Characteristics of 148 Pre-Series Production Sensors from Hamamatsu –B2 Sensors for the Japanese Cluster–

Abstract

The Japanese cluster has received in total of 148 silicon sensors from Hamamatsu Photonics for a part of pre-series production for the Barrel SCT. ⋆ We summarize the characteristics of these sensors which were measured by the manufacturer. Also the leakage current stability of 12 sensors was measured for a period of 24 hours. The detector characteristics in general are satisfactory, which convinces us that Hamamatsu Photonics is able to provide high quality silicon sensors with a delivery rate as expected.

1 Delivery

In total of 148 B2 pre-series sensors have been delivered from Hamamatsu Photonics (HPK). The delivery took place on three times: delivery #1 to #3. The numbers of delivered sensors and numbers of production batches for each delivery are summarized in Table 1. Delivery #3 consisted of four production batches while Delivery #1 and #2 consisted of single batch for each.

Table 1
Delivery of 148 sensors from Hamamatsu (B2 for Japanese Cluster).

Delivery	Serial number range	Delivered number	Number of batches
#1	0200016–032	17	1
#2	0200033–065	30	1
#3	0200236–354	101	4
Total		148	6

⋆ More plots including the raw data can be found in; http://www-hep.px.tsukuba.ac.jp/ hara/sct/148.html

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2 Tests on Each Sensor

2.1 Leakage Current at 150 V

The I-V curves were measured from 0 to 350 V at a voltage step of 10 V. The ambient temperature ranged from 26 to 31°C with typically 27°C. In the following presentation, the leakage current values are corrected for the temperature variation and expressed at 20°C using the relation:

$$I(T) \sim T^2 \exp(-\frac{E_g}{2k_B T}) \tag{1}$$

where E_g=1.12 eV and k_B is the Boltzmann constant.

Figure 1 shows the leakage current distribution at 150 V for 148 sensors. Most of the sensors populate in the range below 0.15 μA with the maximum being 0.43 μA.

We specify that the leakage current be less than 6 μA at 150 V. The 148 delivered sensors all satisfy this specification. The leakage current is typically 1/40 of the specified limit.

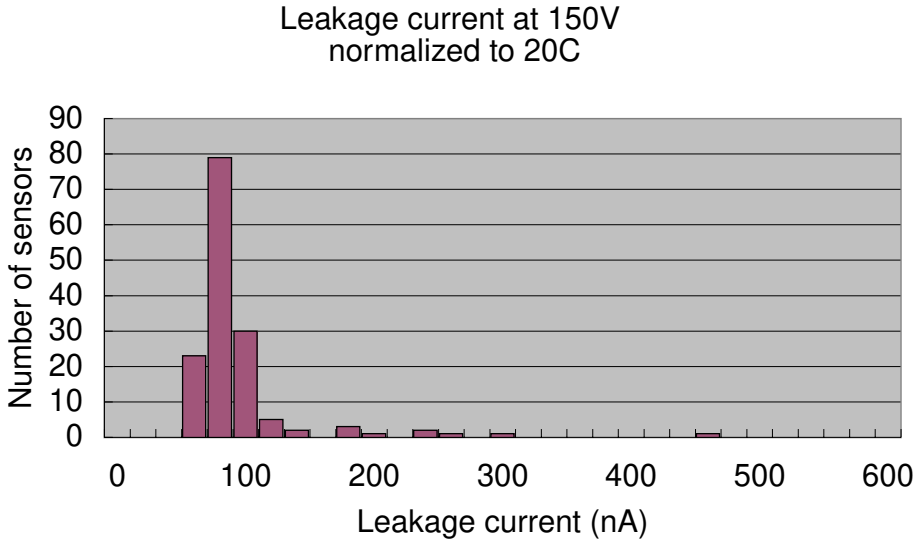

Fig. 1. Distribution of leakage currents at 150 V bias voltage. The values are normalized to 20°C.

2.2 Leakage Current at 350 V

Figure 2 shows the leakage current distribution at 350 V. The most probable values are in the range from 0.1 to 0.2 μA. The maximum value is 0.54 μA.

We specify that the leakage current be less than 20 μA at 350 V. The 148 delivered sensors all satisfy this specification. The leakage current is typically two orders of magnitude smaller than the specified limit.

