

**EASTMAN KODAK COMPANY**

**IMAGE SENSOR SOLUTIONS**

**QUALITY ASSURANCE AND RELIABILITY**

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Eastman Kodak Company - Image Sensor Solutions

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Eastman Kodak Company reserves the right to change the information contained in this document, without notice, in order to demonstrate improved product quality or performance.



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## INTRODUCTION

Image Sensor Solutions (ISS) is committed to providing high quality, reliable solid-state image sensors. This document describes the quality assurance and reliability program that has been developed to continuously improve our image sensor capability, quality, and reliability.

ISS has implemented a quality management system compliant to the ISO 9001 standard and certified by the British Standards Institute (BSI). Our Certificate Number is FM 27770. This system is described in the Quality Manual and a series of governing General Operating Procedures. Product manufacturing and testing steps are fully documented in a series of Work Instructions. These documents reference, where appropriate, to established industry standards.

Changes in process and test specifications are made in accordance with Engineering Change Notice approval systems. Changes in product specifications are made in accordance with a Product Change Request. These changes may require customer(s) approval.

ISS, as part of the Eastman Kodak Company Kodak Park site, is also certified by BVQI to ISO 14001:1996 (Certificate No. 63445).

The cornerstones of the Quality Assurance and Reliability Program are:

- Optimization of performance and reliability by design and thorough characterizations;
- Process control at every manufacturing stage;
- Guarantee of product conformity to published specifications before shipping;
- Continual improvement using an established and formalized process.

Kodak image sensors are designed with proven, certified and controlled design and processing rules. These rules ensure that image sensors are reliably manufactured with predictable parametric values and operating characteristics.

During the manufacture of Kodak image sensors, an electronic routing system is used to record and track the entire manufacturing process from receipt of raw materials to shipment of finished goods. Data, taken on a continuous basis as part of the manufacturing Statistical Process Control (SPC) system, are recorded and maintained in an SPC database. Parametric data (from process control monitors) are recorded and maintained in a parametric database. Functional (image) data are maintained in an image sensor-testing database. All test records are maintained for a minimum period of two years after date of delivery. All test and measurement tools are calibrated to traceable standards.

The Kodak Image Sensor Quality Assurance and Reliability Program may be envisioned as a pyramid in which each testing layer is supported by, and confirms any testing layer(s) below while assuring the validity of the testing layer above. This hierarchy of activity is shown pictorially in Figure 1.



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## INTRODUCTION: Continued...

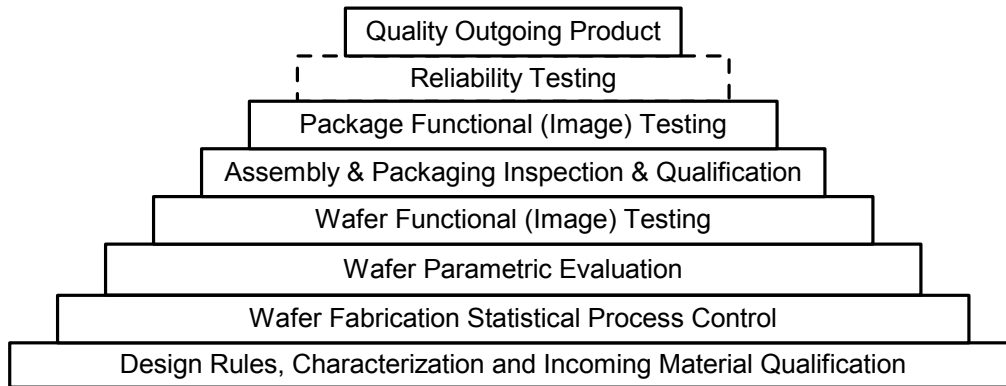


Figure 1  
Relationships in the ISS Image Sensor Quality Assurance and Reliability Program

**DESIGN AND DEVELOPMENT**

ISS follows a phases and gates process for design and development. This process is shown in Figure 2 together with the ongoing production phase and the eventual product discontinuance.



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## DESIGN AND DEVELOPMENT Continued...

