MEMS Optical Scanner "ECO SCAN"

Application Notes

Quality Assurance Edition

Ver.0

Visionary Business Center

Micro Electro Mechanical Systems Promotion Dept

The Nippon Signal Co., Ltd.

A-LG9644A-001

Precautions

Caution

- Since ECO SCAN uses strong magnets, there are the following risks:
  - Moving a magnetic material close to the mirror part may cause damage or affect its performance characteristics.
- Since the moving plate is exposed, there are the following risks:
  - The moving plate may be damaged if it is hit by fingers or tweezers, or strongly blown by air
- Since ECO SCAN is a precision optical component, there are the following risks:
  - Using it outside the scope of specifications may cause malfunction or failure.
  - During transportation and handling, the mirror part may be damaged if it is dropped or hit.
  - Disassembly or alteration may cause abnormal motion, failure, and damage.
- Applying a torsional force to ECO SCAN may break away attached parts
- Touching the drive unit while ECO SCAN is turned on may cause abnormal heat, burning, and damage.
- Installation, maintenance, and troubleshooting while ECO SCAN is turned on may cause damage.
- Wrong connection may cause unexpected malfunction, heat, and fire. See the circuit diagram and connect ECO SCAN properly.

Preface

This document summarizes precautions and quality assurance for MEMS optical scanner "Eco Scan".

Table of Contents

1. Nippon Signal's approach to quality assurance

Our MEMS Promotion Department acquired ISO9001 in 2008. We perform various activities based on the standards in order to ensure product quality assurance and continuous quality improvement.

We operate Sales, Technology, Production Management, and Quality Assurance departments ourselves, and outsource production to our affiliate company Fab. To ensure quality assurance in this system, our product development process covers the following:

(1) Facilitate product development based on the input from the sales department and the road map of the technology department.

(2) For each phase of development (blueprint → baseline design → production design), conduct design review and evaluation timely (including joint design review with Fab) to ensure design validity.

(3) In the above phases, we focus on detecting and verifying possible concerns based on FMEA (Failure Mode and Effect Analysis) to find and address failure in a proactive manner.

(4) Finally, we conduct a reliability test to verify product durability. Note that, if possible characteristic variation is detected in FMEA, we may include this phase partially in the initial development.

Figure 1 shows the mechanism of quality assurance in our production system.

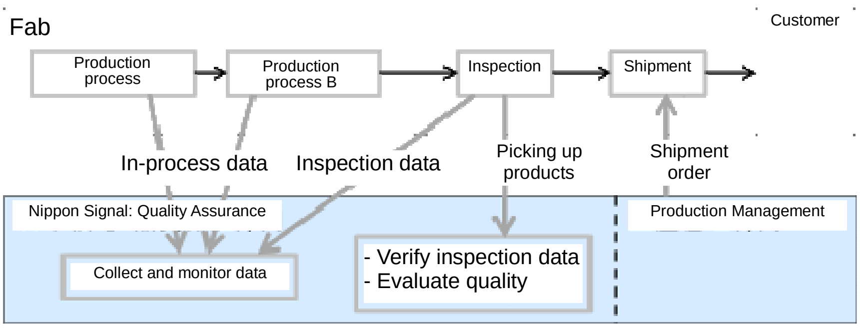


Figure 1. Mechanism of quality assurance in production system

(1) Nippon Signal always monitors data in Fab's processes to check the progress and quality based on the standard values. *)

(2) Nippon Signal supplies Fab with inspection devices to outsource inspection.

(3) Nippon Signal verifies inspection data, and order the shipment.

(4) Nippon Signal has the same inspection devices as Fab in order to pick up products periodically to verify the data and evaluate the quality.

*) Nippon signal communicates with Fab via VPN (Virtual Private Network) to share the in-process data and shipment data in real time.

For these processes of the mechanism, we conduct the PDCA cycle periodically to improve the product quality continuously .

2. Reliability test

2.1 Policies

We conduct a reliability test in order to confirm that a delivered product is assembled and adjusted properly at manufacturer, and its performance in the specified period satisfies the customer’s requirements. Therefore, it is important to "determine the target reliability (acceptable probability)" by considering the determination criteria: (1) the usage environment and conditions, (2) period of service, and (3) usage.