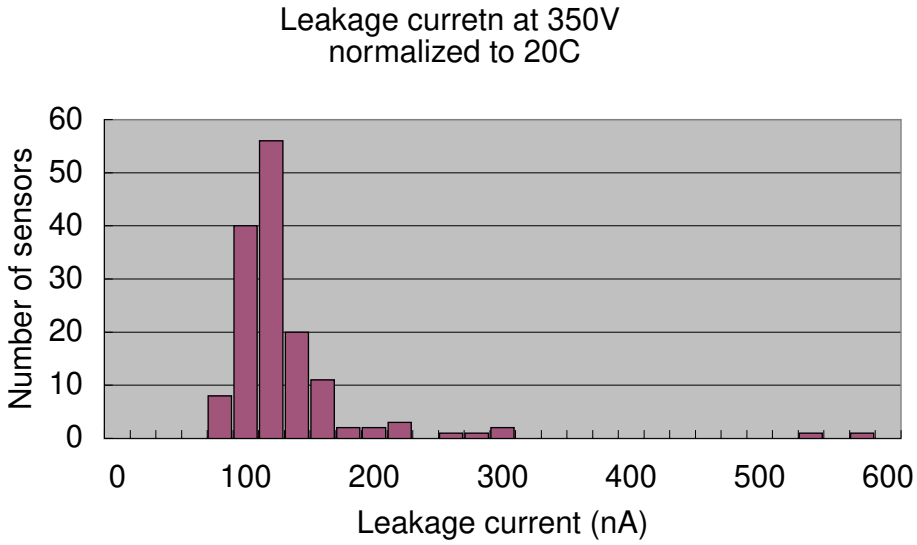

Fig. 2. Distribution of leakage currents at 350 V bias voltage. The values are normalized to 20°C.

2.3 I-V Curves

The *I-V* curves for all the 148 sensors are plotted in Appendix. Most of the sensors show similar curves while a couple of sensors show relatively larger currents (0200017, 0200321) or an instable curve (0200267). They all, however, satisfy the SCT specifications. We need to investigate the stability of such sensors.

2.4 Full Depletion Voltage

The full depletion voltage determined from *C-V* characteristics is plotted in Fig. 3. It ranges from 60 to 90 V with two clusters centered around 65 and 85 V. About 89% of the sensors populate in the larger voltage cluster.

We specify that the full depletion voltage be in the range from 50 to 150 V. Therefore, the whole sensors satisfy this specification.

We note that the wafer thickness distributes in a narrow range from 283 and 290 μm (Specification is 285$\pm$15 μm). Also the full depletion voltage is strongly related to the wafer reference number (wafer lot number). Therefore, the spread of the full depletion voltage should be attributed to the wafer resistivity.

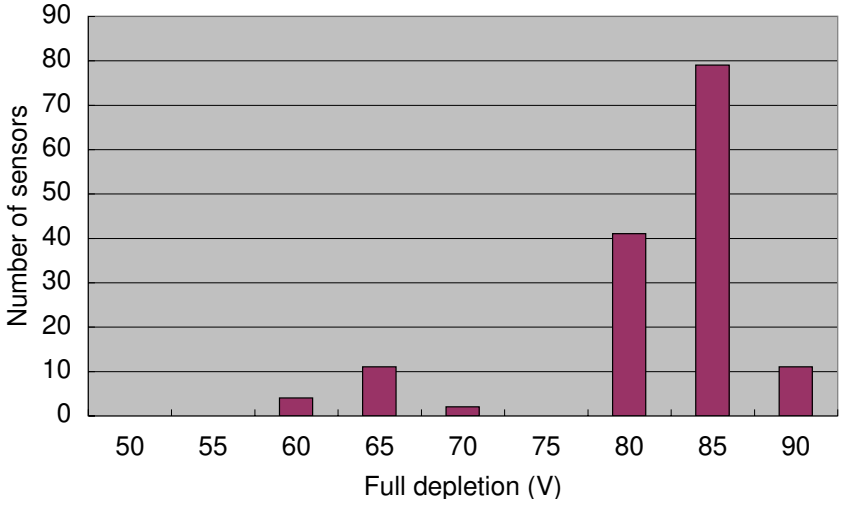

Fig. 3. Distribution of the full depletion voltages.

2.5 Number of Faulty Strips

The number of faulty strips per sensor is plotted in Fig. 4. Out of 148 sensors, 118 sensors (79.7%) show zero faulty strip. The number of faulty strips per sensor is at most six except for one sensor. The sensor 0200017 showed 21 consecutive strips to "punch-through". Actually the Aℓ strips of this sensor are shorted together. It was a bug of the measurement program to classify the fault: "punch-through" should have been "Aℓ short". This bug is fixed in the later delivery batches. The sensor was delivered by mistake since the faulty strip fraction 2.7% exceeds the SCT criteria. Therefore, this sensor is excluded in the statistics of faulty strips.

The main contributors to the faulty strips are the pinholes (20 sensors, or 13.6%), short of neighboring Aℓ electrodes (10 sensors, 6.8%), and discontinuity of the Aℓ electrodes (6 sensors, 4.1%). The statistics of the faulty strips are given in Table 2.

We specify that the faulty strip fraction be less than 2% and the average in a batch is below 1%. The average of the faulty strip fraction is 0.32% among the

sensors with defect strips. It is 0.06% among the whole delivered 147 sensors.