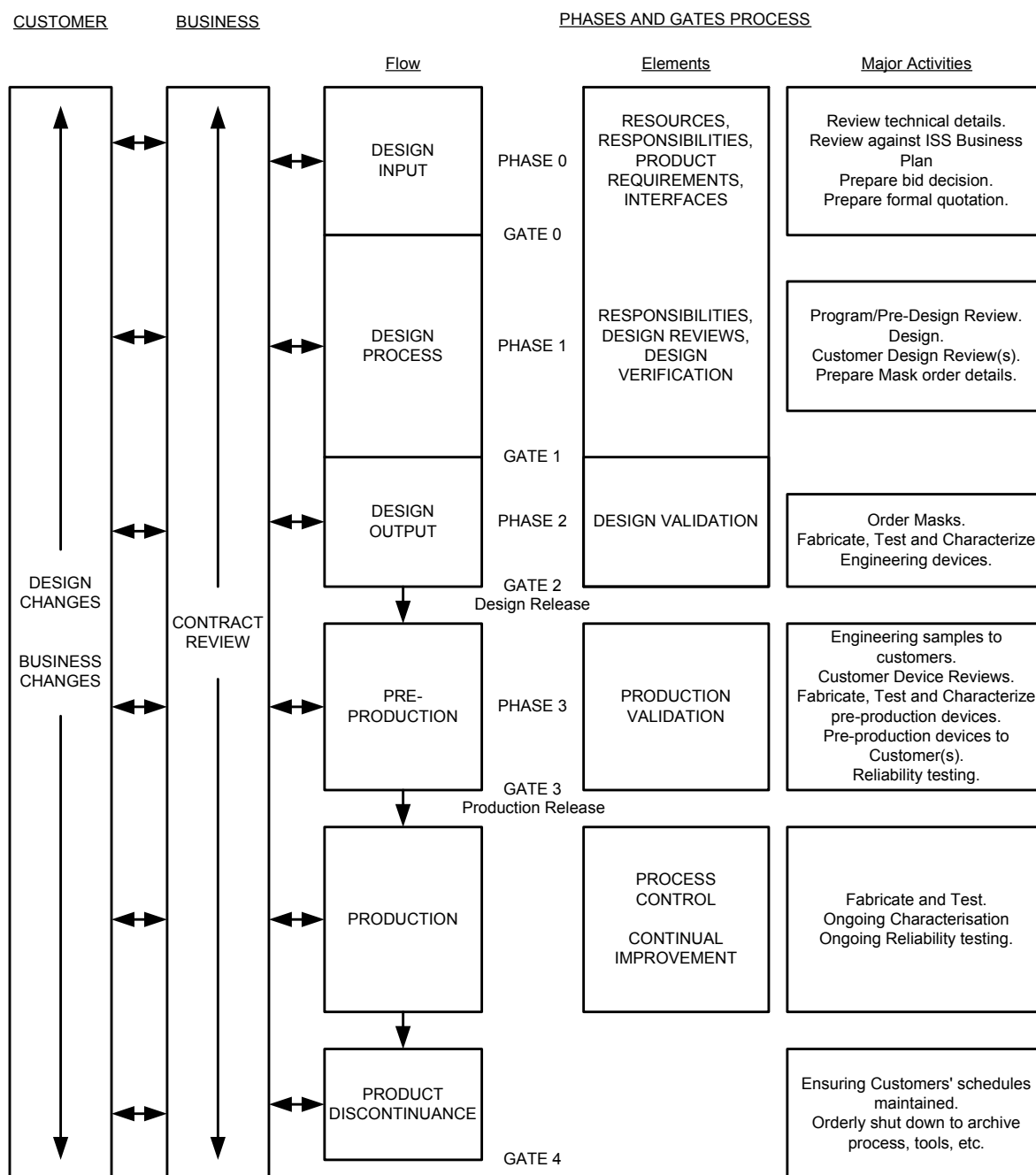


Figure 2  
ISS Phases and Gates Process for Device Development, Manufacturing and Product Discontinuance



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## MANUFACTURING FLOW

Figure 3 shows a generalized view of the production flow that identifies the key testing steps. The menu of Quality Assurance and Reliability testing steps are described in greater detail later in this document.

