnessed by NHTSA staff, Denso determined that a specific integrated circuit (IC) component

[4] The engine would crank over with the starter motor but would not start and run on its own.

known as the sub-microprocessor (or monitor CPU) had failed. The failed component was removed and replaced with a known good IC. NHTSA retained possession of the repaired ECM and failed IC after the Denso assessment. The ECM was subsequently returned to the EMC test team for assessment in the above vehicle and the team confirmed it was functioning correctly after replacement of the single component.

In September 2010, after discussion by staff involved in the EMC testing, the failed IC was sent to Denso's Electronic QA department in Japan. Their assessment, which included destructive analysis by the IC component manufacturer, determined that the IC's flash memory was damaged possibly due to high current produced by abnormal electric fields. In November 2010 Denso produced a report which is attached below as Appendix A.

3.0 APM Sensor Failure

3.1 Vehicle Detail

MY 2007 Toyota Camry XLE w/V6 2GR-FE engine (Vehicle 12C). The vehicle was the subject of NHTSA Vehicle Owner Questionnaire ODI number 10319201[5]

3.2 Description of Testing and Failure

In July and August 2010 the EMC team began evaluating observations made by Dr. Todd Hubing of Clemson University as discussed in a July 2010 presentation to the Electronic Vehicle Controls and Unintended Acceleration committee of the National Academy of Sciences[6]. Dr Hubing studied the effects of RF currents coupled to sensor wiring of the accelerator pedal mechanism (APM) that could, at certain frequencies and power levels, cause the engine to accelerate without driver input. Dr Hubing did not provide evidence of a mechanism, or that such effects were actually occurring in the consumer's use of the vehicle, hence the effects are considered only theoretical in nature. Dr. Hubing's work, including the frequencies and power levels used, formed the basis of evaluation conducted by the EMC team.

The APMs used in Toyota's Electronic Throttle Control System have both a primary and a (redundant) secondary accelerator pedal position sensing device that is referred to as an APP sensor, or just an APP. Each sensor circuit has connections for a power line, a return line (ground), and an output signal line, so six wires are used to connect the APP directly to the ECM[7]. Two technologies were used for the APP sensors; potentiometer based sensors[8] were

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[5] A public copy of the report is available at http://www-odi.nhtsa.dot.gov/complaints/.
[6] The presentation is available at http://onlinepubs.trb.org/onlinepubs/ua/100701hubing.pdf; slide 17 discusses specific testing that was evaluated.
[7] Further technical details of the APP sensor, wiring, and signal characteristics can be found in the main NASA and NHTSA reports available at http://www.nhtsa.gov/UA.

used on MY 2002 to 2006 while Hall Effect (HE) based sensors were used on MY 2007 and later[9]. The Camry HE APP assemblies were manufactured by two suppliers, CTS and Denso[10].

For these tests an inductive coupler was used to introduce RF signals into the APP wiring. The coupler can encircle one or more APP wires and then inject RF energy inductively, i.e., without electrically contacting the wire(s). In testing conducted by the team, the Denso HE based APP exhibited a characteristic that was not observed while testing the other APP type. Specifically, when certain APP wires were encircled by an inductive coupler[11], and exposed to specific frequency and power levels, the engine speed would increase without APM movement. NHTSA notes that it is unaware of any real-world evidence indicating that this characteristics has occurred in service, however it could result in UA if it were to somehow occur.

In the testing conducted on the Denso HE APM, engine speed increases could be observed when the two power supply wires, or the two signal output wires, or the signal output and power wires together were exposed to RF energy via the inductive couple. For instance, in one test conducted at 100 kHz and 100 dB-micro-amps of power, an increase in the APP output signals was observed leading to a throttle opening (without APM application). The testing showed that this outcome only occurs if two or four of the six wires (power and/or signal) in the APM wire bundle are exposed to RF energy[12]; if all six leads are exposed to RF energy together, then no effects are noted. Additionally no such effects were seen for the testing conducted on potentiometer-based or CTS supplied HE APMs.

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[8] Potentiometer sensors utilize a mechanical contact device, known as a wiper that moves against a resistive element electrically situated between the 5 V_{DC} rail and ground. These sensors have high output impedance.
[9] HE sensors are non-contacting devices that improve durability and have low impedance output characteristics.
[10] The CTS pedal makes use of a HE IC manufactured by Melexis, while the Denso pedal uses a Micronas device.
[11] No engine speed change occurs if all of the APP wires are encircled by the inductive coupler.
[12] Note that certain aftermarket devices (e.g. cruise control systems, remote start devices) that connect directly to the APP power or output signals may provide a pathway for EMI into the APM circuitry.

During a portion of the Denso APM testing which involved RF exposure of the two signal return lines only, damage to the sensor occurred and there was a loss of signal output. In this situation a DTC was set, the engine returned to the idle state, and application of the accelerator pedal had no effect on engine speed. Two Denso APMs that failed in this manner were subsequently returned to Denso for analysis. Denso's October 2010 analysis reports for each failed APM, which showed that a bonding lead for the sensor return circuit had been damaged through electrical overstress, are included as Appendix B and C below.

<u>Appendix A:</u> Denso Investigation Final Report on IC Failure Date November 5, 2010

DENSO

5,Nov,2010

TO : DENSO MANUFACTURING TENNESSEE
ELECTRONIC DIVISION QA
FROM : DENSO CORPORATION
ELECTRONICS QA

INVESTIGATION FINAL REPORT

CC. DNJP:ELECTRONICS ENG.DEPT.1 DESIGN SECT.1
ELECTRONICS QA DEPT. PRODUCT QA CENTER 1
QUALITY CONTROL DEPT.

ELECTRONICS QUALITY ASSURANCE DEPT.
PURCHASED PARTS QA

WRITTEN BY Ken Kasahara 5/Nov/2010
Kenji Kasahara

CHECKED BY
Hiroyuki Tanizawa

APPROVED BY M. Soumiya 5.Nov.'10
Masao Soumiya

DENSO

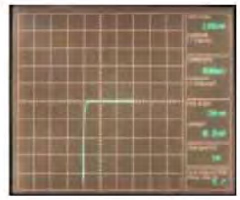
DENSO report the analysis result depend on IC supplier report .

Monitor CPU Preliminary Investigation result

(1) Component Information

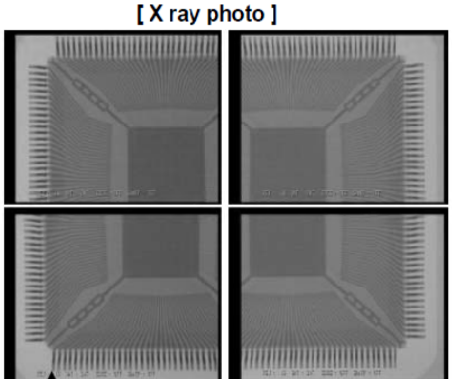
Part Name : UPD76F0004GD(a1)-24-5GD-CAR
Lot No. : 0332MX033 (Product on 2003 , week32)
Supplier name : RENESAS ELECTRONICS CORPORATION

(2) I – V characteristic check : No abnormality was observed

	VDD3,CVDD vs VSS3,CVSS	VDD5 vs VSS5	AVDD vs AVSS
Returned Sample			
Reference Sample			

(3) X-Ray Analysis : No abnormality was observed

[X ray photo]



Pin 1

(4) FLASH Memory Writing check : No abnormality was observed

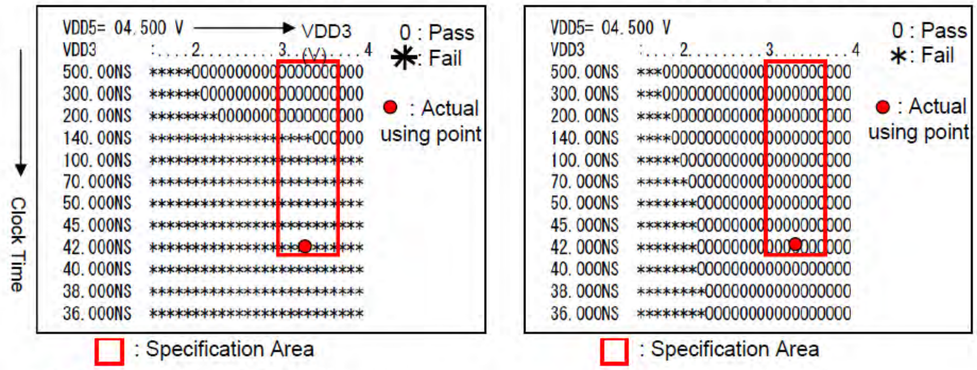
LSI tester : Can write the data correctly in FLASH Memory area

FLASH programmable tool : Can write the data correctly in FLASH Memory area

(5) FLASH Memory Reading check : Abnormality was observed

Can not read out the data from FLASH Memory at high speed frequency .
(Speed marginal failure of reading FLASH memory)

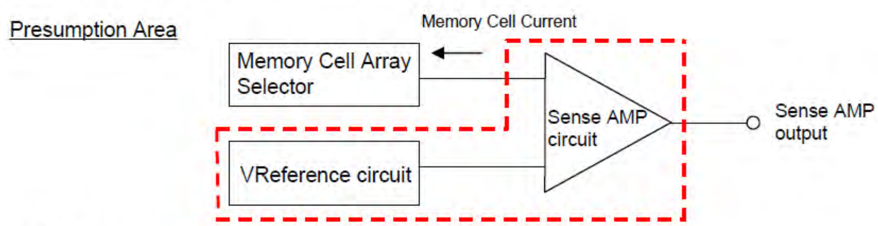
[Returned Sample] [Reference Sample]



(6) Presumption of Defective area

The supplier is presuming that there will be defective point at the circuit relating FLASH reading in FLASH macro area .