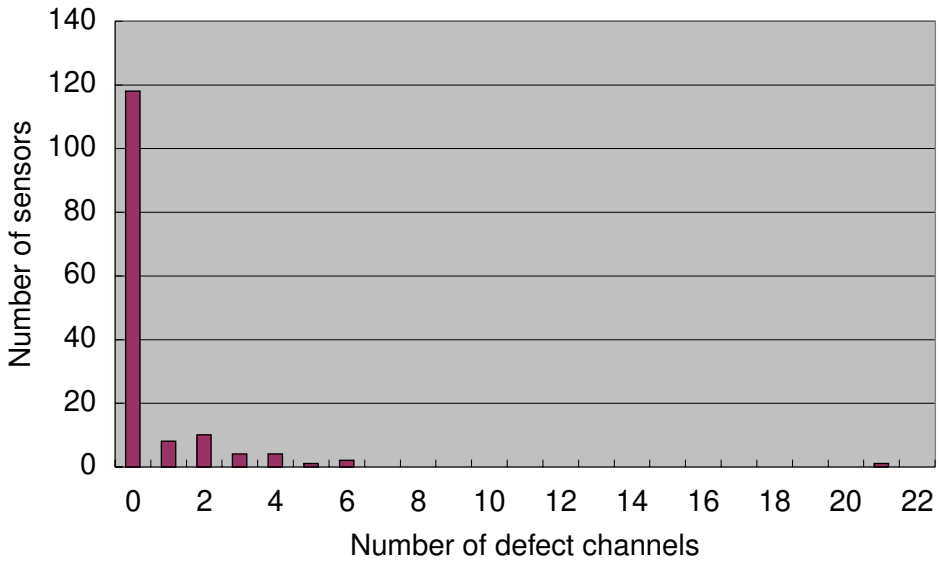

Fig. 4. Distribution of numbers of faulty strips per sensor. The percentages are relative to 147 sensors, or to 768 strips (last two columns). *See text for punch-through.

Table 2
Statistics of faulty strips.

Defect type	#Sensors with defects	Max.#faulty strips	Ave.#faulty strips
Punch-through*	0 (0%)	0	0
Pinholes	20 (13.6%)	5 (0.65%)	1.9 (0.25%)
Aℓ open	6 (4.1%)	4 (0.52%)	1.8 (0.24%)
Aℓ short	10 (6.8%)	4 (0.52%)	2.4 (0.31%)
Total	29 (19.7%)	6 (0.78%)	2.5 (0.32%)

3 Tests on Sub-samples

3.1 Number of Faulty Implant Strips

The defects on the implant strips, implant open and implant short, are evaluated on a sampling basis for 12 sensors, two sensors per production batch. The results are given in Table 2. There is no faulty strips found.

Table 3
Statistics of faulty implant strips. 12 sensors are tested.

Defect type	#Sensors with defects	Max.#faulty strips	Ave.#faulty strips
Implant open	0 (0%)	0	0
Implant short	0 (0%)	0	0
Total	0 (0%)	0 (0%)	0 (0%)

3.2 Polysilicon Bias Resistance

The bias resistors are measured using test structures developed near the real sensor. Measurements are made on a production batch basis, and the maximum and minimum values among the test structures are plotted in Fig. 5. The resistance is expressed in length of real polysilicon resistors. The requirement that the polysilicon resistance be within 1.25 $\pm$0.75 MΩ is fullfilled.

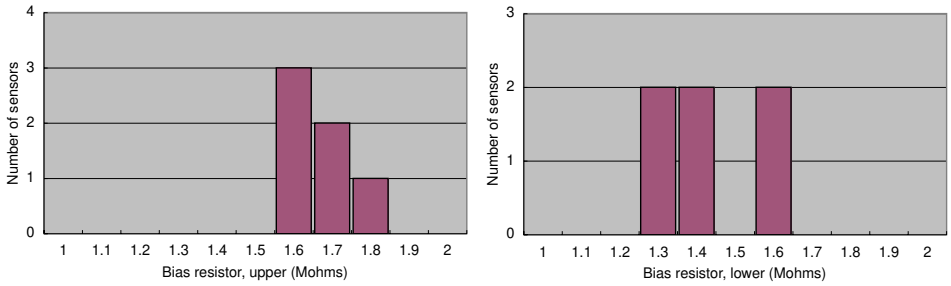

Fig. 5. Polysilicon resistance (left) maximal and (right) minimal in a sensor. Sampling on a production batch basis.

3.3 Leakage Current Stability

The leakage current stability for 24 hours was measured for 12 sensors, two sensors each production batch. The bias voltage was set at 150 V and the temperature was monitored. Figure 6 plots the results of the stability. Although the temperature was stable to within 2°C, we corrected for the temperature variation like the other plots. Unfortunately the temperature was recorded only as an integer, which makes the some of the curves oscillating due to the temperature correction.

All the sensors are quite stable excluding the first data points at T=0. The prompt increase is most distinct for the sensors in Delivery #3: the leakage current measured at T=15 min is nearly twice that measured at T=0. The sensors have experienced various testing before they are measured for the stability. It is most likely that the Delivery #3 sensors have been measured before the surface condition is stabilized.