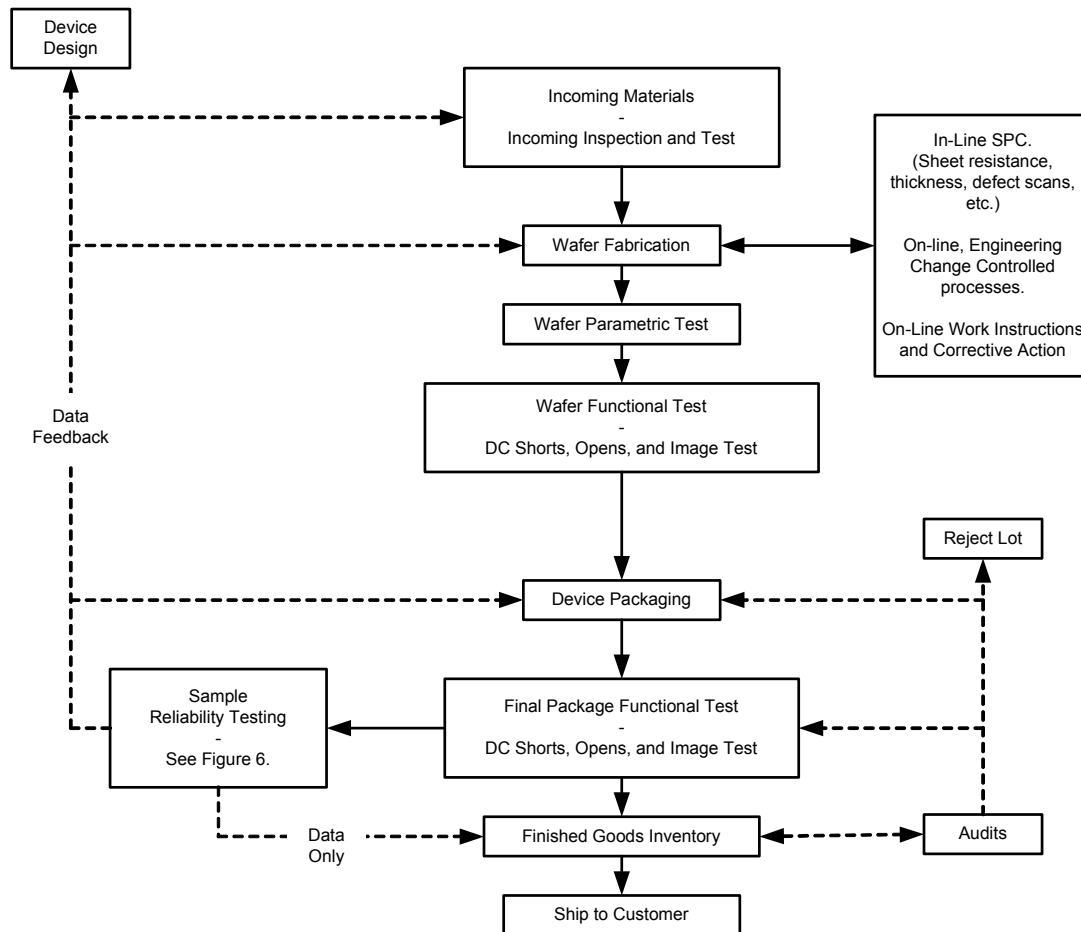


Figure 3  
General Manufacturing Flow



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## CONTINUAL IMPROVEMENT

The basic flow for Continual Improvement in technical processes is shown below. This ensures that problems are driven back to the root cause. Business process improvements require quality plans.

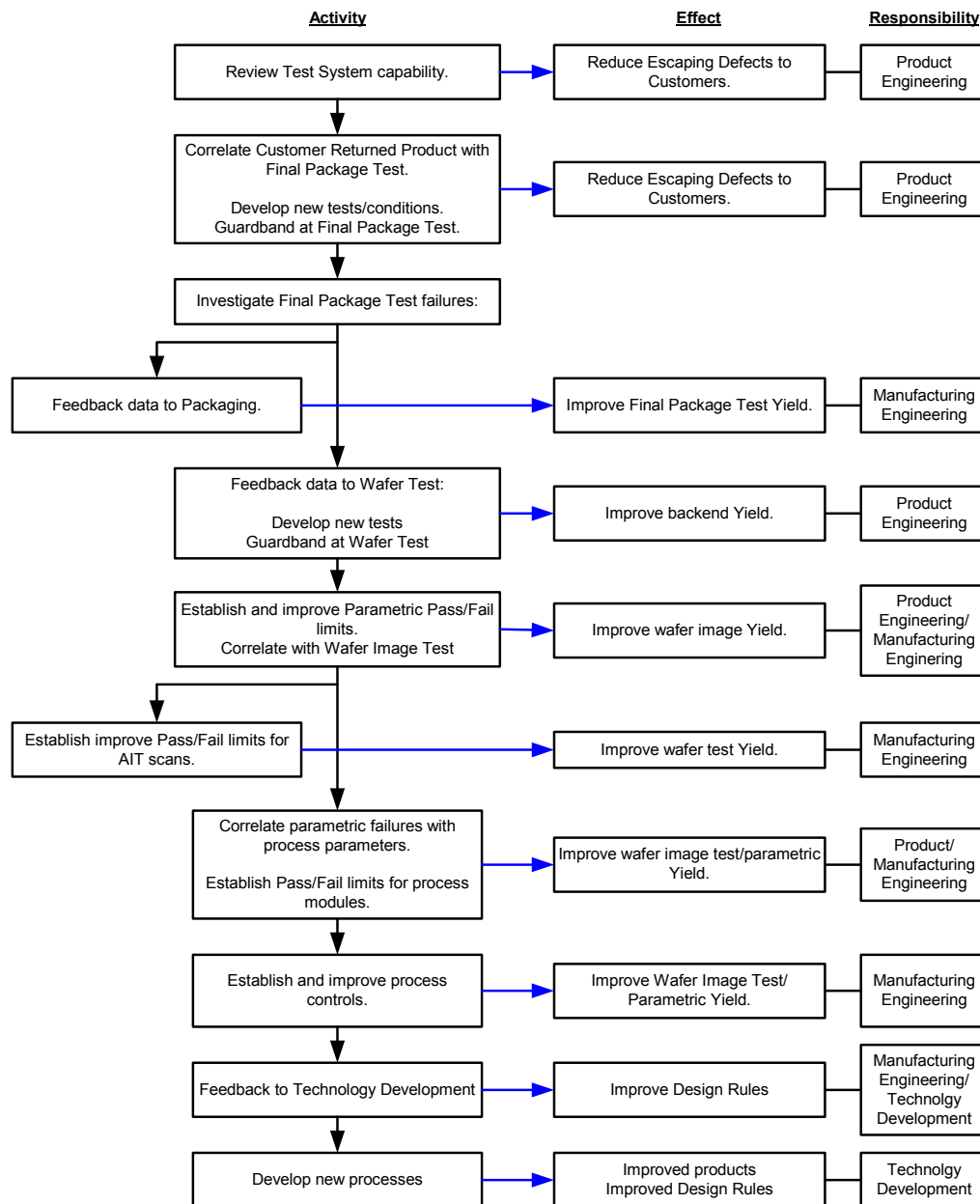


Figure 4  
Continual Improvement



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## **PRODUCT WARRANTY**

### **Stop Shipments:**

When, as a result of a customer product return, long-term reliability results, etc., it is determined that current inventory does not meet specification, ISS has a Stop Shipment process that prevents known defective devices from being shipped. This process requires that current inventory is checked and corrective action is taken before shipments can resume.