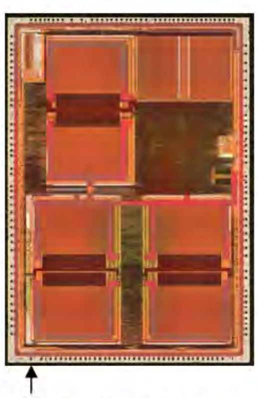
So they are going to do further analysis in this area .



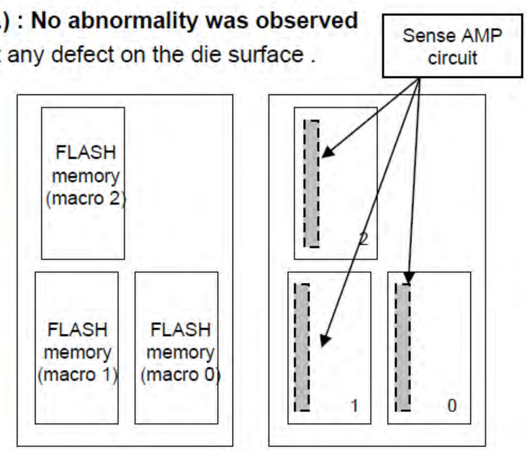
Monitor CPU Investigation result

(1) Die visual check (after decap.) : No abnormality was observed

The supplier could not detect any defect on the die surface .



Die surface



Layout

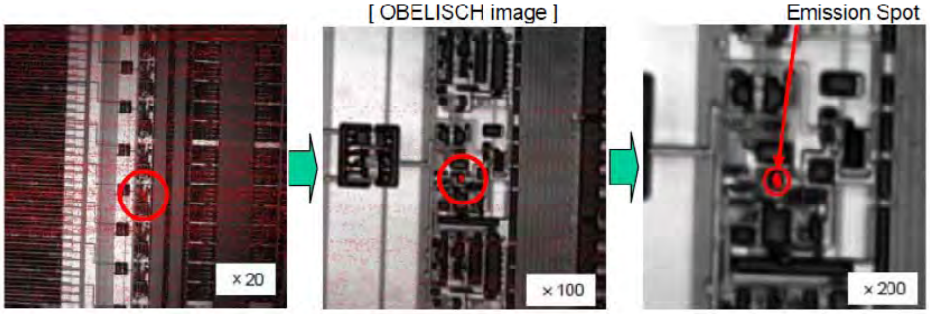
(2) OBELISCH check : Abnormality was observed

The supplier performed OBELISCH analysis at the low marginal memory cell in FLASH macro area , and confirmed the abnormal emission spot in the sense AMP circuit .

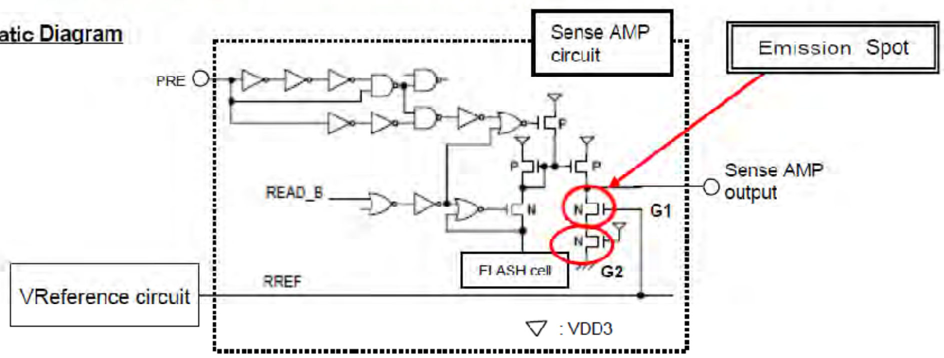
*OBELISCH (Optical Beam induced Logic State Change)

: OBELISCH is one of the analysis method that can localize the defective point by scanning IR-laser with using LSI tester & IR OBIRCH machine .

[OBELISCH image]



Schematic Diagram



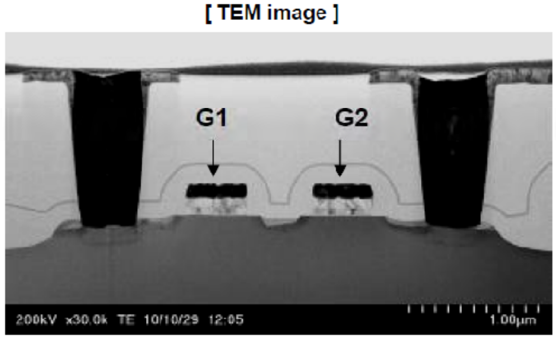
(3) TEM check : Abnormality was observed

The supplier performed TEM analysis at the above emission point (N-ch Transistor) , and confirmed the abnormality (delamination & Void) .

*TEM (Transmission Electron Microscope)

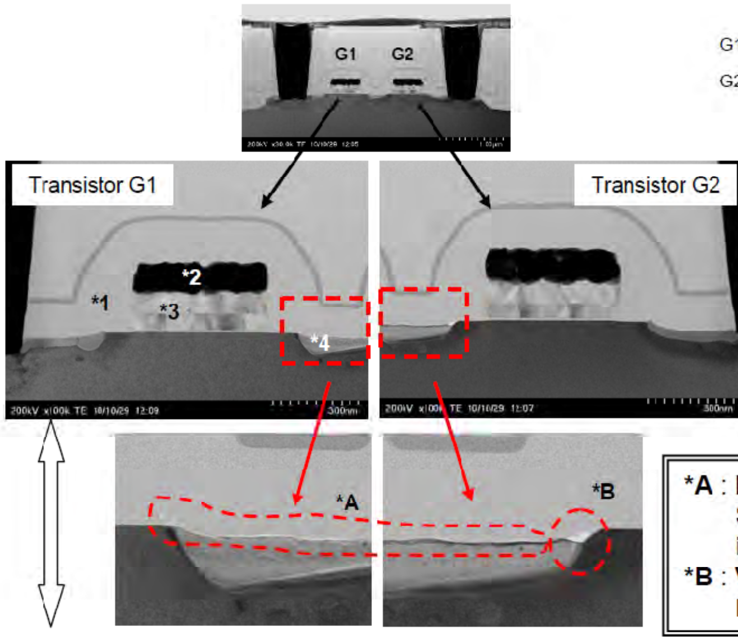
: TEM is a microscopy technique whereby a beam of electrons is transmitted through an ultra thin specimen , interacting with the specimen as it passes through .

[TEM image]



DENSO

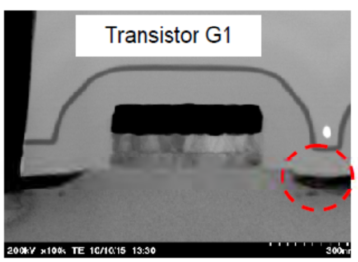
[Returned Sample]



*1 : Interlayer insulator
*2 : Gate silicide (WSi)
*3 : Gate electrode (Poly Si)
*4 : Silicide (TiSi)

***A : Delamination between Silicide and Interlayer insulator**
***B : Void (Ti-ion was moved by heat)**

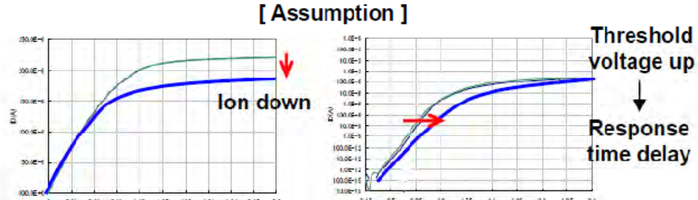
[Reference Sample]



No Delamination , Void

Above physical analysis revealed that the resistive impedance between G1 drain and G2 source goes up and it introduced malfunction of FLASH memory reading at high frequency .