Figure 7 shows the increase in the leakage current for the 12 sensors. As for the initial leakage current values, we took two values: the leakage current at T=0 in the stability measurement and I_{150} from the I-V curve measurement which was made on a separate day. For the sensors 1 to 4 (Delivery #1 and #2) which showed a stable leakage current in the stability tests, I_{150} tends to larger. For the sensors 5 to 12 (Delivery #3), I(T=24h) agrees better with I_{150}. In any case, the deviations are smaller than ∼90 nA, and most important the leakage currents are stable for 24 h from T=15 min. The speficiation that the leakage current be stable to 2 μA is satisfied.

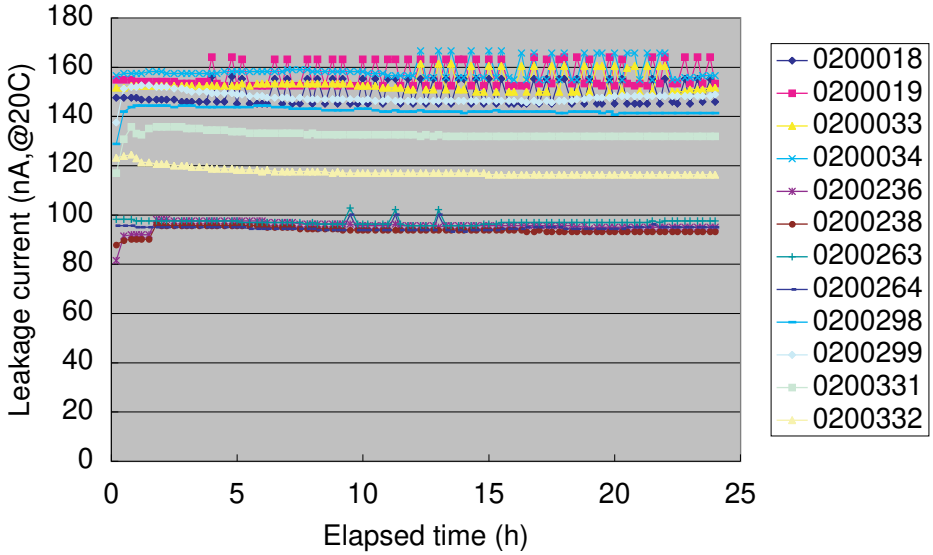

Fig. 6. Stability of leakage current measured at 350 V. The temperature variation is corrected.

4 Summary

We have received 148 B2 pre-series sensors from Hamamatsu. The Hamamatsu sensors satisfy the every aspects of the specifications. The faulty strip fraction was at most 0.8% while 90% of the sensors showed no defective strips. 91% of the sensors had leakage currents smaller than 200 nA at 350 V, and no sensor with >600 nA was found. The leakage current was stable to ∼90 nA for a period of 24 h.

5 Appendix

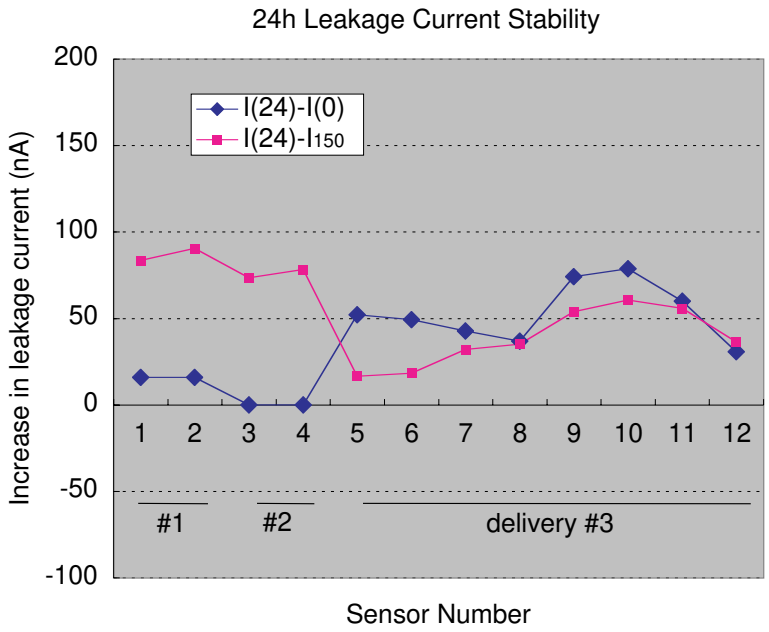

Fig. 7. Increase in the leakage current in the stability tests. (diamonds) Difference between T=24h and T=0. (squares) Difference between T=24h and the leakage current from I-V curve measurement.