When such a situation arises, customers will be contacted if delivery commitments are expected to be affected.

### **Product Returns:**

In situations where product shipped to the customer does not meet specification, ISS has a Product Return process to investigate the cause and make good on confirmed failures. This process requires the customer to contact the appropriate Sales Representative for a Return Authorization Number. When the product is returned to ISS an investigation is carried out and a report issued to the customer.

## **GENERAL INFORMATION - IMAGE SENSOR TECHNOLOGY**

### **Image Sensor Characteristics:**

Image sensors are very large area MOS-type devices (typically  $>100\text{mm}^2$ ). Photosensitive pixel counts often exceed 1,000,000 for area arrays and 5000 pixels for linear arrays. Image sensors are inherently low power consumption devices where steady state currents are often less than 10mA with package and junction temperatures remaining relatively similar. Charge Coupled Devices (CCDs) operate at higher voltages for clocks and biases than most MOS devices including MOS image sensors. (See ECN.com 12/01/01 for a review of MOS image sensor technology.)

### **Packaging Characteristics:**

High levels of cleanliness and certain other requirements make the packaging of image sensors unique. High quality glass windows are used instead of typical ceramic or plastic encapsulation methods and special handling precautions are required to prevent scratching, chipping, and particulate formation. Die flatness and the precise alignment of the photosensitive area to the package may also require special attention.

ISS supplies both sealed and unsealed image sensors. Cover glass sealing for image sensors typically requires the use of organic resins and these resins are permeable to moisture; long-term exposure to high humidity environments should be avoided. Devices should be carefully stored in dry air or nitrogen environments.



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## GENERAL INFORMATION - IMAGE SENSOR TECHNOLOGY Continued...

Resistance to mechanical stress for image sensor packages may be less than for a conventional ceramic or plastic package because of the cover glass and the much larger internal cavity needed to accommodate large-area devices. Thermal expansion coefficient mismatches between packaging materials (glass, ceramic, plastic, and resin) may lead to mechanical instabilities and damage when subjected to temperature change rates greater than 15°C/minute. Thermal shocks in liquids should be avoided.

**Electrostatic Discharge Characteristics:**

Image Sensor Solutions image sensor devices, unless stated otherwise in the device performance specifications, are rated as follows for ElectroStatic Discharge (ESD) sensitivity:

**CCD Image Sensors:**

Class 0 (<250V per JESD22 Human Body Model test), or Class A (<200V JESD22 Machine Model test.)

Note: If the specification does not state JESD22 testing, Class 0 / Class A may be inferred.

The most sensitive pins on ISS Class 0 / ACCD sensors have limited ESD protection and are at the low end of the voltage range (~50V).

**CMOS Image Sensors:**

Class 2 Human Body Model (>2000V), Class B Machine Model (200 - 400V)

These sensors may be used in high reliability equipment, but must be handled with the precautions described below during testing and assembly. Extremely high voltages (thousands of volts) may be experienced due to careless handling or inadequate procedures and equipment during final product assembly.

During manufacturing and test, all image sensors are protected from ESD damage and are shipped in anti-static magazines or carriers.

Customers need to insure that equal care is followed upon receipt of the devices. Suggested basic precautions include:

- ESD Training for test and assembly personnel;
- Using ESD protected equipment and tools;
- Storing the assembled circuits with their pins short-circuited or inserted in conductive foam;
- Removing all sources of electrostatic charge.  
(Examples: nylon garments, plastic bags, etc.);
- Maintaining assembly area humidity at >45% RH.

Additional information on ESD control may be found in the following documents in the ISS Application Note Electrostatic Discharge Control, MTD/PS-0224



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**Color Image Sensors and Microlens:**

Image sensors with organic color filter arrays (CFA) and/or microlens have additional limitations that impact quality assurance and reliability. Organic dyes, used as color filter arrays in many image sensors, are subject to spectral changes when exposed to excessive light or heat. These changes can also be a function of the ambient during the exposure. Inorganic color filters are available for some image sensors. Similarly, microlens are fabricated from organic materials that may discolor or melt at elevated temperatures.



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## **QUALITY ASSURANCE TESTING – CCD IMAGE SENSORS**

Quality Assurance (QA) testing begins with the receipt of raw materials. The quality of the materials used in the fabrication of Eastman Kodak image sensors is monitored and controlled by vendor certification or by incoming tests established to monitor critical material parameters.