[Assumption]

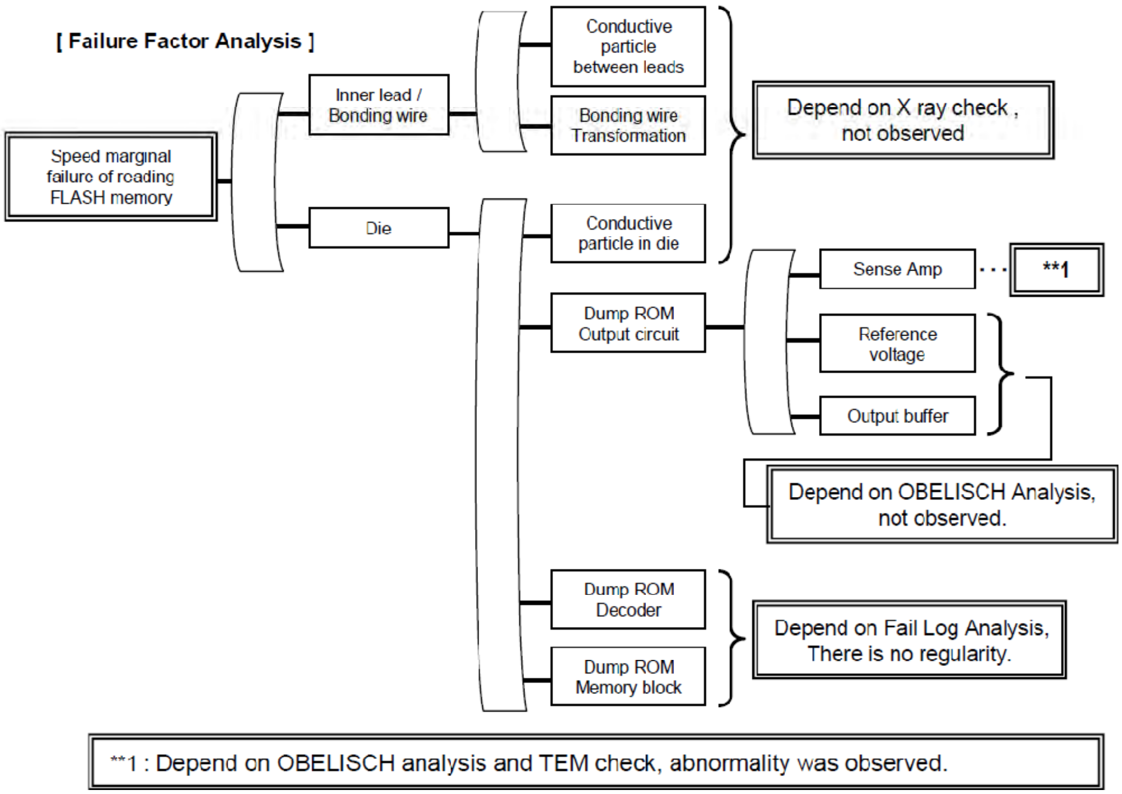


VD-ID characteristic VG-ID characteristic

The supplier assumed that the electrical characteristics of this transistor should be changed , for example , Ion current should be smaller and threshold voltage should be higher than normal .

DENSO

(4) FTA (Failure Tree Analysis)



(5) Conclusion

The supplier found defective points of die, and these were sense Amp circuit N-ch MOSs (G1 & G2).

These points had delamination and voids, and became high resistive characteristic.

This high resistive characteristic of these transistors can explain the malfunction of FLASH memory reading at high speed frequency.

The supplier could not find manufacturing fault .

It is assumed that this abnormality occurred for the reason of the following.

・A high current flowed into the sense AMP circuit under the abnormal electric field, and overheated.

・The delamination and voids occurred.

Appendix B: Denso Investigation Final Report on APM Sensor Failure (production date 01M21) Dated October 20, 2010

Final report

TO:National Highway Traffic Safety Administration

SENSOR ASSEMBLY, ACCELERATOR PEDAL

INVESTIGATION REPORT

Part Name: **SENSOR ASSY, ACCELERATOR PEDAL**

Customer Part Number: **78110-33020 （DN:198800-7190）**

Investigation part No.2 (Production date : 01M21)

DENSO CORPORATION SYSTEM CONTROL COMPONENTS ENG DEPT3.	
Checked	N.Kihara K.Horie H.Suzuki
Approved	T.Hamaoka

ISSUE DATE:
20.Oct.2010

DENSO CORPORATION SYSTEM CONTROL COMPONENTS QA DEPT4.	
Written	T.Kobayasi
Checked	S.Nakano
Checked	K.Kato
Approved	T.Sakai

1. Investigation parts Data

No.	Customer.P/N	Denso .P/N	Production date (DENSO)	Content
2	78110-33020	198800-7190	21.Jan.2010 (01M21)	APM Component failures during NHTSA testing.

2. SENSOR ASSY, ACCELERATOR PEDAL Investigation Result

Item	Result	Page
1) Appearance	No abnormality is found.	3/10
2) Operation feeling check	No abnormality is found.	3/10
3) Performance	Abnormalities are observed in Vpa1 and Vpa2 other than the pedal effort.	3/10
4) Output waveform	Abnormalities are observed in Vpa1 and Vpa2.	4/10
5) Pedal effort	No abnormality is found.	4/10
6) X-ray	Abnormal IC is confirmed.	5/10
7) Disassembly	We can see that it smells melting resin.(Sensor cover IC section)	5/10
8) IC Investigation	A broken wire bonding is found.	6/10,7/10

3. Conclusion

Investigation part No.2 (01M21)

As a result of the investigation, we found abnormalities in the electrical characteristics other than the pedal effort. During disassembly check, we identified the cause of the defect, based on the results of the broken IC wire bonding and the IC replacement check.

The broken IC wire bonding caused an abnormality in the electrical characteristics.

Therefore we asked the IC supplier (overseas maker) for analysis.

We have never experienced the IC wire bonding failure in the SENSOR ASSY, ACCELERATOR PEDAL before. We would appreciate it if you could let us know your test conditions.

<Results of the investigation carried out by the IC supplier>
Through the investigation, at both VPA 1 and VPA2, we identified the wire bonding molten which are used to make interconnections between IC and terminals.
We identified molten metal wires (Al) and the discoloration at several areas including bond pads.
Therefore we came to a conclusion that excessive electrical overstress was applied to the IC through the external sources. The electrical overstress (EOS) may have caused the IC to break.

1) Appearance

Overall figure	Base side
	
No significant scratches and deformation are found in the sensor and pedal rod part.	No significant scratches and deformation are found.

Connector	Vehicle installation side	A view
		
No significant scratches and deformation are found.	No significant scratches and deformation are found.	No foreign material contamination is found.

2) Operation feeling check

<Method>Step 1 : The returned part is clamped with bolts to a jig.

Step 2 : The pedal is repeatedly moved to the full-open position from the full-close position by hand.

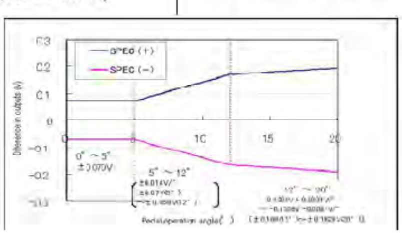
<Result> ・ The pedal is moved smoothly.

3) Performance at room temperature:

・We found abnormalities in the electric characteristics (Vpa1 and Vpa2) other than the pedal effort.

ITEMS			SPEC	RESULT (at RT) Vpa1	RESULT (at RT) Vpa2	JUDGMENT
OUTPUT VOLTAGE AT FULL-CLOSE		Vpa1	0.75～0.89V	0.065		NG
REPRODUCIBILITY OF OUTPUT VOLTAGE AT FULL-CLOSE			±0.040V	-	-	NG
OUTPUT VOLTAGE RISING POINT (Vpa1)			0.29°+0.50/-0.16°	5.000		NG
LINEARITY OF OUTPUT VOLTAGE (LINEARITY AT 25±10℃)		θ₁°～2°	±0.040V	0.000	0.000	NG
		2°～4°	±0.060V	0.000	0.000	NG
		4°～10°	±0.120V	-0.745	-0.745	NG
		10°～15.9°	±0.135V	-1.624	-1.624	NG
DIFFERENCE IN OUTPUTS (25±10℃) See Fig-1		0°～5°	Fig-1	-0.69		NG
		5°～12°		-0.692		NG
		12°～20°		-0.709		NG
PEDAL EFFORT	TO FULL-CLOSE (at 1.55°)	PRESSING	±30% OF INITIAL VALUE (N・m) (SPEC：14.0～25.9N・m)	4.7% (Initial:20.0N Investigation parts:20.9N)		OK
		RELEASING	±30% OF INITIAL VALUE (N・m) (SPEC：5.3～9.9N・m)	-7.9% (Initial:7.6N Investigation parts:7.0N)		OK
	TO FULL-OPEN (at 15.9°)	PRESSING	±30% OF INITIAL VALUE (N・m) (SPEC：22.5～41.7N・m)	7.5% (Initial:32.1N Investigation parts:34.5N)		OK

