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Pin photodiode
Quality Assurance Procedure
v.1.1

Fermionics

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Revision History

V 1.0 First draft 3 July, 2003

V 1.1 Corrections to measurement procedures and acceptance criteria following discussions and preliminary measurements.

Quality Assurance Programme outline

The Quality Assurance Programme described in this document consists of the procedures to be carried out by CERN upon reception of pre-production and production batches from Fermionics. The definition of procedures allows the resultant data to be consistently compared to the specification thus leading to the acceptance or rejection of the tested batch based upon the described criteria.

1.1 Documentation

All test results will be documented in the form of a pre-production qualification report or a lot acceptance report depending upon the nature of the batch to which the results pertain. Copies of said reports will be sent to Fermionics and be placed in the CERN document archive (EDMS). Direct access to the documents in EDMS will be restricted to members of the CMS experiment.

1.2 Delivery Schedule

The production of pin photodiodes will proceed in *Batches*, all of which will be shipped from Fermionics to CERN. Acceptance of these batches by CERN will be based on the delivered devices passing the tests described in this document.

The delivery schedule for the pin photodiodes to CERN is reproduced in Table 1.

Table 1: Delivery schedule for Fermionics pin photodiodes.

Batch	Description	Quantity	Delivery date to CERN
P1	pre-production pieces	100	30 June 2002
P2	AVT	90	31 July 03
P3	Series production	50	31 Oct 03
P4	Series production	300	30 Nov 03
P5	Series production	300	31 Dec 03
P6	Series production	300	31 Jan 04
P7	Series production	300	29 Feb 04
P8	Series production	280	31 Mar 04
P9	Series production	80	30 Apr 04
	Total :	1800	

1.3 Quality Assurance programme overview

The quality assurance programme overview is shown in Table 2. The table shows the tests to be carried out during both pre-production qualification and lot acceptance testing, together with the test target specifications from the technical specification for delivered photodiodes (CMS-TK-ES-0016). The test procedures for lot acceptance (described in Section 2) form a sub-set of the pre-production qualification procedures (described in Section 3). All tests are carried out at room temperature unless otherwise noted.

Table 2: Validation Programme overview table.

#	Specification to be tested		Test Target Specifications				CERN Testing		
			Min	**Typ**	**Max**	**Units**	**Advance Validation**	**Pre-production Qualification**	**Lot Acceptance**
2.3.1	Number of channels		1				①	①	①
2.3.2	Active material structure		InGaAs on InP p-i-n						
2.3.3	Tensile load on connector side of pigtail				7	N		③ ⑤	
2.3.4	Target Package Size			10x4x3		mm		①	
2.3.4	Package type		Wire-bond or solder attach						
2.3.6	Operation rate			4000		hours/year	②		
2.3.21	Dark current at –5V				1	nA		②	②
2.3.22	Capacitance at –2V, 100kHz				1.0	pF		②	②
2.3.23	Bandwidth (risetime)		100			MHz		②	②
2.3.24	Reverse bias voltage			2.5	20	V		②	②
2.3.25	Max forward current		2.0			mA		②	②
2.3.31	Wavelength		1260	1310	1360	nm		②	②
2.3.32	Input power range		2			mW		②	②
2.3.33	Responsivity		0.75			A/W		②	②
2.3.34	Fibre type		Single-mode 900μm tight-bufferedfibre				①	①	①
2.3.35	Connector type		MU				①	①	①
2.3.36	Pigtail length	short	0.56		0.60	m	①	①	①
		long	2.00		2.04				
2.3.41	Magnetic field resistance				4	T		④	
2.3.42	Hadronic fluence				3×10^{14}	cm^{-2}	⑥		
2.3.43	Gamma radiation dose				1.5×10^{5}	Gy(Si)	⑥		
2.3.44	Temperature		-20		70	°C			
2.3.45	Operating humidity		Dry lab environment during testing						

Legend:
① Visual inspection ② Opto/electronic characteristic test ③ Non-destructive tensile load test ④ Magnetic field test ⑤ Destructive tensile load test ⑥ Irradiation test

2 Lot Acceptance Procedures

This section states the sample size required for each described lot acceptance procedure. The failure criteria are given for each test in the description of the relevant procedure.

2.1 Lot Acceptance Flow

Sample sizes for lot acceptance are 3% of the lot, or a minimum of 10 photodiodes for a monthly delivery. No failures at the lot acceptance level are allowed. Furthermore the samples used for lot acceptance will pass sequentially through all of the procedures in the order they appear in Figure 1. After use in the final test, although the samples are not physically destroyed they will not be re-useable for mounting on optohybrids. The test samples used for lot acceptance testing will be stored at CERN for archival purposes to allow re-testing in the future should this become necessary.