Manufacturing processes are defined and qualified for each of the Interline, Full-Frame and Linear device types. In each of the manufacturing and testing steps, the Work Instructions describe or reference test conditions, failure criteria, data collection, data storage, equipment calibration and disposition of product. These process steps and work instructions are computer based and monitored. Traceability of completed image sensors back to wafer fabrication lots and critical starting materials is maintained by these computer-controlled records.

A preventative maintenance program is in place to prevent loss of process control due to equipment failure. In addition, all critical equipment is backed up.

Additional testing is carried out during fabrication at over 150 individual steps using process or zone monitoring systems and statistical process control (SPC) techniques that serve to qualify product through the many stages of the fabrication process. The SPC data is also used to evaluate the capability of individual processes and this data is integrated into procedures for new device/process design to ensure highly producible products.

At the completion of wafer fabrication, electrical parameters are sampled on all wafer lots on special test structures. These tests verify that the processing has been correctly performed by measurement of the thresholds, resistance, line width, breakdown voltages, and other operational or parasitic parameters. The results of these tests are fed back to wafer fabrication for process control evaluation and also qualify the product wafers for further testing.

All image sensors on wafers passing parametric tests are functionally tested while still in wafer form. Full DC and image testing is completed and includes measurements of basic functionality, cosmetic defects, dark current levels, and response integrity. This testing is carried out at elevated temperature to stress the device under test at a number of parameters. Die with acceptable performance are recorded and appropriately identified for assembly and packaging.

Traceability of all image sensors to an identifiable manufacturing lot is either coded into the package marking and/or through a cross-reference of the package marking to controlled computer records.

During the packaging process, product is inspected and/or otherwise qualified for the following items:

- Package marking;
- Die cleanliness and structural integrity;
- Wire bond strength and position;
- Cover glass seal;
- Package and lead integrity, and cleanliness.



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## QUALITY ASSURANCE TESTING – CCD IMAGE SENSORS Continued...

Packaged device functional testing evaluates the electrical and optical performance of the devices under varying exposures and verifies that product satisfies the device specifications. All critical parameters defined in the device performance specification, such as gate/diode functionality, responsivity, linearity, defects, etc., are measured on every device at this step. Additional tests may be contracted by the customer or instituted by the product engineers as required. Figure 3 details the testing flow and some of the optional tests are detailed below.

- **Burn-In:**  
Burn-in may be contracted by the customer to identify and reject early life failures. The particular conditions for burn-in will vary according to the application. Stress temperatures between 45°C and 80°C are typical for image sensors. (Higher temperatures may cause CFA degradation in color devices.)
- **Sample Tests:**  
Some parameters, described in the device performance specifications, only require sampling and need not be performed on all packaging lots from a wafer lot that has already been sample tested. Examples of parameters that may be sample tested include: spectral response, saturation signal, and dark current.

Some parameters may only require testing when product or process changes are implemented. These parameters are typically determined during initial device development and are considered stable, non-critical, derived values or guaranteed by design such as pin capacitances and pixel size.

During QA testing, image sensors are handled in accordance with documented procedures. These include, where specified, the use of clean (air-filtered), ESD-protected workstations, grounded wrist straps and appropriate protective clothing.

## QUALITY ASSURANCE TESTING – CMOS IMAGE SENSORS

ISS CMOS Image Sensors are designed in accordance with the procedure previously described. However, they are manufactured at subcontractors. The subcontractor's reliability methodology is followed and verified by ISS.



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## QUALITY ASSURANCE TESTING: Continued...