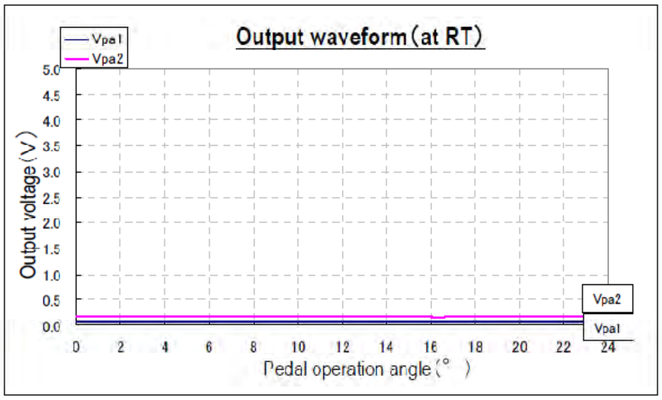
Fig-1：DIFFERENCE IN OUTPUTS



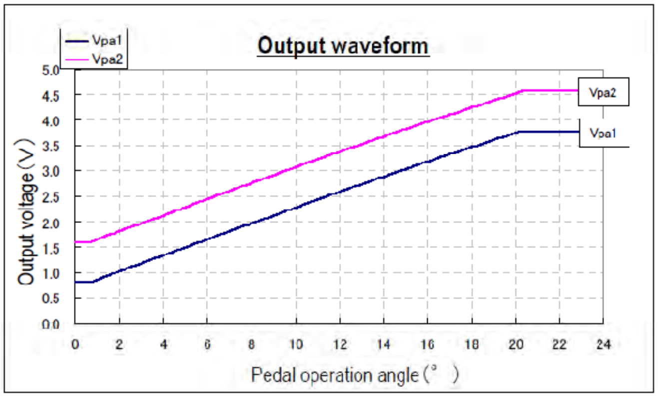
4) Output waveform

・**Abnormalities are observed in Vpa1 and Vpa2.**

Waveform of
the investigated part



OK waveform

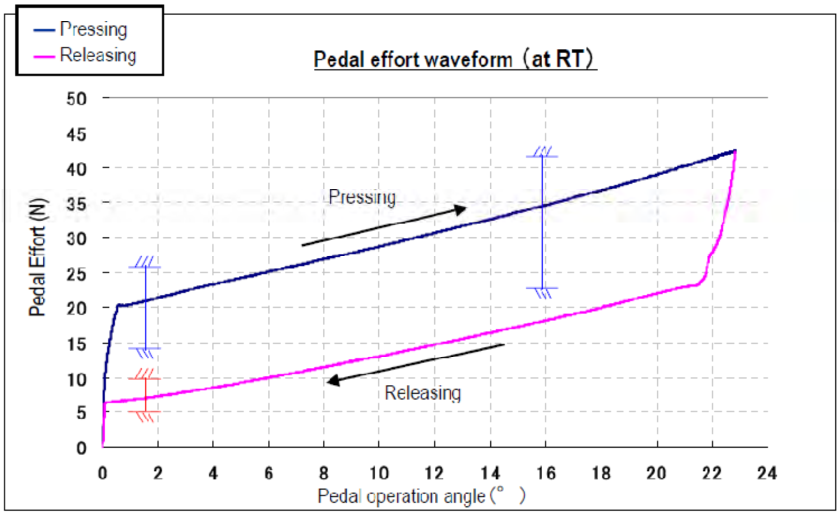


5) Pedal effort waveform

・We cannot find any sticks in the pedal opening angle.

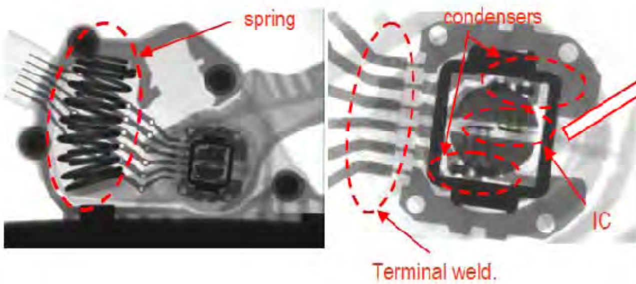
・We cannot find any abnormalities in the pedal effort waveform.

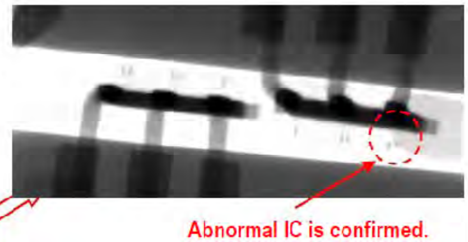
・We cannot find any symptoms that lead to a defect.

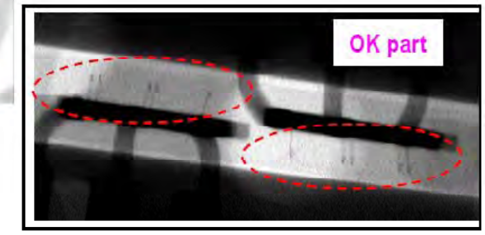


6) X-ray

- No abnormality was found in the internal assembling conditions.
- No abnormality was found in the capacitor assembling conditions.
- **Abnormal IC is confirmed.**







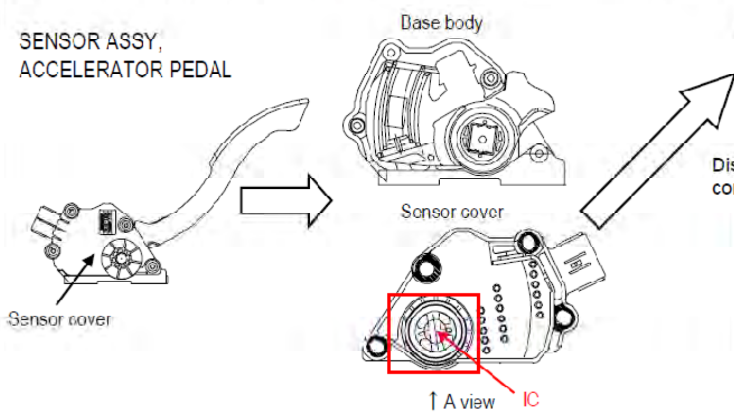
7) Disassembly

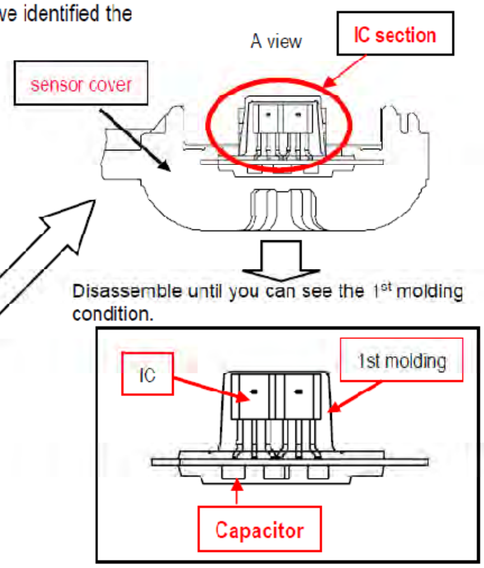
Internal View	Pedal SUB-ASSY	Rotor pedal	Washer friction
			
No abnormality was found in the internal assembling conditions. No foreign material contamination was found.			
Shaft part			
Sensor cover 			
We can see that it smells melting resin	Cracks were not found in the internal component parts.		

8) IC Investigation

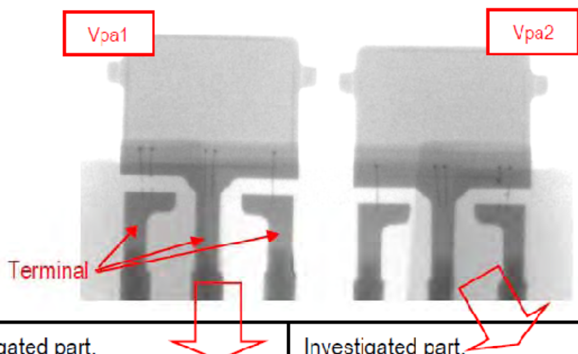
We had our full attention on the IC when investigating the part because we identified the abnormality in the IC during X ray check.

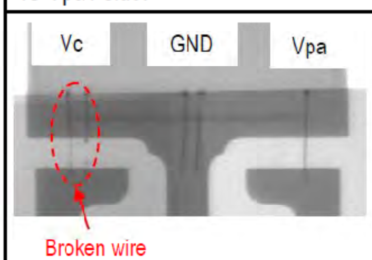
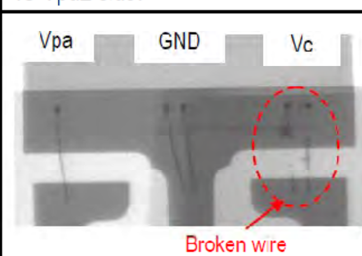
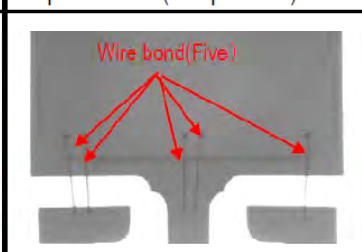
①Disassembly check
(Disassemble the part until you can see the 1st molding condition)





②X ray check for the 1st molding condition.
The wire bonding was broken.