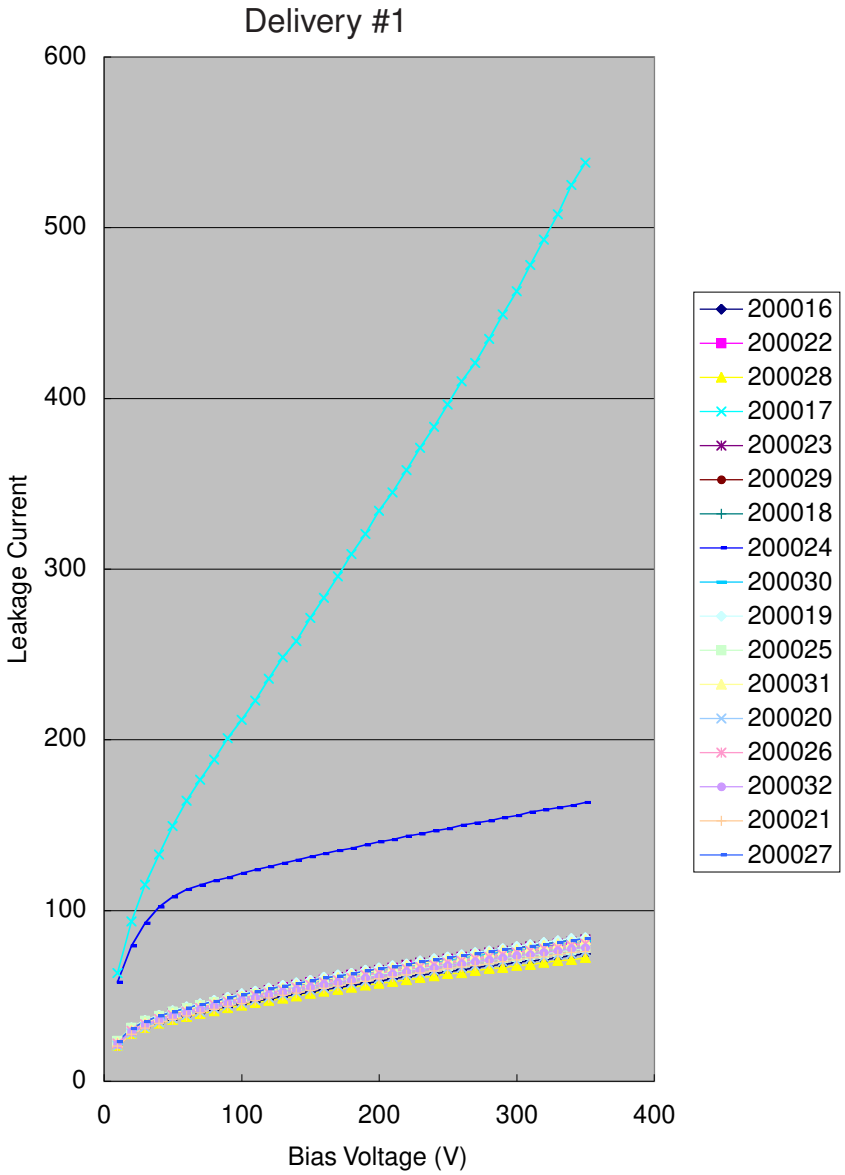

Fig. 8. I-V curves of 17 sensors (Delivery #1). The temperature is 20°C.

