AN13412

Process for X-ray Inspection of Packaged Semiconductor Parts

Rev. 1.1 — 8 October 2021 Application note

Document information

Information	Content
Keywords	X-ray inspection
Abstract	This application note describes best practices for X-ray inspection of packaged semiconductor parts to detect manufacturing defects.

Revision history

Revision history

Rev	Date	Description
v1.1	20211008	Updates in Section 2.
v.1	20210922	Converted to latest NXP style.
v.0	20210801	Initial version

1 Introduction

This document describes the best practices for X-ray inspection.

X-rays are used for inspection of packaged semiconductor parts to detect manufacturing defects in the packaging. X-ray inspection is an invasive technique and can cause shifts in device performance. As a result, the impact of X-ray exposure needs to be controlled by considering image quality, sample orientation (relative to the incident beam), spectral filtering, collimation, dose rate, exposure time, and total dose.

2 Background

Ionizing radiation, such as X-rays, provides image contrast in the exposed material through mass attenuation and photoelectric absorption of photons. Due to this, electron-hole pairs are generated in the exposed material. At sufficiently high doses, the generated charge can be trapped in dielectrics and dielectric interfaces and can result in shifts in threshold voltages of transistors, changes in state (e.g., for SRAM and non-volatile memories), and unwanted leakage paths.

X-rays are generated when highly accelerated electrons strike a suitable target material. The choice of the target material depends on the materials that are sought to be detected in the sample under inspection. For semiconductor chips, the target material is typically tungsten. The resulting X-ray spectrum consists of two major types of radiation: bremsstrahlung (braking radiation), defined by the accelerating voltage and covering the majority of the resultant spectrum, and characteristic radiation from the source material, which depends on the electron transitions in the material.

The absorption efficiency of X-rays in a material depends on the energy of the X-rays and the chemical element. Using a filter made of a material with a higher atomic number, e.g., copper, molybdenum, or zinc, can help absorb the bremsstrahlung and reduce the number of photons in the beam and therefore, the amount of charge generated in the exposed material (see Figure 1). This reduces the risk of damage to the device.

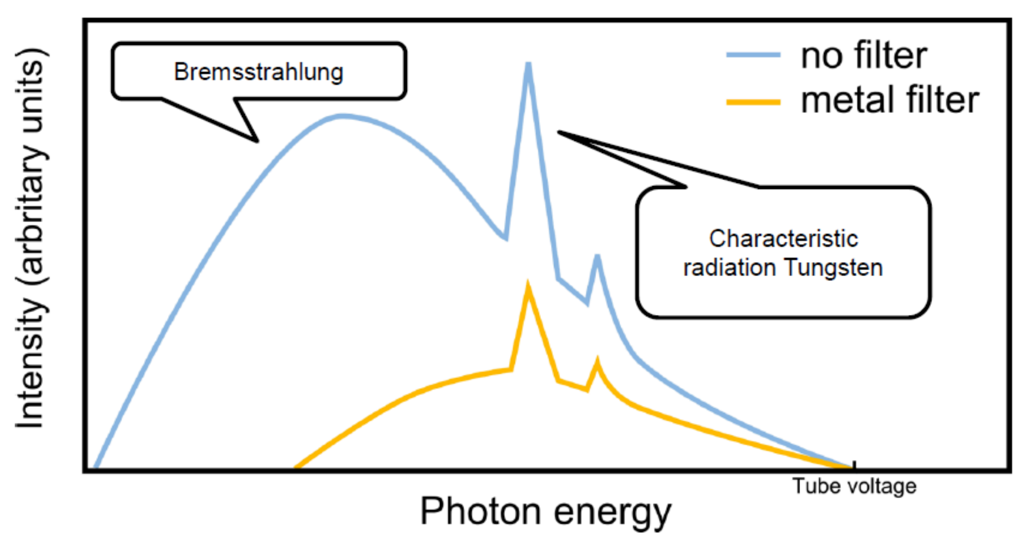

Figure 1. Typical X-ray spectrum and impact of metal filter.

3 Recommended Best Practices for X-ray Inspection

The following practices are recommended to mitigate the risks of device damage during X-ray inspection:

- Minimize total dose with the shortest possible exposure time and lowest possible beam current. Ensure adequate controls are in place to avoid longer exposure times. A total dose << 1 Gy (including rework / re-inspection) is recommended.
- Dose rate must be regularly monitored and controlled, and especially when the inspection tool undergoes repairs, parts replacement, or preventive maintenance. A well-calibrated dosimeter, which is qualified for inspection systems used for semiconductor parts, should be used.
- Use a collimated beam with the smallest possible opening to focus the beam on the part being inspected and reduce secondary exposure on adjacent parts. If this is not feasible, inspect one part at a time.
- As described in the previous section, use spectral filtering to reduce the bremsstrahlung to reduce the absorption and charge generation in the part being inspected.
- Inspect the device from the back side along with an appropriate filter and collimator (see Figure 2). This allows use of the package frame and the semiconductor region underlying the devices to additionally filter the beam and avoid interaction of the X-rays with the package materials above the devices.
- Electrical testing of parts post-irradiation is recommended, regardless of whether the guidelines listed above are followed. Any resultant failures should be suitably dispositioned along with appropriate corrective actions.