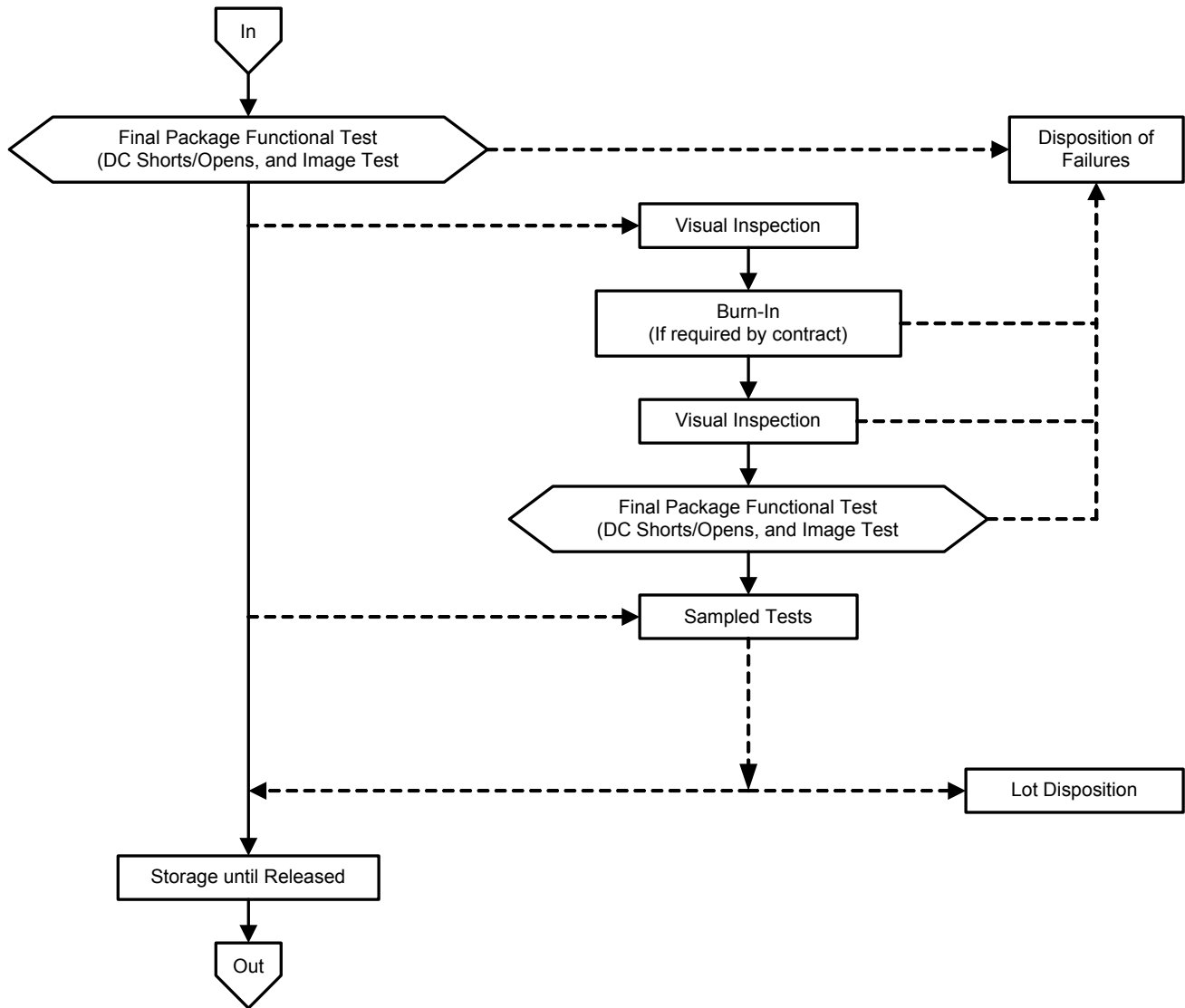


Figure 5  
Package Functional (Image Test) Final Acceptance Testing with Options



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## RELIABILITY TESTING – CCD IMAGE SENSORS

While the Quality Assurance Testing program is intended to ensure that product shipped to a customer will perform as published in device specifications, the Reliability Testing program is intended to ensure that product will continue to perform according to specification.

The reliability program is based on a hierarchy of device selection for testing. This recently established hierarchy has been based on reliability results collected over the last 10 years and is shown in Figure 6.