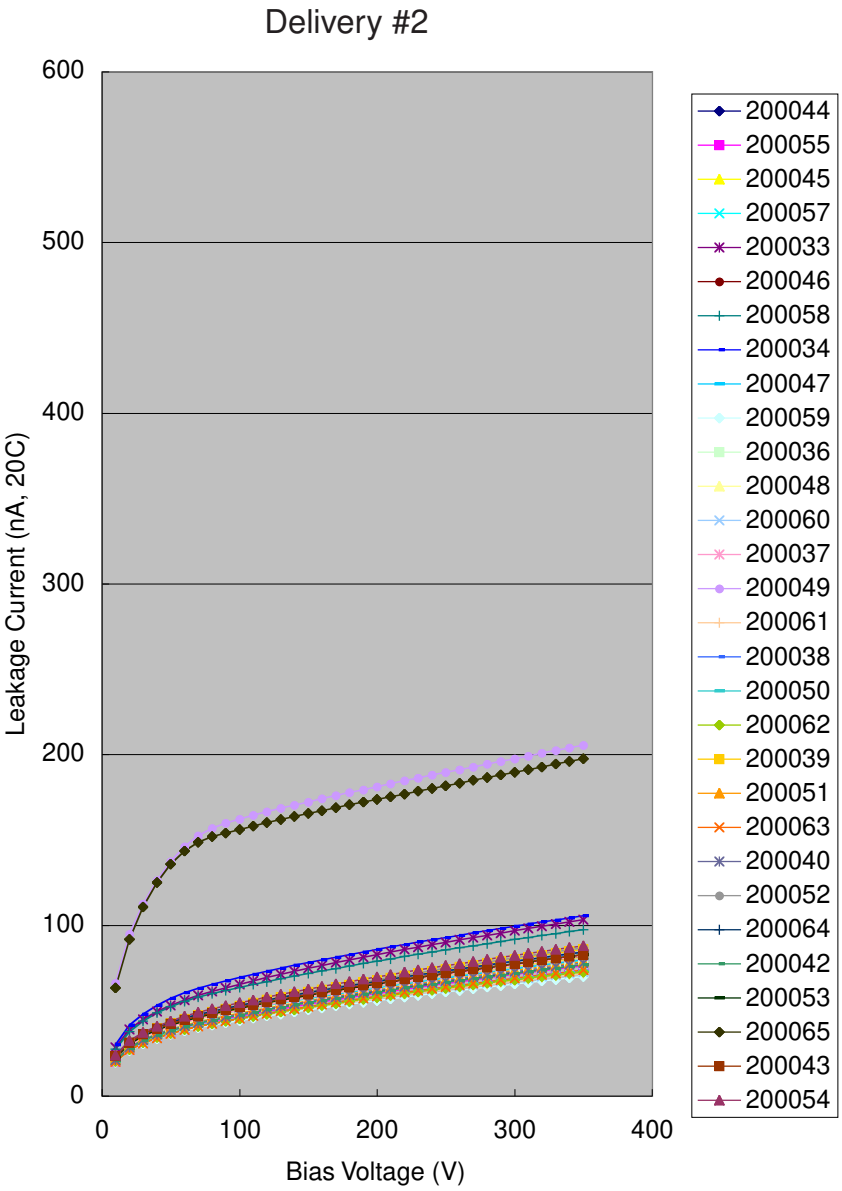

Fig. 9. I-V curves of 32 sensors (Delivery #2). The temperature is 20°C.

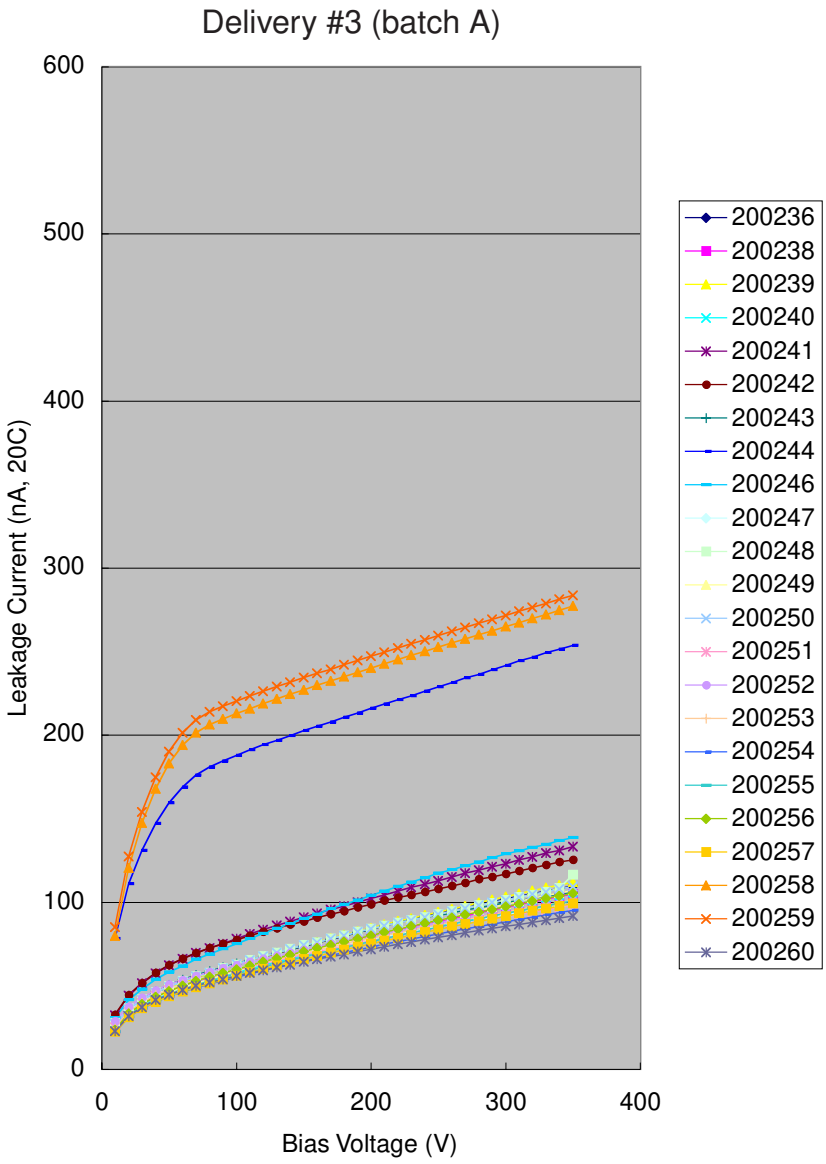

Fig. 10. I-V curves of 26 sensors (batch A of Delivery #3). The temperature is 20°C.