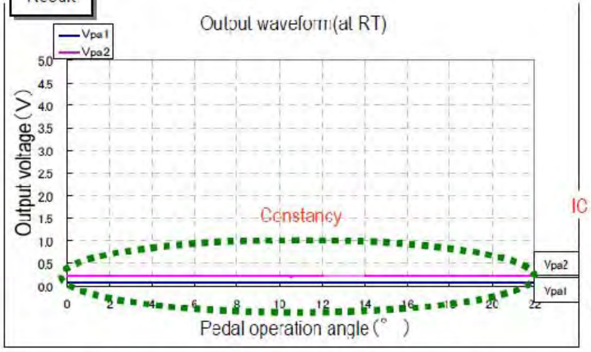


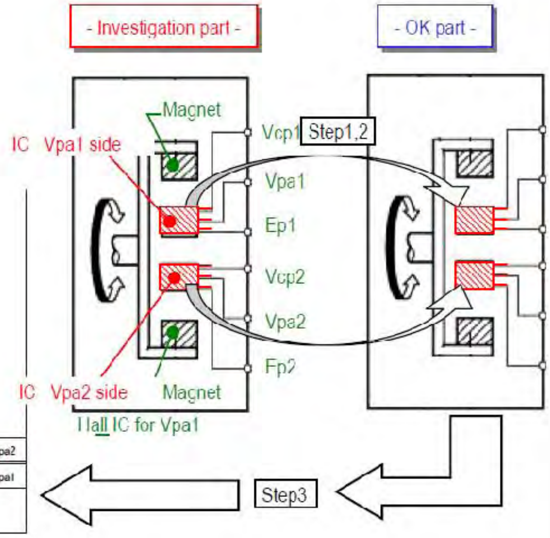
Investigated part. IC Vpa1 side.	Investigated part. IC Vpa2 side.	OK part. Representative(IC Vpa1 side)
		
Terminal Vc: **The wire bonding is broken.**	Terminal Vc: **The wire bonding is broken.**	No abnormality is found.

③IC replacement check

< Procedure >
Step1 : Pull out the Vpa1,Vpa2 IC from investigation part.
Step2 : Install each IC onto an OK part.
Step3 : Measure an output voltage.

Result





Abnormalities are observed in Vpa1 and Vpa2.

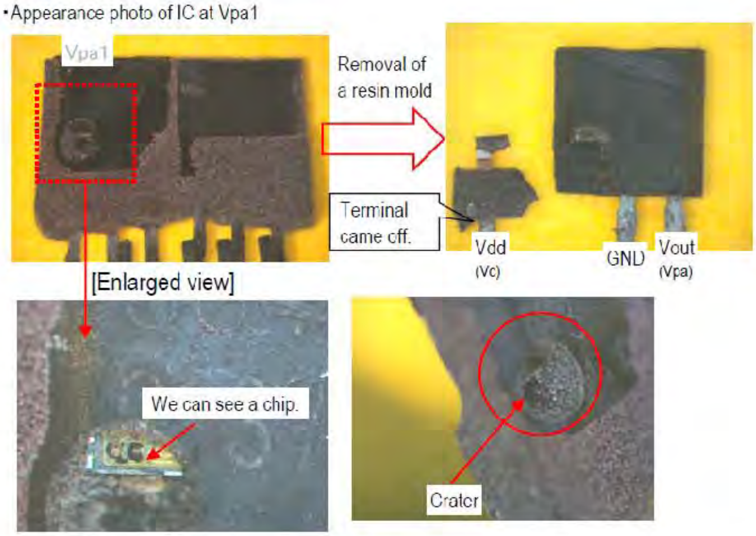
IC(Vpa1/Vpa2): Abnormalities were found in Vpa1 and Vpa2 .

4. Contents of this report

<Results of the investigation carried out by the IC supplier>

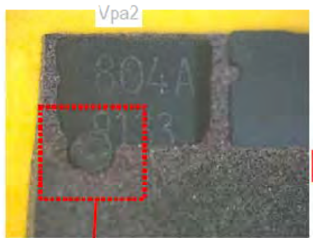
4-1 External Visual Inspection

・Appearance photo of IC at Vpa1



・When removing a resin mold, Vdd terminal came off.
・To the extent that we can see the chip inside, a crater (molten material) in the package near Vdd was found.

・Appearance photo of IC at Vpa2



Removal of a resin mold

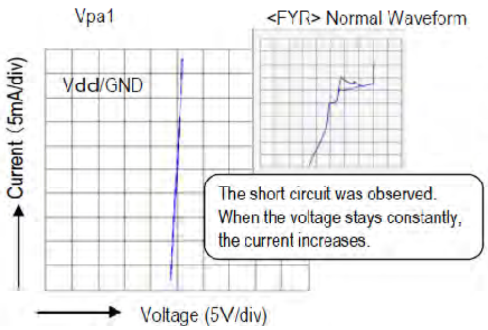
Enlarged view

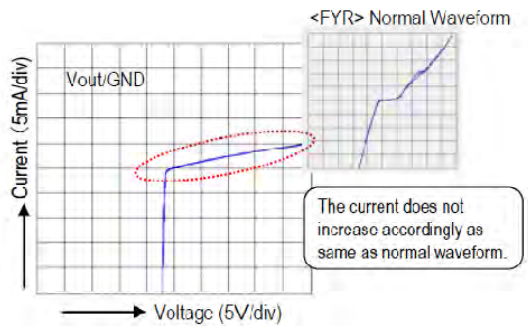
A crater caused by molten package materials was observed near Vdd at the IC package.

4-2 Curve Tracing

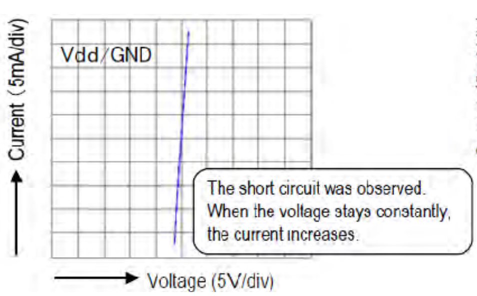
The characteristics of carve tracing are no good for Vpa1 and Vpa2.

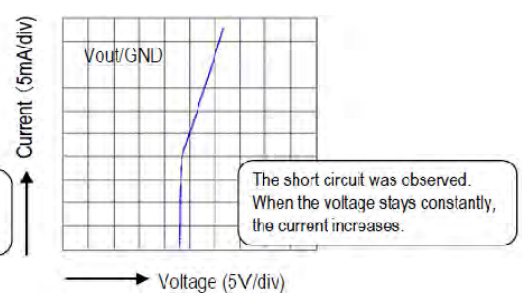
Vpa1





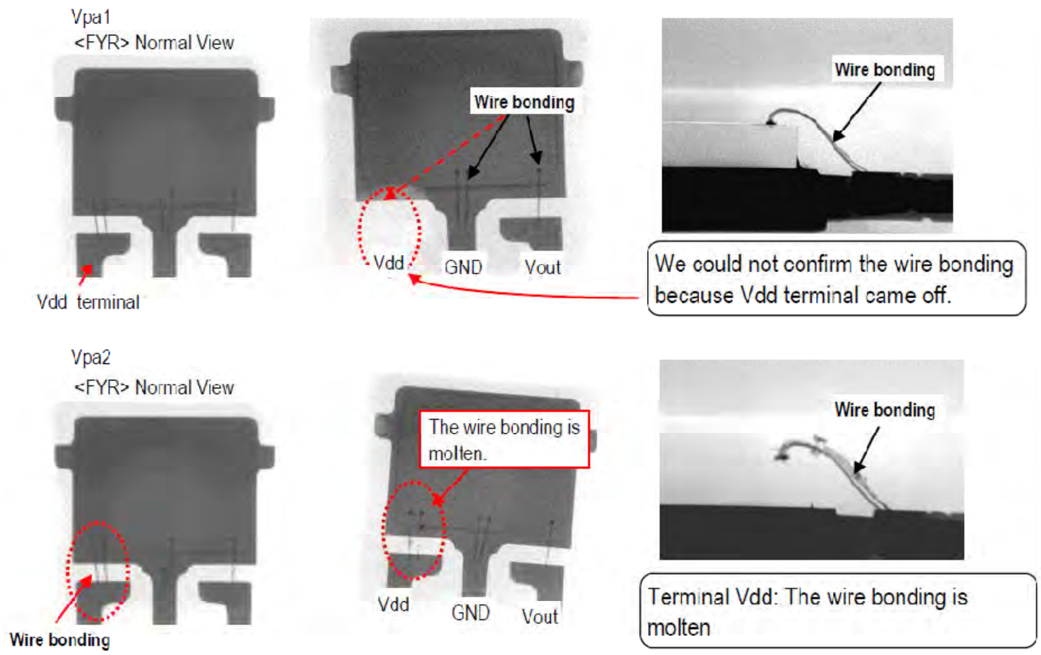
Vpa2





* Abnormalities were found in the electrical characteristics. (Vpa1 and Vpa2)