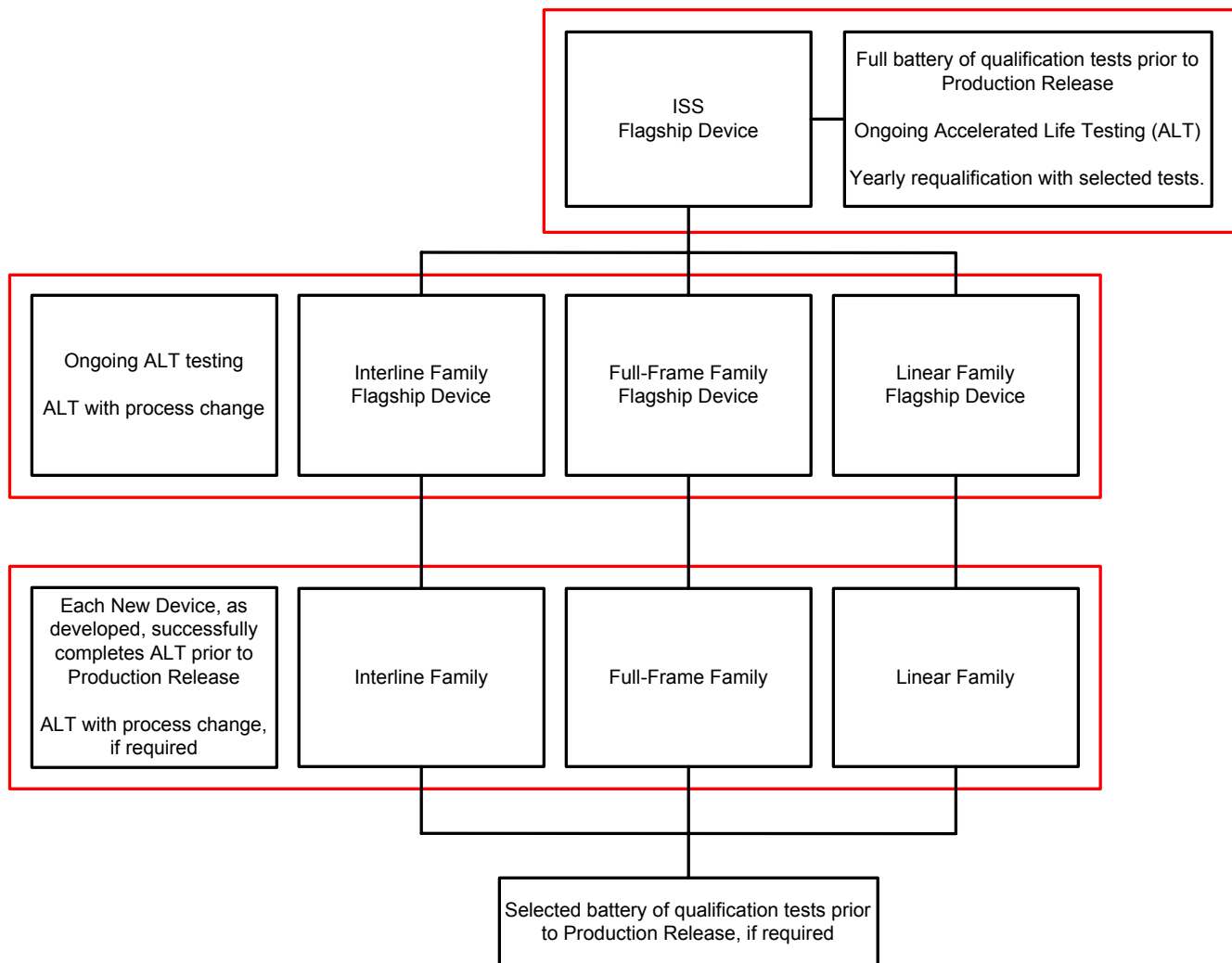


Figure 6  
Reliability Testing Hierarchy



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## RELIABILITY TESTING – CCD IMAGE SENSORS: Continued...

The ISS Flagship device is selected as the most representative ISS product with sufficient production volume to support ongoing reliability and qualification testing. This device has been subjected to a full battery of reliability tests and selected requalification tests.

Other product families also have flagship devices that have ongoing Accelerated Life Testing schedules.

New devices are subjected to Accelerated Life Testing prior to Production Release. In addition, further selected testing may be performed based on the manufacturing process and package construction. If the new device is sufficiently similar to flagship devices, no additional testing is required.

During reliability testing, all image sensors are handled in accordance with documented procedures that require, where necessary, the use of clean (air-filtered), ESD protected workstations, protective clothing and grounded wrist straps.

Some reliability samples may be selected at wafer-level functional testing and processed through packaging with production devices. Samples are selected on a random basis from all wafers of the packaging lot. These samples may be designated to have unsealed cover glass for use in humidity tests. (The function of the humidity testing is to verify the integrity of the passivation layers on the device.)

Samples for other reliability tests may be chosen from image sensors that fail the final package test for cosmetic defects only, i.e. they are completely functional image sensors with defects that mar the captured image but will not materially alter the response of the device to the environmental stress.

All image sensors that fail reliability testing are analyzed to identify and categorize the cause and mechanism of the failure. These causes are fed back to Design and/or Process Engineering for corrective action.

### Standard ISS Flagship Qualification Reliability Tests:

#### Accelerated Life Test (ALT):

Test Conditions: Temperature 125°C, Time: 1000 Hours, 1MHz, No Power-Up Flush Cycle

Pre-Tests: From Final Package Test

Post-Tests: Standard electrical test consisting of, but not limited to: Full DC, Functional response, CTE. Anti-Blooming performance evaluated on 5 pieces.

Sample Size: 40, Accept on 0, Reject on 1 (Sample Size 5, Accept on 0, Reject on 1 for Anti-Blooming.)



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**High Temperature Storage:**

Test Conditions: Temperature 125°C, Time: 1000 Hours, No Bias

Pre-Tests: From Final Package Test

Post-Tests: Standard electrical test consisting of, but not limited to: Full DC, Functional response, CTE. Anti-Blooming performance evaluated on 5 pieces.

Sample Size: 45, Accept on 0, Reject on 1. (Sample Size 5, Accept on 0, Reject on 1 for Anti-Blooming.)

**Low Temperature Storage Life:**

Test Conditions: Temperature -40°C, Time: 1000 Hours, No Bias

Pre-Tests: From Final Package Test

Post-Tests: Standard electrical test consisting of, but not limited to: Full DC, Functional response, CTE. Anti-Blooming performance evaluated on 5 pieces.

Sample Size: 45, Accept on 0, Reject on 1. (Sample Size 5, Accept on 0, Reject on 1 for Anti-Blooming.)

**Temperature Humidity Storage:**

Test Conditions: Temperature 60°C, 90% RH, Time: 1000 Hours

Pre-Tests: From Final Package Test

Post-Tests: Standard electrical test consisting of, but not limited to: Full DC, Functional response, CTE. Visual Inspection CCD and Package

Sample Size: 45, Accept on 0, Reject on 1

**Temperature Cycling:**

Test Conditions: Temperature -40°C, to +125°C, Dwell Time , 100 Cycles Ramp 10°C/minute maximum. (Ramp time 16.5 minutes minimum.) Dwell Time 16.5 minutes each extreme

Pre-Tests: From Final Package Test, Leak Test (Gross -  $10^{-4}$ cc/s and Fine -  $10^{-6}$ cc/s)

Post-Tests: Visual Inspection CCD and Package. Leak Tests (Gross and Fine)

Sample Size: 22, Accept on 0, Reject on 1.