For semiconductor devices such as LSI, the standard testing methods are defined by Japanese Industrial Standards (JIS). Since Eco Scan has many materials and processes in common with semiconductor devices, we consider its mechanical component characteristics in view of semiconductor devices, and determine and operate reliability test contents ourselves. In case a customer asks for an additional test or modifying the reliability test, we consult with a customer to take into account the necessity and considerations before making a decision.

2.2 Test Contents

Table 1 summarizes Eco Scan standard reliability test contents defined by Nippon Signal.

Table 1. Reliability test contents

Test item	Compliance standards	Purpose	Testing method and conditions
Vibration	JIS C 60068-2-6 (Formerly known as JIS C 0040)	Confirm resistance in case vibration is applied during transportation.	Frequency of vibration: 55 to 500 Hz, peak acceleration: 98 m/s^2, duration: 120 minutes for each direction (10 cycles)
Impact	JIS C60068-2-27 (Formerly known as JIS C 0041)	Confirm resistance in case a non-repeat impact is applied during transportation.	Pulse waveform: Sine half wave, peak acceleration: 500 m/s^2, duration: 11 ms
Natural drop	JIS C 60068-2-32 (Formerly known as JIC C 0044)	Confirm resistance in case the device is dropped during transportation, handling, and repair work.	Height: 75 cm or less Material: Rubber plate Number of times: 2 Thickness: 2 mm or more
Consecutive operations	-	Confirm the product lifespan in an acceleration test.	See 4.1.2 "Acceleration test".
Operation at a high temperature/ humidity	JIS C60068-2-3	Confirm resistance to high temperature and humidity. Since the absolute humidity applies, this test item is the same as "consecutive operations".	
Storage at a high temperature	JIS C 60068-2-2 (Formerly known as JIS C 0021)	Confirm resistance in domestic transportation at a high temperature.	Temperature: 85°C, humidity: not controlled Duration: 96 hours

Test item	Compliance standards	Purpose	Testing method and conditions
Storage at a low temperature	JIS C 60068-2-1 (Formerly known as JIS C 0020)	Confirm resistance in domestic transportation at a low temperature.	Temperature: -25°C, humidity: not controlled Duration: 96 hours
Storage at a high temperature and a high humidity	JIS C 60068-2-3 (Formerly known as JIC C 0022)	Confirm resistance in domestic transportation at a high temperature and a high humidity.	Temperature: 85°C, humidity: 85%RH Duration: 96 hours
Temperature change	JIC C 0025	Confirm resistance when the device is exposed at high and low temperatures.	Temperature/duration: -25°C (30 minutes) → normal temperature (5 minutes) → 85°C(30 minutes) → normal temperature (5 minutes), number of cycles: 5
Thermal shock	JIC C 0025	Confirm resistance when the device is exposed to a sharp temperature change.	Temperature/duration: -25°C (5 minutes) → transfer time: 2 seconds → 85°C (5 minutes) → transfer time: 2 seconds, number of cycles: 10

2.3 Setting Environmental Conditions

As described in the Application Notes Design edition, Eco Scan is an electromagnetic drive MEMS optical scanner. The moving plate consists of the monocrystal silicon substrate (with the mirror and drive coil on its surface), beams, and supporting section. The drive coil is connected to the external power supply via the metallic thin film wiring formed on the beams. Since the beams twist greatly, polyimide is used for the wiring protection film. This feature is designed to prevent short-circuit and damage in production processes. Using it at a high temperature and a high humidity may cause material and characteristic variations due to oxidation.

Therefore, we take into account the concept of the "absolute humidity of 36 g/m^3 (the highest possible humidity in Japan defined by IEC standards 721-2-1)" in view of a possible usage environment in a mild and humid climate, and consider the ranges shown in Figure 1 the standard usage and storage conditions. If you are considering the use outside the range, please consult with us.