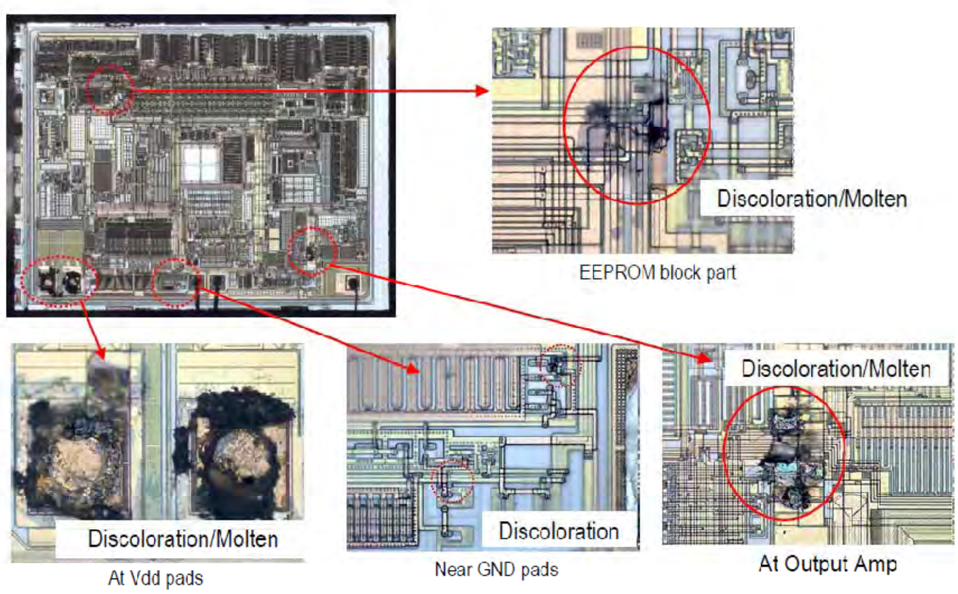
4-3 X-ray Inspection



4-4 Disassembly Check (Dissolve the IC package resin with a chemical solution.)

(a) Internal visual inspection (Surface of an IC chip)

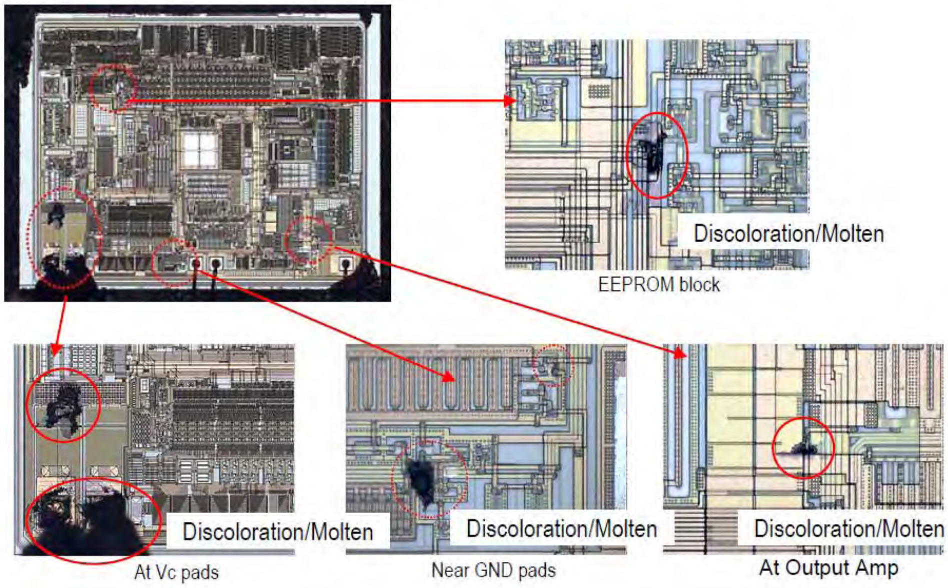
Vpa1



We identified the discoloration and molten near Vdd pads, GND pads, Output Amp and EPROM block.

(a) Internal visual inspection (Surface of an IC chip)

Vpa2



We identified the discoloration and molten near Vdd pads, GND pads, Output Amp and EPROM block.

4-5 : Remarks

Through the investigation, at both VPA 1 and VPA2, we identified the wire bonding molten which are used to make interconnections between IC and terminals.
We identified molten metal wires (Al) and the discoloration at several areas including bond pads.
Therefore we came to a conclusion that excessive electrical overstress was applied to the IC through the external sources. The electrical overstress (EOS) may have caused the IC to break.

Appendix C: Denso Investigation Final Report on APM Sensor Failure (production date 03H20) Dated October 20, 2010

Final report

TO:National Highway Traffic Safety Administration

SENSOR ASSEMBLY, ACCELERATOR PEDAL
INVESTIGATION REPORT

Part Name: **SENSOR ASSY, ACCELERATOR PEDAL**

Customer Part Number: **78110-33020 （DN:198800-7190）**

Investigation part No.1(Production date : 03H20)

DENSO CORPORATION SYSTEM CONTROL COMPONENTS ENG DEPT3.	
Checked	N.Kihara K.Horie H.Suzuki
Approved	T.Hamaoka

ISSUE DATE:
20. Oct.2010

DENSO CORPORATION SYSTEM CONTROL COMPONENTS QA DEPT4.	
Written	T.Kobayasi
Checked	S.Nakano
Checked	K.Kato
Approved	T.Sakai

1. Details of investigation part

No.	Customer.P/N	Denso .P/N	Production date (DENSO)	Content
1	78110 33020	198800 7190	20.Mar.2006 (03H20)	APM Component failures during NHTSA testing.

2. SENSOR ASSY, ACCELERATOR PEDAL Investigation Result

Item	Result	Page
1) Appearance	*Connector crack is confirmed.	3/7
2) Operation feeling check	No abnormality is found.	3/7
3) Performance	Abnormalities are observed in Vpa1 and Vpa2 other than the pedal effort.	3/7
4) Output waveform	Abnormalities are observed in Vpa1 and Vpa2.	4/7
5) Pedal effort	No abnormality is found.	4/7
6) X-ray	Abnormal IC is confirmed.	5/7
7) Disassembly	The resin has melted. (Sensor cover IC section)	5/7
8) IC Investigation	A broken wire bonding is found.	6/7

*Connector crack

The appearance and the performance are 100% checked so it is possible to detect nicks and cracks in our production process.
As a result of the investigation, we presumed that the deformation occurred after shipping from our plant.

3. Conclusion

Investigation part No.1 (03H20)

As a result of the investigation, we found abnormalities in the electrical characteristics other than the pedal effort.
During disassembly check, we found that the wire bonding in the IC got cut off.

The broken IC wire bonding caused an abnormality in the electrical characteristics.

Therefore we asked the IC supplier (overseas maker) for analysis.

We have never experienced the IC wire bonding failure in the SENSOR ASSY, ACCELERATOR PEDAL before.
We would appreciate it if you could let us know your test conditions.

<Results of investigation carried out by IC supplier >
Si chip of Vpa1 came off when disassembling, Si chip got stuck in the molded resin part. We cannot continue to carry out further investigation. However, we confirmed the discoloration of the Vpa2 platform. Therefore we came to a conclusion that excessive electrical overstress was applied to the IC through the external sources. The electrical overstress (EOS) may have caused the IC to break.

1) Appearance

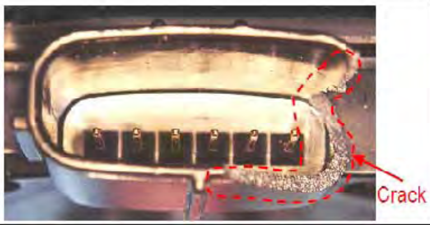
Overall figure

No significant scratches and deformation are found in the sensor and pedal rod part.

Base side

No significant scratches and deformation are found

Connector



Cracks are found.

Vehicle installation side

No significant scratches and deformation are found.

A view

No foreign material contamination is found.

2) Operation feeling check

<Method>Step 1 : The returned part is clamped with bolts to a jig.

Step 2 : The pedal is repeatedly moved to the full-open position from the full-close position by hand.

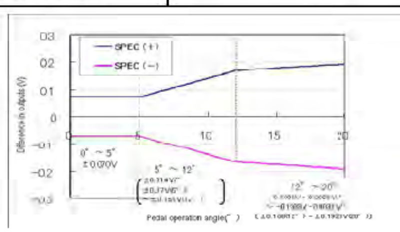
<Result> ・The pedal is moved smoothly. A sticking pedal is not found.