In the event of failure of an early test, the full test program will be carried out on the sample if it is possible. This will allow the maximum amount of feedback information to be given in the lot acceptance report.

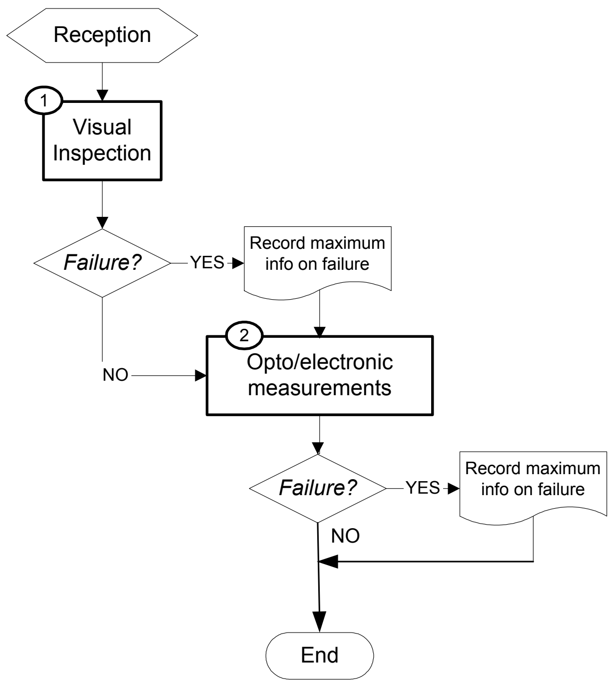

Figure 1: Flow chart of lot acceptance procedures.

2.2 Lot Acceptance Test Descriptions

2.2.1 Visual Inspection

Visual inspection consists of the following sequence:

1. Unpack the sample from its transportation container.
2. Inspect and measure the length of the pigtail.
3. Inspect and measure the dimensions of the package using vernier callipers

Acceptance criteria for the corresponding step of photodiode visual inspection are:

1. Channel count must equal one.
2. Pigtail length must be within the specified range for the particular overall length (L_{nom} –0mm/+40mm). Lengths falling outside this window will fail.
3. Outer package dimensions must be smaller than the stated specification. Out-sized packages will fail.
4. All samples should be free from visible defects. The fibre pigtail should not be damaged in any significant way and no cuts, compression marks, or scratches should be visible to the naked eye.

2.2.2 Opto/electronic characteristic test

Measurement of the photodiode characteristics is made following the sub-procedures below.

The device under test is temporarily mounted in a measurement jig, which can be connected to an instrument, such as pico/source, capacitance meter, or oscilloscope via the BNC electrical connector.

The fibre pigtail is connected to a 1310nm laser transmitter, through an optical splitter where one channel is connected to a power meter and used as a reference power measurement.

(a) Capacitance

The jig and device are connected to a Keithley C-V meter and the capacitance at 100kHz (series resistance mode) is measured over a reverse bias voltage range of 0V to –5V in 0.1V steps.

The acceptance criterion is such that the capacitance is below 1.0pF at –2.0V.

(b) Dark current and responsivity

The jig and device under test are connected to a Keithley pico/source. The pigtail is connected to the 90% output channel of a 90:10 optical splitter that is connected to a 1310nm laser. The laser power is measured using an optical power meter via the other splitter channel.

The I-V measurement is then repeated for different values of input optical power, effectively moving along the L-I characteristic in 10 steps of the external laser from 0 to 2mW in steps. The optical power injected into the photodiode is then calculated based on an earlier calibration of the splitter ratio at the different optical powers.

The I-V characteristic is measured over a reverse bias voltage range of 0V to –5V in 0.2V steps.

The slope of the characteristic of photocurrent versus injected optical power is defined as the responsivity.

The acceptance criteria are such that the dark current should be <1nA and the responsivity should be >0.75A/W at –5V bias voltage.

(c) Maximum reverse bias voltage

The dark current is measured over the reverse bias voltage range of 0V to –10V in 2V steps and then the device is biased for 5 seconds at –20V, after which time the current is measured. The dark current is then re-measured in the range of 0V to –10V in 2V steps.

The acceptance criteria are such that the device should have exhibited no evidence of electrical breakdown and should not have been damaged. The dark current at –20V should be <1μA and the dark current in the second set of I-V measurements up to 10V should show no significant signs of degradation and, in all cases, the dark current should remain below 1nA at –5V after this test.

(d) Max forward current

The dark-current at –5V is measured. The photodiode diode is then forward-biased with the voltage being increased from 0V in small (0.05V) steps until the forward current exceeds 2mA. The dark-current at –5V is then remeasured.

The acceptance criterion is such that the dark current at –5V does not increase by more than 100% between the two measurements. In all cases, the dark current should remain below 1nA at –5V after this test.