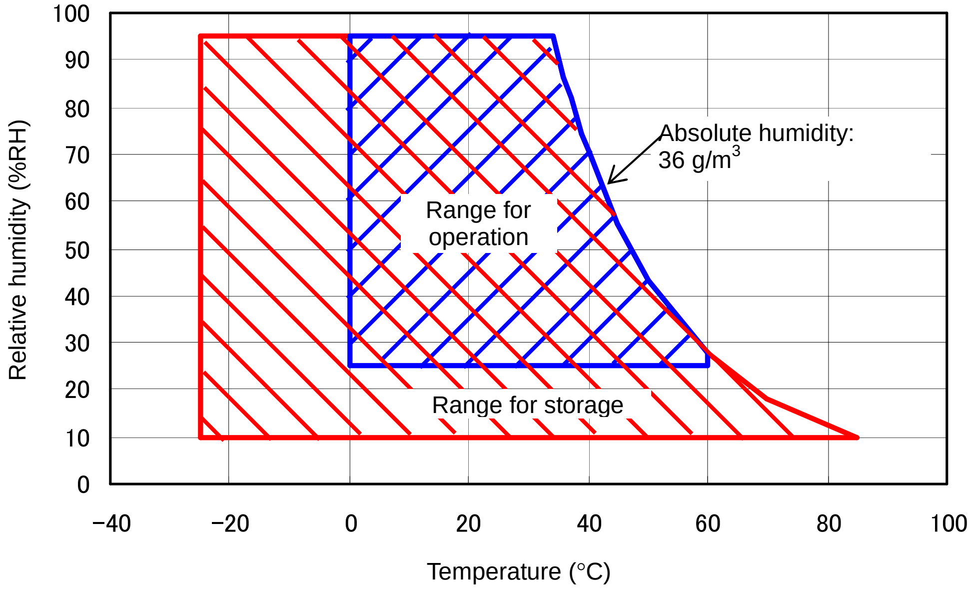


Figure 1. Eco Scan usage/storage range

3. Preventing initial defective products from deliver

3.1 Screening

Eco Scan utilizes its excellent mechanical characteristics of the monocrystal silicon substrate to ensure a large deflection angle. However, a crystal defect that occurs (discontinuity of crystals) at a certain frequency in monocrystal silicon and a production-related shape defect may cause stress concentration on the silicon structure. As a result, some products cannot enable an intended deflection angle (initial defective products).

Screening is intended for excluding these initial defective products without damaging or deteriorating non-defective products by intentionally applying an appropriate deflection angle (stress) to them. Figure 2 describes this concept. Eco Scan to be delivered must pass the screening inspections that are optimized for it based on its usage and environment conditions.

