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ABSTRACT

PHOTOCURRENT VARIABILITY OF DISCRETE BIPOLAR DEVICES

Thirty-nine (39) bipolar device lots (195 devices) were tested for peak photocurrent. Difference in average photocurrent between lots of same device types was less than a factor of three in all cases.

DISCLAIMER

SUMMARY

PHOTOCURRENT VARIABILITY OF DISCRETE BIPOLAR DEVICES*

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PURPOSE OF WORK:

The purpose of this work was to determine: (1) the peak photocurrents (I_{pp}) of test devices over a wide range of dose rates, (2) the variability of I_{pp} across any given lot, and (3) the variability of I_{pp} from lot to lot.

SIGNIFICANT RESULTS:

This paper focusses on variability of the I_{pp} between lots and within lots of selected bipolar part types. Lot to lot variability is frequently a question which arises in Hardness Assurance (HA) programs. The study sample showed a variability of up to a factor of two in lot to lot variation in diode photosensitivity and as much as 2.8 for transistors. Variation over a wafer or date lot code was of the same order of magnitude, with wafer traceability making little or no difference.

TEST DEVICES:

Twelve diode device types were tested, with multiple lot testing for five types. Six of the test lots were wafer traceable. The remaining eleven diode lots were date lot coded. Twenty-three transistor lots were tested, of which seventeen had wafer traceability and three were only traceable to the diffusion run. The remaining three transistor lots were date lot coded. Multiple lots were sampled from all six transistor types. All devices were manufactured in 1987, except for one lot date coded for 1985.

TEST APPROACH:

The devices were tested with a linear accelerator (LINAC) at the IRT Corporation in San Diego, California. Three to six microsecond pulse widths of 18 MeV electrons were used, producing essentially steady-state photocurrents in the tested devices. A specially designed low noise test fixture was used that minimized electromagnetic pickup from the LINAC. The photocurrent was integrated to further improve the signal to noise ratio. These methods were found essential for accurate measurement of photosensitivity in small and medium-sized devices. Five samples were tested from each lot.

*This work was performed at Sandia National Laboratories, which is operated for the U.S. Department of Energy under contract number DE-AC04-76DP00789.

TEST RESULTS:

Typical test results showing lot to lot variability are shown in Figures 1 through 4. The dose rate used in calculating these data is the average dose rate for a number of measurements in which the dose rate varied by no more than 1.0E7 rad(Si)/s. I_{pp} at the average dose rate was calculated using the formula:

$$I_{pp} = Kg^N,$$

where K and N are constants specific to the device type and are derived from measurements over a wide range of dose rates. The variable g is dose rate. The average dose rate used for testing transistors was different from the average dose rate for diodes in order to avoid errors in interpolation.

The average photocurrent of various lots varied considerably for both diodes and transistors. The ratio of maximum lot average photocurrent to minimum lot average photocurrent is as high as 1.97 for diodes and 2.79 for transistors, depending on part type. The parts with the lowest lot to lot variability had ratios of 1.16 and 1.23 for diodes and transistors, respectively. Wafer traceability of lots within a part type did not affect its lot to lot variability.

Photocurrent variation within lots is represented by the ratio of the standard deviation and the average, or relative standard deviation. For diodes, this varied from 2 percent to about 45 percent, depending on part type. Variability within a lot was smaller for transistors, ranging from 4.5 percent to 23.9 percent relative standard deviation. Again, wafer traceability was not a significant factor determining variation within a lot.

SUMMARY AND CONCLUSIONS:

Photocurrent measurements on bipolar junction transistor and diode lots manufactured in the same year by the same manufacturer show significant lot to lot variability. The greatest ratio of maximum to minimum lot average photosensitivities was 2.79 for a transistor type and 1.97 for a diode type. Photosensitivities within a given lot showed a similar degree of variability. However, the diodes were observed to vary more within a lot than the transistors. Wafer traceability was not a significant factor determining variation within a lot.

In the full paper we intend to present the correlation of photosensitivities to measured resistivity profiles in epitaxial and substrate layers. Such an inexpensive (about $100 per specimen) characterization should predict relative photosensitivity variation in discrete bipolar device types. This technique may supplant actual photocurrent measurements in many cases where continued lot monitoring is required. Because the technique focusses on epitaxial and substrate layers rather than finely scaled features, it can be applied to integrated bipolar technologies as well.

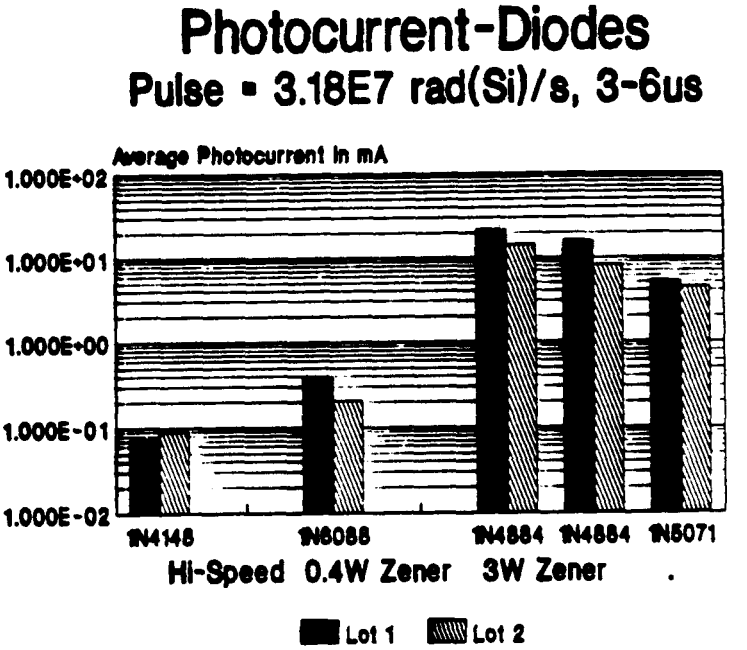

Figure 1. Lot to lot photocurrent variation for 5 lots of diodes.