(e) Bandwidth (rise time)

The jig and device under test are connected to an oscilloscope input, such that the device operates as an optical head, with –2V reverse bias applied to the photodiode.

A fast optical pulse train (risetime <5ns) is transmitted to the sample under test. The output current pulse waveform is observed the risetime of the signal is measured.

The acceptance criterion is such that the contribution to the risetime of the pulse from the photodiode, calculated by subtracting in quadrature the reference pulse risetime, is not increased beyond 3ns.

3 Pre-production Qualification Procedures

Pre-production qualification will take place only on the pre-production batch of 100 photodiodes. It consists of the lot acceptance tests already described and some more detailed tests, summarised in Table 2, that are described below.

3.1 Pre-production Qualification Flow

Samples sizes for the pre-production qualification testing are given in Table 3. Testing will be carried out in order of test number for tests 1-3. Following the first three tests, 60 devices will be used for optohybrid pre-production and will become otherwise unusable in the further parts of the qualification. The remaining 40 devices will first be tested for magnetic compatibility, followed by non-destructive pull-testing of the fibre-pigtail. Ten of these devices will then be used in a 'destructive' fibre pull-test in the latter part of the qualification phase.

All possible tests will be carried out even if one of the early tests results in a failure. This is shown in the process flow of Figure 2. The procedure described will allow maximum information to be passed back to Fermionics for process evaluation and improvement.

Table 3: Sample sizes for use in pre-production qualification testing

Test Number	Test Procedure	Sample Size	Samples destroyed during test
	Total Sample Size	*100% of pre-production batch*	–
1	Visual Inspection	100 devices	0
2A	Optoelectronic characteristic	100 devices	0
3	Non-destructive Fibre pull test	40 devices	0
2B	Optoelectronic characteristic	40 devices	0
4	Magnetic Field Test	10 devices	0
5	Destructive Fibre pull test	10 devices	10

3.2 Pre-Production Test Descriptions

3.2.4 Visual Inspection

The test is the same as for Lot Acceptance (Section 2.2.1)

3.2.5 Opto/electronic characteristic test A

The test is the same as for Lot Acceptance (Section 2.2.2)

3.2.6 Opto/electronic characteristic test B

The test is the same as for Lot Acceptance (Section 2.2.2) but is limited to a measurement of dark current and responsivity, with the same acceptance criteria.

3.2.7 Measurement of Magnetic Compatibility

The bare photodiode sample is placed in a magnetic field of at least 0.1T and any deflection due to the presence of the magnetic field is recorded. The sample size for this test may be reduced from the numbers given in Table 3 and Figure 2 if the first samples tested pass the test.

The acceptance criterion is such that only a weak deflection due to the magnetic field is allowed. This magnitude should be no more than that measured on the earlier prototype Fermionics photodiode with gold-plated copper-ferrule.

3.2.8 Non-destructive pull-test of fibre-pigtail

A tensile load of 7N is applied to the joint between fibre pigtail and photodiode package.

The acceptance criteria are such that no break is allowed and the sample should pass the repeated test of opto/electronic characteristics (B), described in Section 3.2.6.

3.2.7 Destructive pull-test of fibre-pigtail

The photodiode package and MU connector are fixed in the two opposing mounting jaws of a pull-test machine. An increasing tensile load is applied between the connector and package. The load at break is recorded.

When the break occurs, the position of the break is noted for future reference.

The acceptance criterion is such that the breaking load must not be smaller than 7N.