3) Performance at room temperature:

・We found abnormalities in the electric characteristics (Vpa1 and Vpa2) other than the pedal effort.

ITEMS			SPEC	RESULT(at RT) Vpa1	Vpa2	JUDGMENT
OUTPUT VOLTAGE AT FULL-CLOSE		Vpa1	0.75～0.89V	0.031		NG
REPRODUCIBILITY OF OUT VOLTAGE AT FULL-CLOSE			±0.040V	-	-	NG
OUTPUT VOLTAGE RISING POINT (Vpa1)			0.29°+0.50/-0.16°	5.000		NG
LINEARITY OF OUTPUT VOLTAGE (LINEARITY AT 25±10℃)		θ_1°～2°	±0.040V	0.000	0.000	NG
		2°～4°	±0.060V	0.000	0.000	NG
		4°～10°	±0.120V	-0.745	-0.745	NG
		10°～15.9°	±0.135V	-1.621	-1.609	NG
DIFFERENCE IN OUTPUTS (25±10℃) See. Fig-1		0°～5°	Fig-1	-0.617		NG
		5°～12°		-0.619		NG
		12°～20°		-0.617		NG
PEDAL EFFORT	TO FULL -CLOSE (at 1.55°)	PRESSING	±30% OF INITIAL VALUE(N・m) (SPEC ;14.0～25.9N・m)	-0.7% (Initial:19.9N Investigation parts:19.8N)		OK
		RELEASING	±30% OF INITIAL VALUE(N・m) (SPEC ;6.1～11.3N・m)	-12.6% (Initial:8.7N Investigation parts:7.6N)		OK
	TO FULL OPEN (at 15.9°)	PRESSING	±30% OF INITIAL VALUE(N・m) (SPEC ;23.0～42.8N・m)	-1.9% (Initial:32.9N Investigation parts:32.3N)		OK

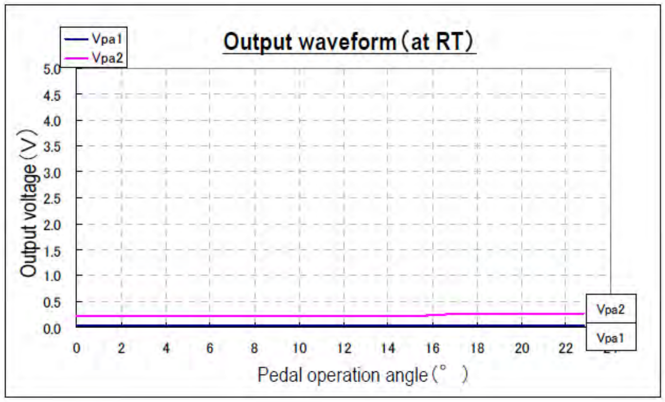
Fig-1 : DIFFERENCE IN OUTPUTS



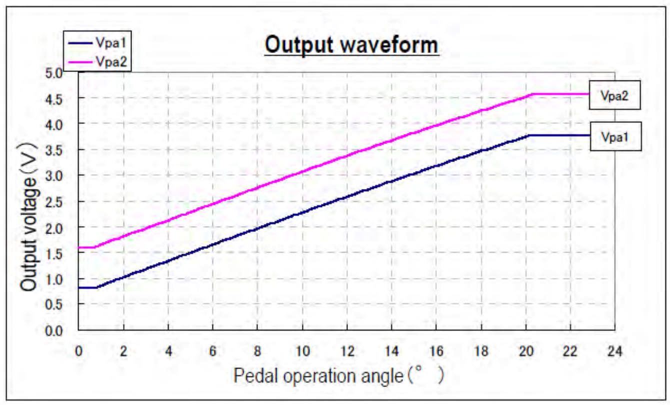
4) Output waveform

・Abnormalities are observed in Vpa1 and Vpa2.

Waveform of the investigated part



OK waveform

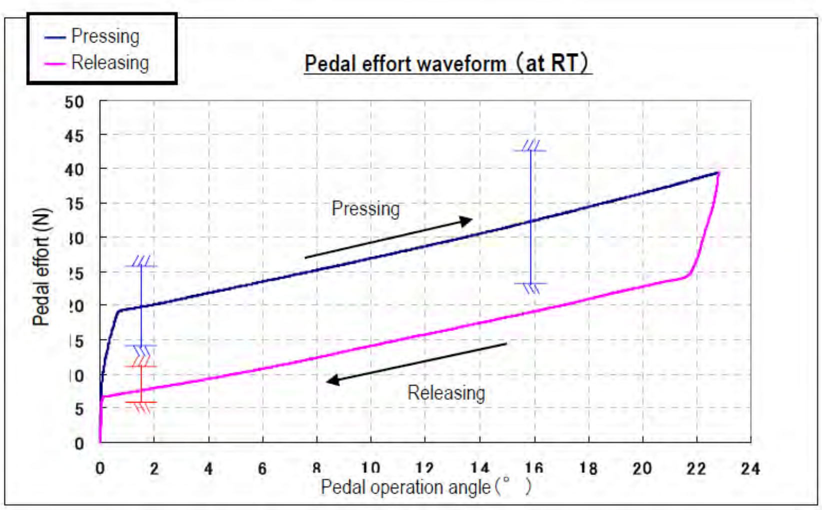


5) Pedal effort waveform

・We cannot find any sticks in the pedal opening angle.

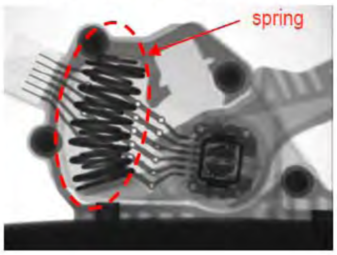
・We cannot find any abnormalities in the pedal effort waveform.

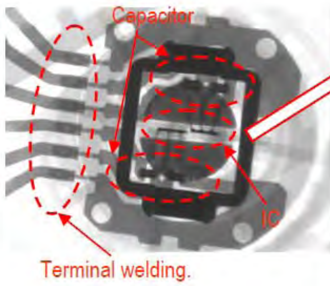
・We cannot find any symptoms that lead to a defect.

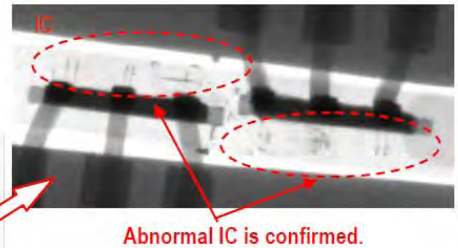


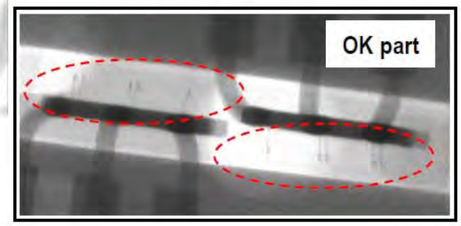
6) X-ray

- No abnormality was found in the internal assembling conditions.
- No abnormality was found in the capacitor assembling conditions.
- **Abnormal IC is confirmed.**



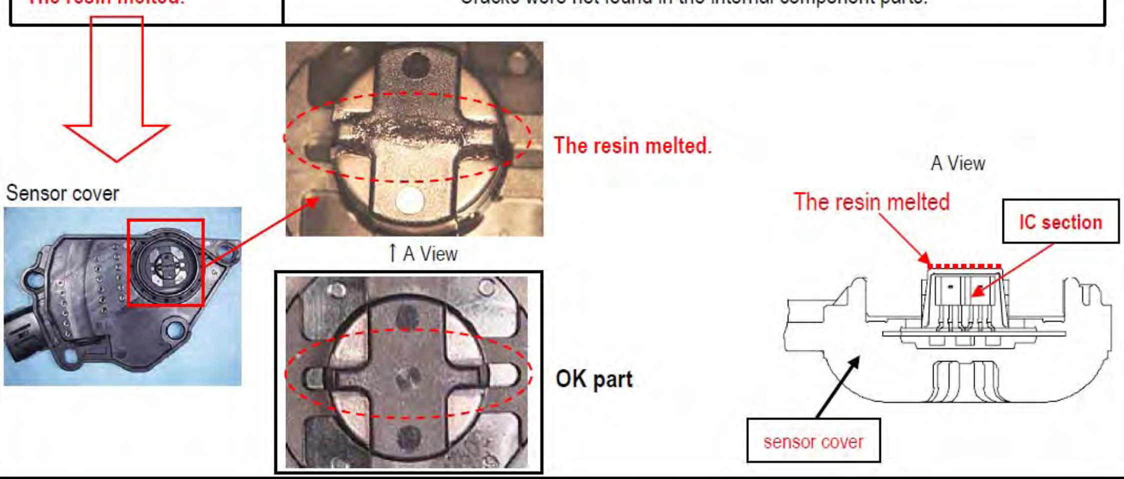






7) Disassembly check

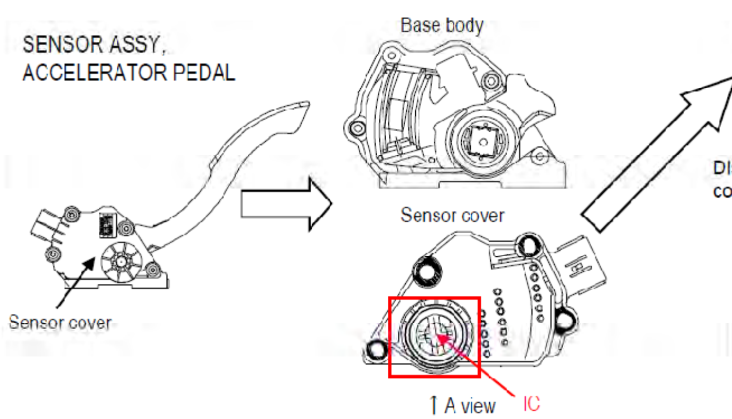
Internal View	Pedal SUB-ASSY	Rotor pedal	Washer friction
			