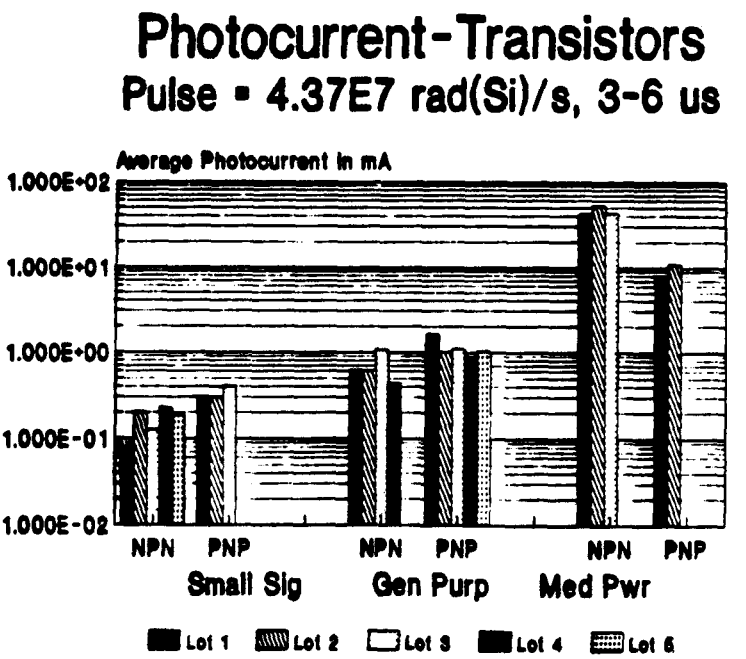

Figure 2. Lot to lot photocurrent variation for 22 lots of transistors.

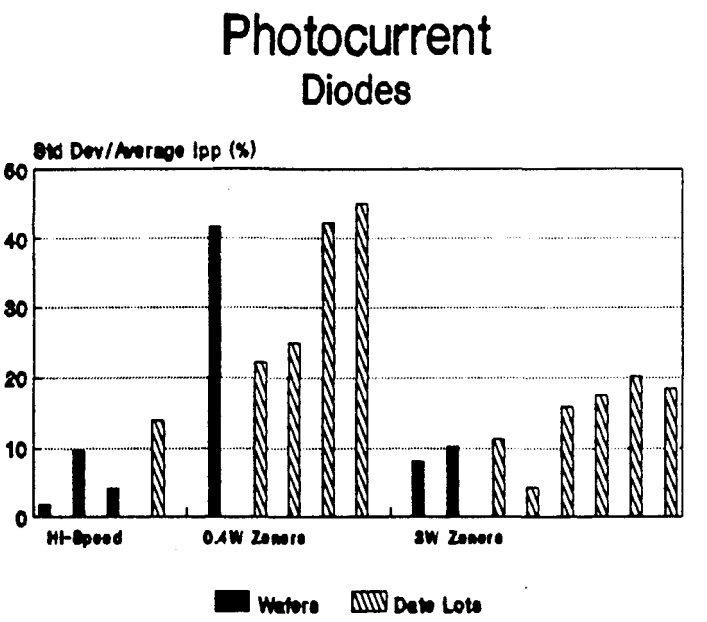

Figure 3. Standard deviation as a percent of average photocurrent for 17 diode lots.

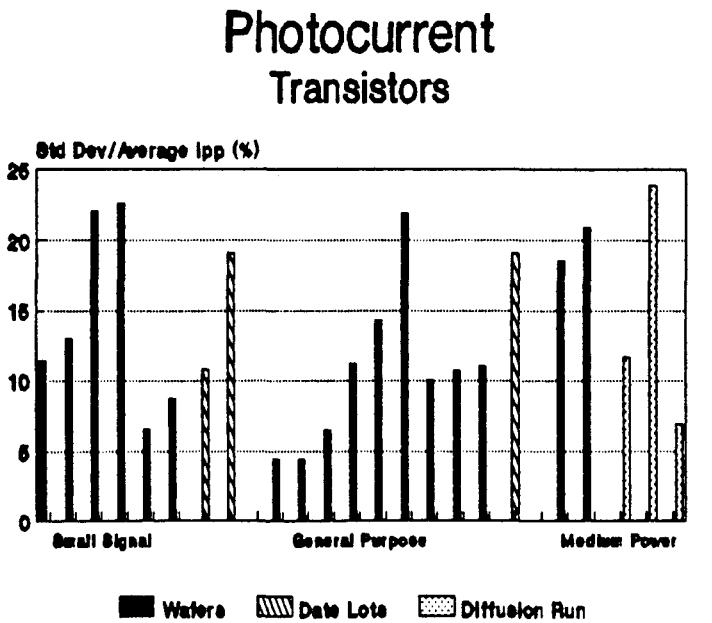

Figure 4. Standard deviation as a percent of average photocurrent for 23 transistor lots.