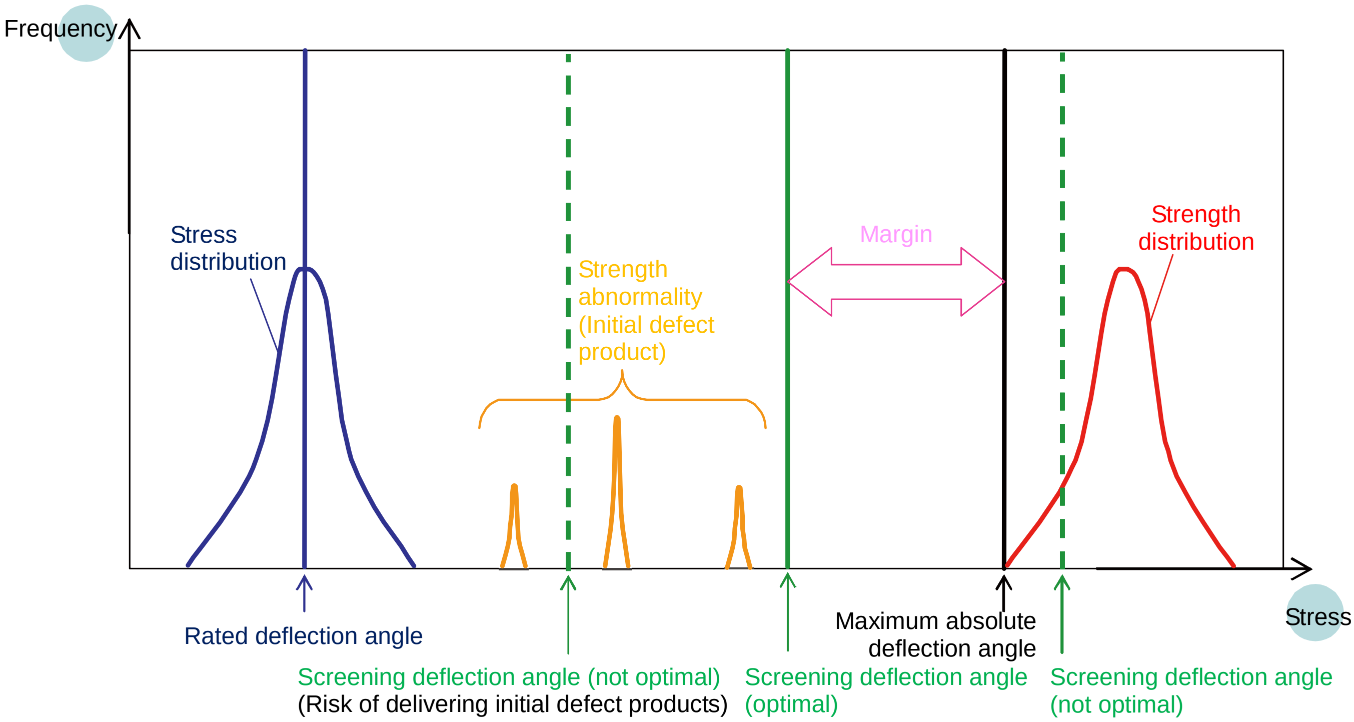


Figure 2. Conceptual diagram of screening

4. Product lifespan

Failure mode that determines the lifespan of Eco Scan is due to (1) breaking of wire, (2) variation of resonant frequency, or (3) damage to the beams. The cause of (1) can be electromigration and stress migration, which are addressed by optimized wiring dimensions. Details of (2) and (3) are given below.

4.1 Variation of Resonant frequency

4.1.1 Causes

Eco Scan's normal drive system is the resonance drive with a fixed drive frequency. The repeated control sequence is "the resonant frequency changes (temperature characteristics, secular change)" → "the deflection angle decreases" → "more current applies to ensure the deflection angle". When the power supply capacity of the drive circuit reaches the limit, the specified deflection angle cannot be retained and thus failure results. This is due to secular change caused by corrosion of the metallic thin film formed on the beams.

The resonance drive that traces the frequency or non resonance drive are not targeted for this failure mode. (For details, refer to Application Notes Control Edition)

4.1.2 Acceleration test

The cause of secular change is a chemical reaction on the metal wiring, thus the "Arrhenius model", that is often used for semiconductor device lifespan tests, can be used to calculate the lifespan. Equation (1) indicates the relation. We calculate and use the activation energy (Ea) to project the worst case of the actual usage environment, and define the product lifespan based on the temperature acceleration.

$$\ln L = A + \frac{E_a}{kT} \quad \cdots\cdots (1)$$

L: lifespan, *A*: constant, *E*a: activation energy (eV), *k*: Boltzmann constant (eV/K),
T: absolute temperature (K)

4.1.3 MTBF*1)

Figure 3 describes a result example. The resonant frequency variation is defined and Weibull-plotted after the temperature acceleration test. The shape parameter (*m*) is over 1, and that means the failure mode is of wear. This data is of temperature acceleration, and we confirm that MTBF is 50,000 hours or more in a standard usage environment for Eco Scan.

*1) MTBF (Mean Time Between Failure): The average time until a device or system malfunctions. The average time between the start of use (or recovery from damage) and the next malfunction.