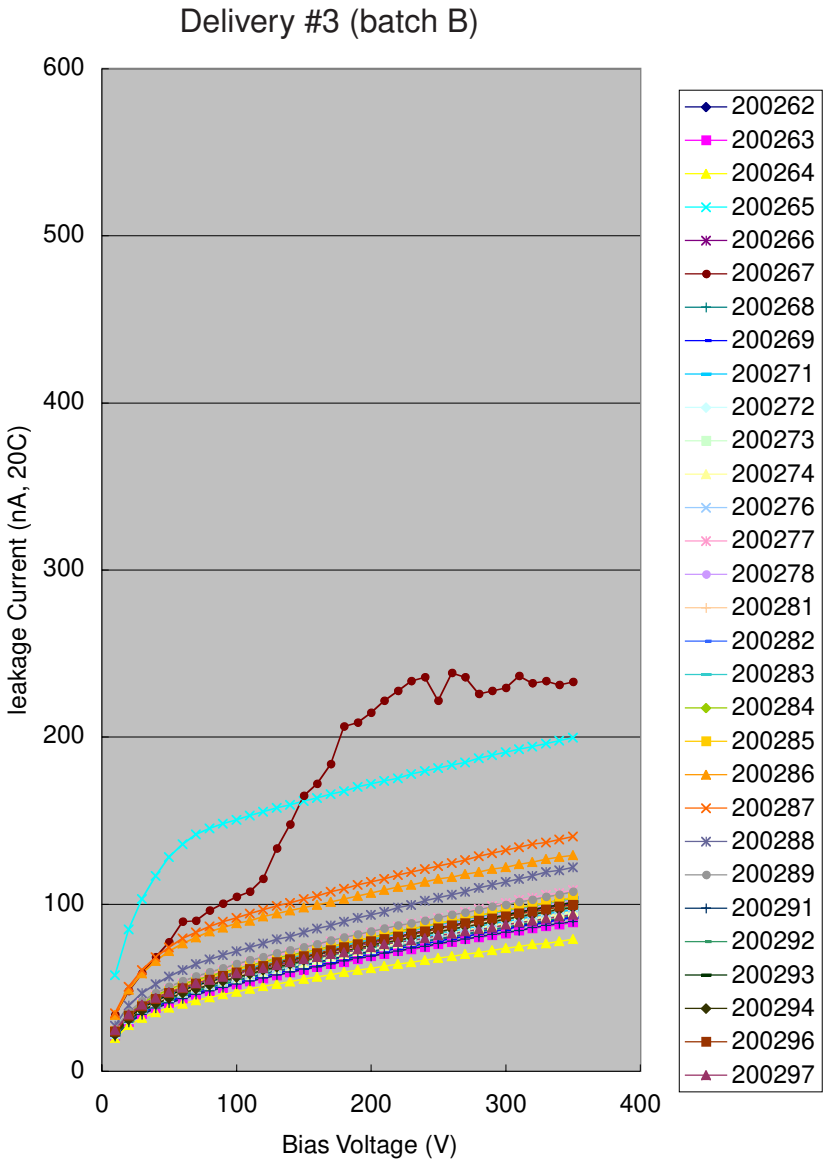

Fig. 11. I-V curves of 36 sensors (batch B of Delivery #3). The temperature is 20°C.