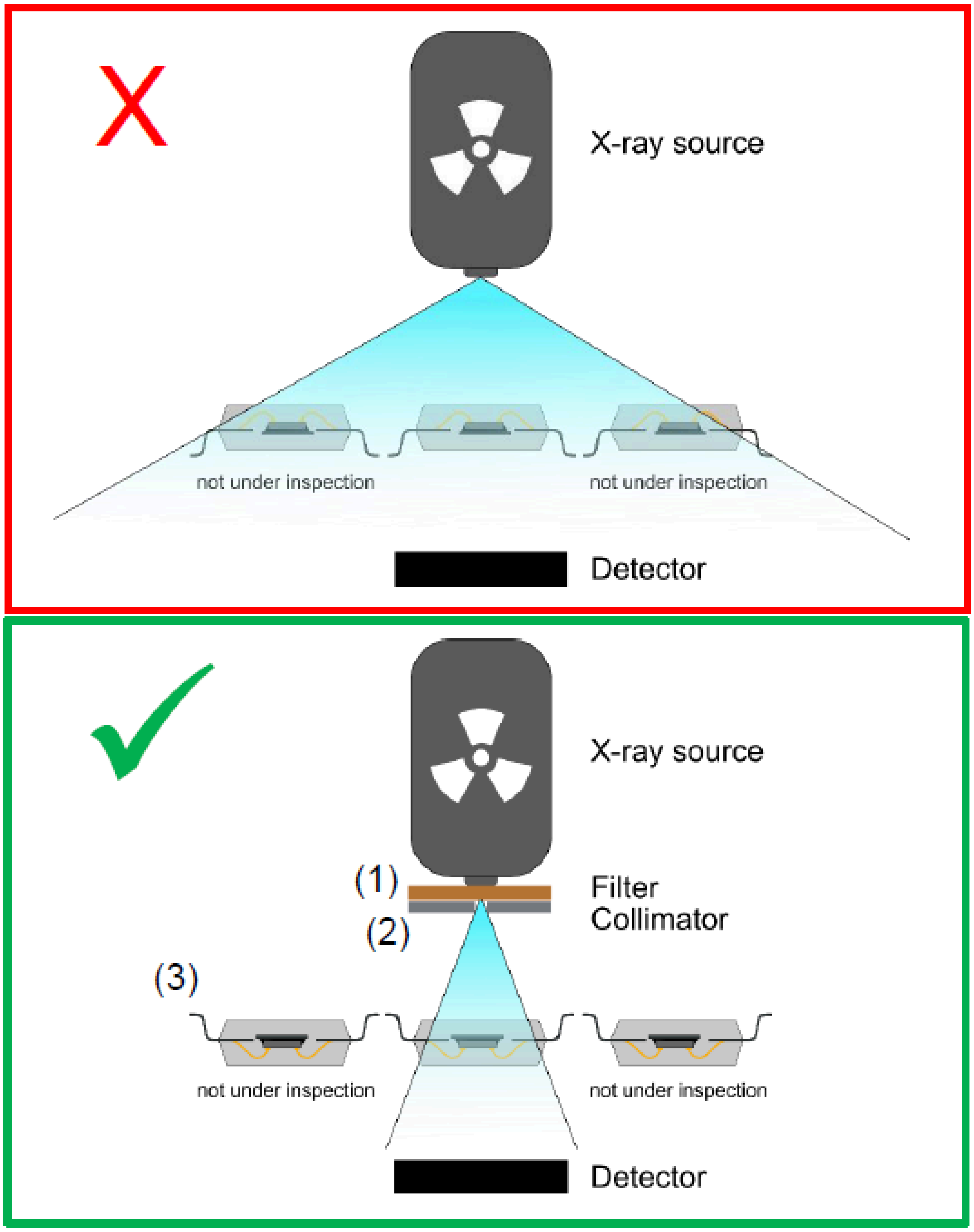

Figure 2. Non-preferred (top) and preferred (bottom) directions and configurations of X-ray inspection.

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Date of release: 8 October 2021