X-ray Inspection and Radiation Effect

Inspection with minimizing dose damage

This material describes how to perform X-ray inspection of semiconductor devices with minimizing dose damage in failure analysis.

Contents

1. Background

X-ray inspection is a non-destructive analysis which can inspect internal object without any physical damage. However, X-ray irradiation causes electric damage on semiconductor devices by the energy transition from X-ray to an exposed device. The electric damage results in electrical characteristics shift of an exposed device. It also affects the data when the device has a non-volatile memory. Usually, the risk of electric damage is low in X-ray inspection performed as a quick quality check in manufacturing because of controlled radiation conditions. On the other hand, in failure analysis, electrical characteristics shift occurs due to absorbing high dose amount when careful analysis is performed.

2. Total dose

The energy which an object receives from X-ray is defined as absorbed dose. Gray (Gy) is the unit of total absorbed dose amount. The difference of electrical characteristics before and after X-ray irradiation is small at low dose. However, electrical characteristics shift at sufficient dose. What is important is to recognize the risk of electrical characteristics shift of devices when you perform X-ray inspection. It is generally expected that the total dose for semiconductor devices which are not designed as a radiation hardened product, except for some specific products which are individually guided, less than 1 Gy to avoid failure induced by dose damage.

3. Recommendations

Minimizing total dose damage is crucial to avoid electrical characteristics shift when you perform X-ray inspection. The following describes the recommended practices. The relation between the X-ray inspection conditions and the dose depends on the equipment. It is recommended to evaluate it by using each equipment.

3.1 X-ray intensity

X-ray intensity from X-ray source is determined by X-ray tube voltage and X-ray tube current. The dose rate varies as the square of tube voltage and in proportion to tube current. Setting lower conditions within the range that can provide good X-ray image is effective to reduce dose damage. Since the relation between the conditions and the quality of X-ray image depends on X-ray inspection equipment, an evaluation to find the best conditions is recommended by using each equipment.

3.2 Magnification

Increasing the magnification decreases the distance between an X-ray source and a device. The dose rate varies with the square inverse of the distance. One example that when you increase magnification 10-fold, the dose rate become 100-fold. The lowest magnification possible is recommended to reduce the total dose damage.

3.3 Exposure time

When dose rate is constant under the fixed tube voltage, tube current, and magnification, the total dose increases with the exposure time in proportion. The shortest cumulative exposure time possible is recommended to reduce the total dose.

3.4 Metal filter

Inserting a metal filter between an X-ray source and a device is effective to reduce dose damage because it reduces X-ray intensity by absorbing soft X-ray.

3.5 Analysis plan

Electrical testing post-irradiation is recommended to find whether there are any electrical characteristics shift induced by the dose damage.

In failure analysis, devices possibly suffer dose damage by performing detail analysis like repeat X-ray inspection with varying the direction and the magnification, and X-ray 3D analysis (X-ray CT scan, computer tomograph). However, these are the effective analysis techniques to analyze structural failure. It is recommended to consider both the analysis purpose and the risk of electrical characteristics shift of a device when you perform such analysis.

Notes

1. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. We do not provide any answers to inquiries of X-ray radiation hardness of our semiconductor products and failure analysis request of a product degraded by X-ray inspection.
2. Relation of X-ray dose damage and electrical characteristics shift depends on not only a semiconductor product and X-ray inspection conditions, but also the equipment. You are responsible for evaluating X-ray irradiation effect of your analysis equipment.

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Oct 10, 2023	-	Initial release

General Precautions in the Handling of Microprocessing Unit and Microcontroller Unit Products

The following usage notes are applicable to all Microprocessing unit and Microcontroller unit products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

1. Precaution against Electrostatic Discharge (ESD)

   A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.
2. Processing at power-on

   The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.
3. Input of signal during power-off state

   Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.
4. Handling of unused pins

   Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.
5. Clock signals

   After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.
6. Voltage application waveform at input pin

   Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between V_{IL} (Max.) and V_{IH} (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between V_{IL} (Max.) and V_{IH} (Min.).
7. Prohibition of access to reserved addresses

   Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.
8. Differences between products

   Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

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