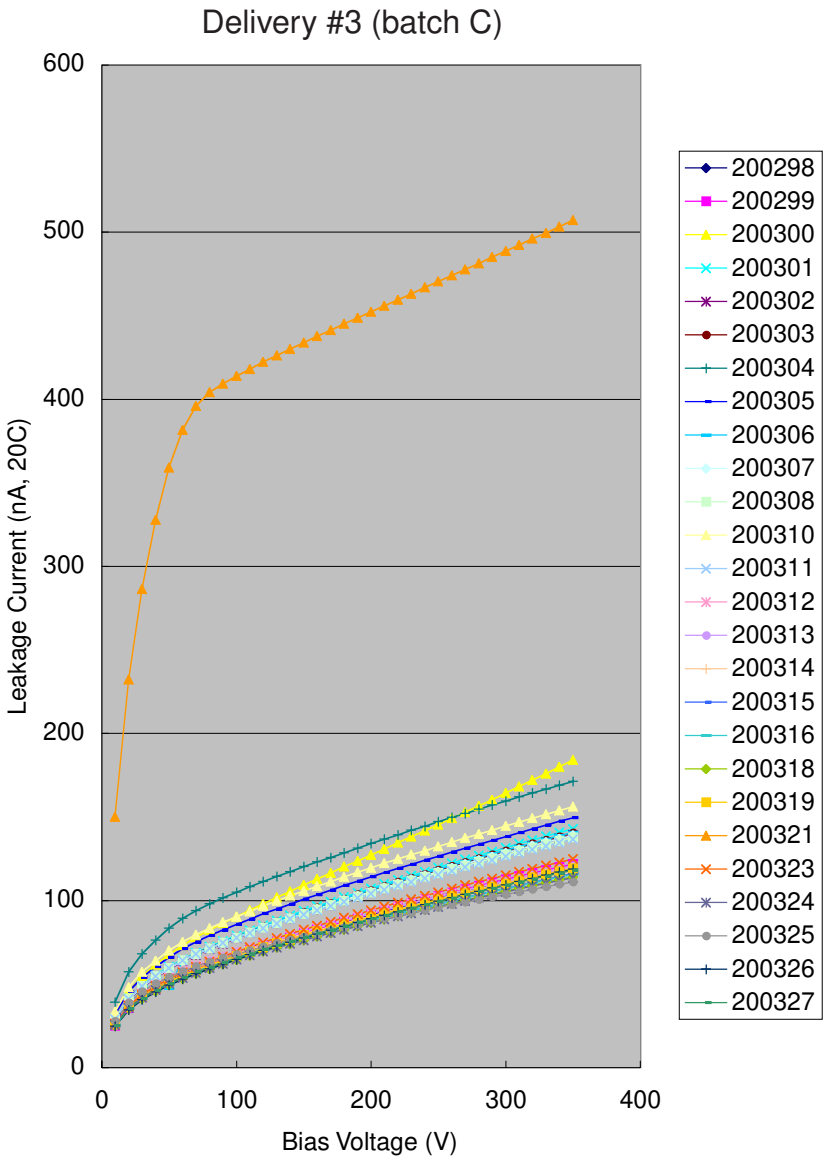

Fig. 12. I-V curves of 30 sensors (batch C of Delivery #3).The temperature is 20°C.

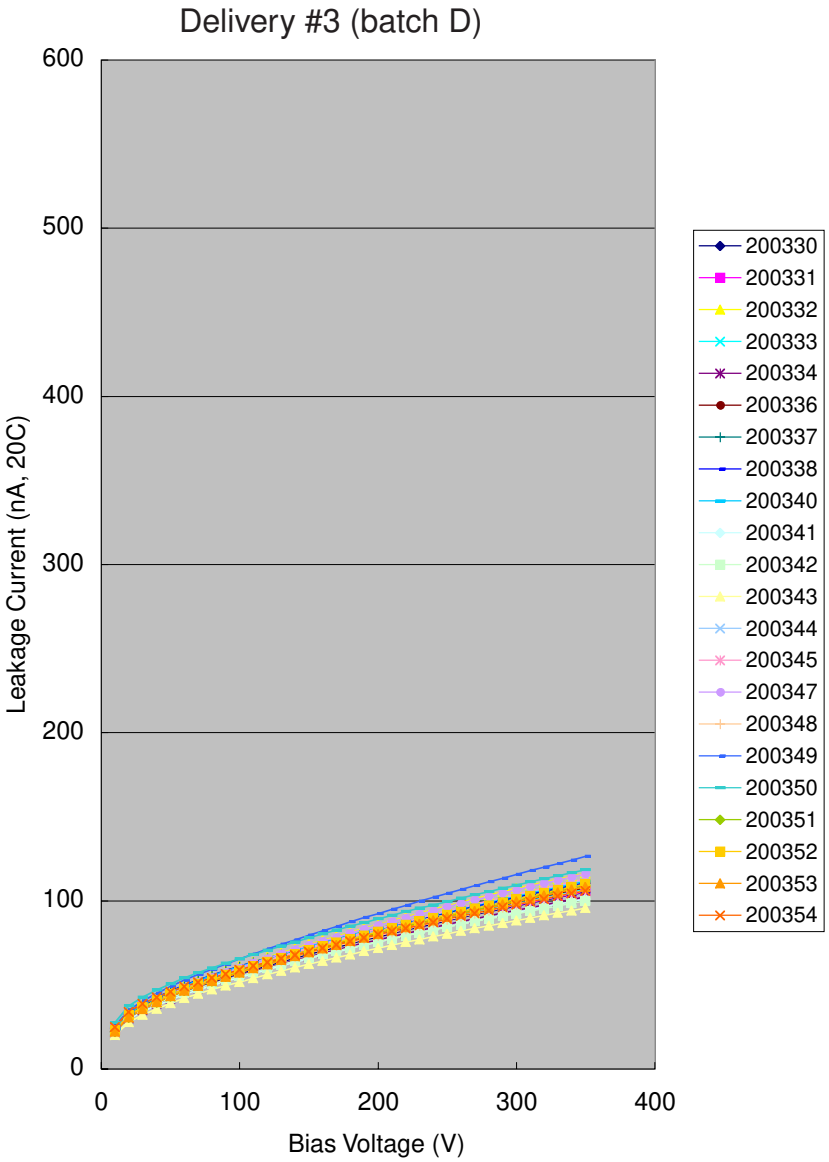

Fig. 13. I-V curves of 27 sensors (batch D of Delivery #3).The temperature is 20°C.