No abnormality was found in the internal assembling conditions. No foreign material contamination was found.			
Shaft part			
			
The resin melted.	Cracks were not found in the internal component parts.		

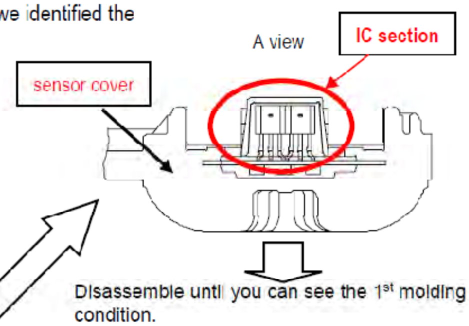


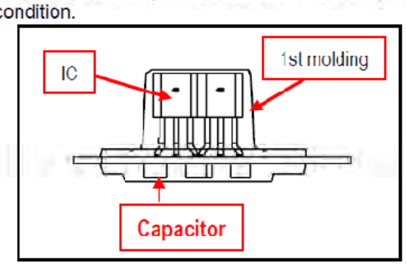
8) IC Investigation

We had our full attention on the IC when investigating the part because we identified the abnormality in the IC during X ray check.

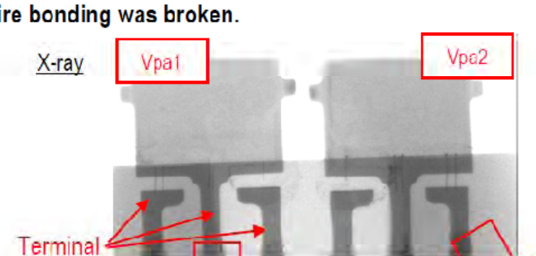
①Disassembly check
(Disassemble the part until you can see the 1st molding condition)

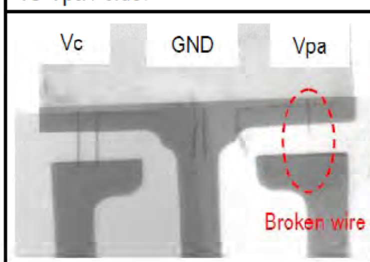
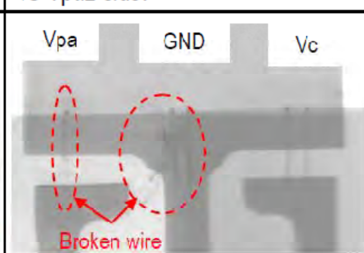
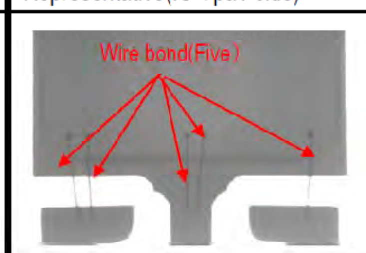






②X ray check for the 1st molding condition.
The wire bonding was broken.



Investigated part. IC Vpa1 side.	Investigated part. IC Vpa2 side.	OK part. Representative(IC Vpa1 side)
		
Terminal Vpa: **The wire bonding is broken.**	Terminal Vpa and GND: **The wire bonding is broken.**	No abnormality is found.

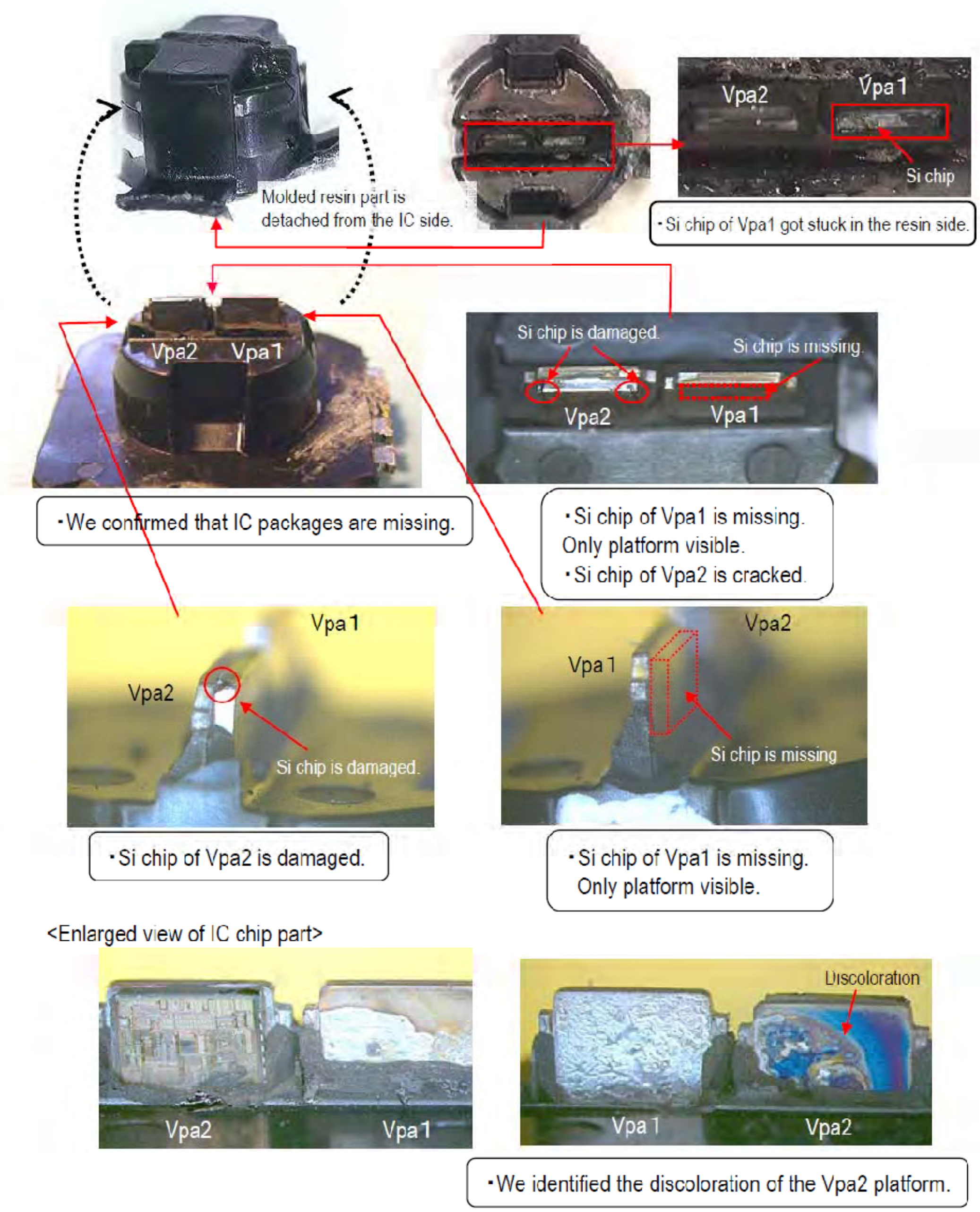
IC(Vpa1/Vpa2): Abnormalities were found in Vpa1 and Vpa2 . ⇨ We asked the IC maker to investigate it.

We usually check if the abnormality is reproduced after swapping the abnormal IC for the OK cover. However, we found out that the resin melted on the surface of the sensor cover. therefore, we did not perform "IC replacement check" this time.

4. Contents of this report

<Results of investigation carried out by IC supplier >

4-1 External Visual Inspection



4-2 Summary

Si chip of Vpa1 came off when disassembling, Si chip got stuck in the molded resin part. We cannot continue to carry out further investigation. However, we confirmed the discoloration of the Vpa2 platform. Therefore we came to a conclusion that excessive electrical overstress was applied to the IC through the external sources. The electrical overstress (EOS) may have caused the IC to break.