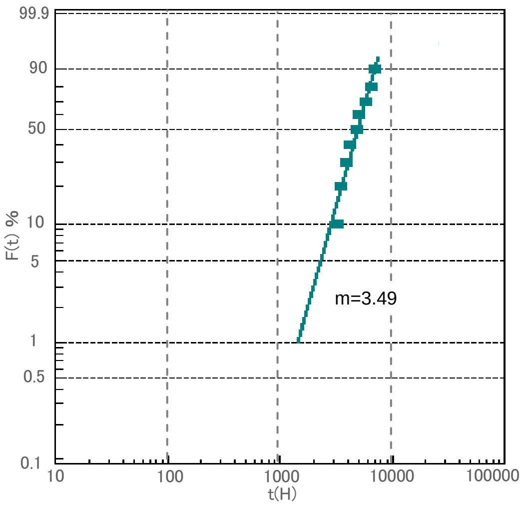
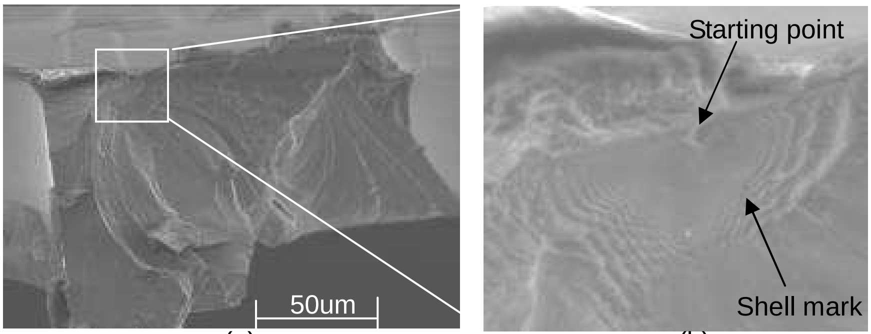


Figure 3. Example of Weibull-plotting the resonant frequency variation

4.2 Beam Breaking

4.2.1 Causes

The beams, to which high stress is applied, use monocrystal silicon, thus there is no fatigue phenomenon. The beams work semipermanently if they are used in the rated deflection angle and within the usage range described in Section 2.3. Using the device beyond the maximum absolute rated deflection angle causes cracks on the beam (when stress applied to the beam is the break strength of silicon). The cracks get larger although the component may not break immediately. The cross section of the crack*2) looks like a shell surface (See Figure 4). The degree of this stress concentration varies depending on the conditions (position, size, shape, etc.), and therefore the lifespan cannot be calculated. Using the device within the scope of silicon break strength, as well as conducting screening, are essential.



(a) (b)

Figure 4. SEM picture of a damaged beam cross section

*2) Reference: “Fatigue breaking of mechanical parts and the viewpoint of fractured cross section” Sakae Fujiki, (Nikkan Kogyo Shinbun)

4.2.2 Acceleration test

As described above, it is impossible to implement the concept of acceleration test. We have examined design values and thresholds of actual products for over eight years, and use these data as basic data for designing new products and assuring the product lifespan in case of this failure mode.

4.2.3 MTBF

Figure 5 is an example of a breaking test. Results of the operation beyond the maximum absolute rated deflection angle are Weibull-plotted. Inevitably, the lifespan is short, and MTBF is about 2000 hours under this condition. The beam breaking times do not vary so much, and the “m” values are specifically used for brittle materials.

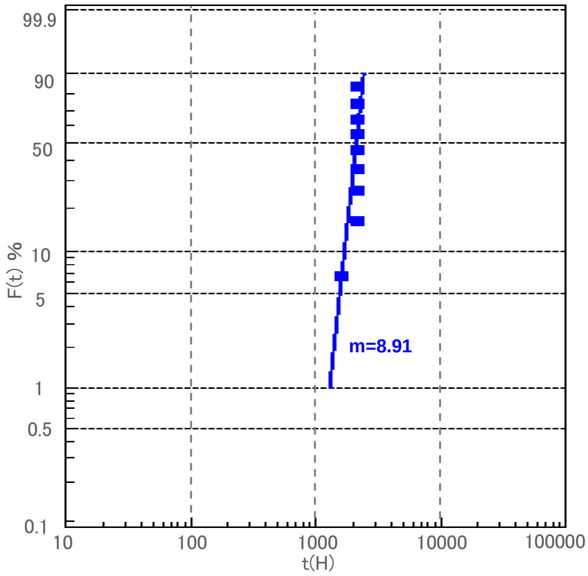


Figure 5. Weibull-plot regarding beam breaking