**Resistance to Solder Heat – Leaded Devices:**

Test Conditions: Temperature 320°C, Dwell Time 10 seconds, pin-to-pin

Pre-Tests: From Final Package Test

Post-Test: Standard electrical test consisting of, but not limited to, Full DC, Functional response and CTE

Sample Size: 10, Accept on 0, Reject on 1



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**ESD Sensitivity:**

Machine Model: Cs = 200pF, Ra = 0 +/- 200V(EIA/JEDEC C-A115-A)

Human Body Model: Cs = 100pF, Ra = 1500 (JESD22-A114-B)

Pre-Tests: From Final Package Test

Post-Tests: Standard electrical test consisting of, but not limited to: Full DC, Functional response, CTE

**Steady State Temperature/Humidity/Bias:**

Test Conditions: Temperature 60°C, 90% RH Time: 1000 Hours, Bias

Pre-Tests: From Final Package Test

Post-Tests: Standard electrical test consisting of, but not limited to: Full DC, Functional response, CTE. Visual Inspection CCD and Package

Sample Size: 40, Accept on 0, Reject on 1

**Solderability:**

Package vendor testing.

**Lead Integrity:**

Package vendor testing.

**Mechanical Shock:**

Test Conditions: MIL-STD-883, Method 2002.3B, 1500g, 0.5ms, XYZ planes

Pre-Tests: From Final Package Test

Post-Tests: Standard electrical test consist of, but not limited to, Full DC, Functional response, CT,. Visual Inspection CCD and Package, Leak Test (Gross and Fine)

Sample Size: 22, Accept on 0, Reject on 1

**Vibration Variable Frequency:**

Test Conditions: MIL-STD-883, Method 2007.2A, 20-2000-20Hz, 4 minutes

Pre-Tests: From Final Package Test

Post-Tests: Standard electrical test consisting of, but not limited to: Full DC, Functional response, CTE. Visual Inspection CCD and Package. Leak Test (Gross and Fine)

Sample Size: 22, Accept on 0, Reject on 1



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**Shipping Profile Reliability:**

Test Conditions: Profile to simulate product shipping

Pre-Tests: From Final Package Test

Post-Tests: Visual Inspection and Final Package Functional Test

Sample Size: 32, Accept on 0, Reject on 1.

**Strife Testing:**

Test Conditions:

1. 125°C, Test until 50% Fail, 1MHz, Bias applied, Sample size 40

2. 135°C, Test until 50% Fail, 1MHz, Bias applied, Sample Size 20

3. 150°C, Test until 50% Fail, 1MHz, Bias applied, Sample Size 10

Pre-Tests: From Final Package Test

Post-Tests: Standard electrical test consisting of, but not limited to: Full DC, Functional response, CTE.

**RELIABILITY TESTING – CMOS IMAGE SENSORS**

ISS CMOS image sensors are manufactured at subcontractors. Device qualification is performed to the subcontractor's criteria.

Ongoing ALT testing is not performed in ISS.

**ADDITIONAL RELIABILITY TESTS****Color Fade/Storage:**

Color image sensors using integral organic color filter arrays for spectral separation are susceptible, similarly to all organic dyes, to fading with long term excessive exposure to heat and light. The primary effect is 'yellowing' of the blue filter resulting in reduced blue channel responsivity. Accelerated stress tests for heat and light are used to study the effects and quantify the resulting loss in performance. ISS has converted the filter sets on the majority of our image sensors to pigment filters, versus dye-based filters, to provide additional resistance to such fading.

**COMMON CAUSES FOR PRODUCT RETURNS OR FAILURES**

The Quality Assurance and Reliability test program is in place to assure customers receive devices that continue to operate and perform according to specification. The customer should be aware of the device operating and storage specifications to avoid device degradation. Typical causes for device failures experienced by customers include:



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**Electrostatic Overstress and Damage:**

Damaged or destroyed gates, shorted device pins, and improperly functioning output amplifiers are signs of electrostatic damage or voltage over-stress.

Please review the section on ESD susceptibility and follow the recommendations.

**Video Line Overstress:**

Extreme care must be taken when probing in and around image sensors. Inadvertent contact between the video output and a low impedance source or ground will instantaneously cause excessive short circuit current to the device output and will likely damage or destroy the output channel.

**Dirty Cover Glass:**

Defective pixels are often the result of dust, fingerprints or other residues on the cover glass.

The cover glass can be cleaned by applying a few drops of ethanol or isopropyl alcohol to a non-abrasive, lint-free wipe or swab and wiping the cover glass. These solvents dry quickly and will not leave an interfering residue or degrade any optical coatings. (See ISS Application Note: Cover Glass Cleaning for Image Sensors, MTD/PS-0237.)

Precautions to prevent ESD degradation are recommended when cleaning the cover glass.



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