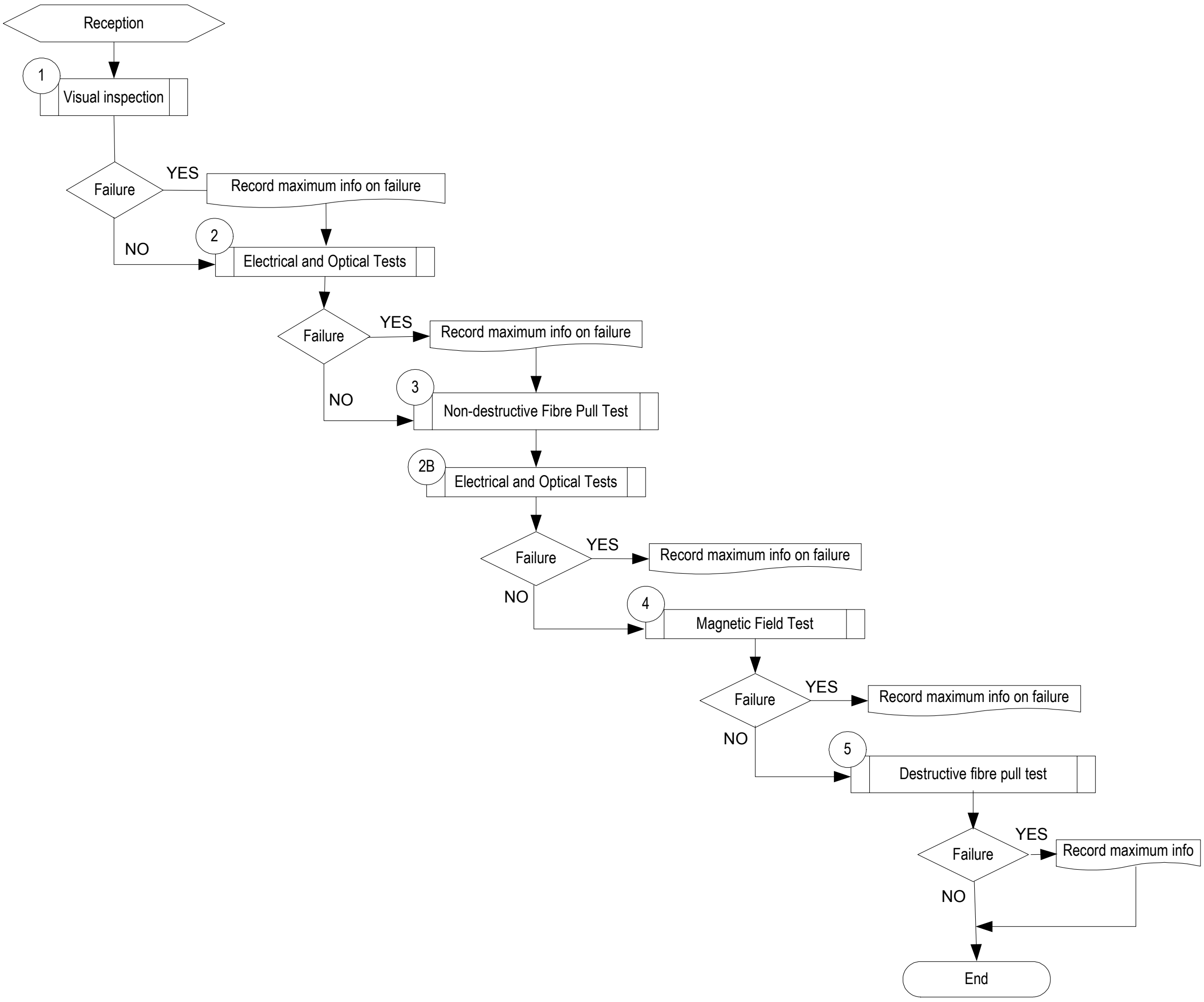

Figure 2: Pre-production Qualification testing flow.

4 Advance Validation Test for radiation resistance

Radiation resistance tests of pin photodiodes will be done in advance validation tests (AVT's). 20 devices from each wafer will be tested for radiation hardness, in advance of the final production of packaged devices from the given wafer. The samples should be packaged in the final form, also with single-mode fibre pigtail having a MU-connector as termination.

The photodiodes will be irradiated under bias, with gamma rays and then with neutrons, up to doses and fluences that are equivalent to the worst-case in the Tracker, i.e. ~150kGy (^{60}Co) and ~5x10^{14}(~20MeV neutrons)/cm^2. (TBD) These figures take into account a safety factor of 1.5 and include the expected damage factor[1] of the neutron source relative to the radiation damage expected from the whole spectrum of particles that will be encountered within the CMS Tracker. The photodiode dark current and photocurrent characteristics will be measured at periodic intervals before, during and after irradiation. The photodiodes will be biased at –5V during the tests.

The 20 irradiated samples, along with the 10 unirradiated samples from each candidate wafer, will be aged at 80°C for 1000 hours. The photodiodes will be biased at –5V during the test. The photodiode dark current and photocurrent characteristics will be measured at periodic intervals.

4.1 Acceptance Criteria

The irradiated photodiodes should have a dark current of no more than 500µA at –5V after gamma and neutron irradiation. The photodiode responsivity should be more than 0.4A/W at –5V after gamma and neutron irradiation.

After aging the dark current at 20°C and –5V should be no more than 500µA for the irradiated samples and no more than 5nA for the unirradiated devices. The responsivity should not fall below 0.4A/W at –5V after ageing of irradiated samples, or 0.75A/W for unirradiated samples.

95% of the photodiode samples from each wafer should pass these criteria for the wafer to be accepted. Should more than 5% of the sample group of photodiodes fail these acceptance criteria, the corresponding wafer will be rejected and a new lot of devices procured from a different wafer.

Given the very good radiation resistance of the devices tested up to this point, the chance of a wafer being rejected should be very small, assuming that the die production technique and starting materials remain the same as those tested in earlier validation tests.

[1] The damage factor for the UCL Louvain la Neuve neutron source is not known for the InGaAs/InP photodiodes, but it is expected to be very similar to that for InGaAsP/InP laser diodes.