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COMPARISON OF NÜR-PIN PHOTODIODE AND BPW34 PIN PHOTODIODE

Emre Doganci[1,2], Aliekber Aktag[1,2], Ercan Yilmaz[1,2*]

[1]Physics Department, Bolu Abant Izzet Baysal University, Bolu, Turkey
[2]Nuclear Radiation Detectors Application and Research Center (NÜRDAM), Bolu Abant Izzet Baysal University, Bolu, Turkey

Abstract. *The Silicon PIN photodiode (NÜR-PIN) with active area (3.5. x 3.5. mm²) was designed and fabricated on (100) N-type floating zone silicon substrates by using conventional photolithography process at Nuclear Radiation Detectors Applications and Research Center (NÜRDAM). To get NÜR-PIN and BPW34 specifications, capacitance-voltage (C-V) and current – voltage (I-V) measurements were accomplished at room temperature by using Keithley 4200-SCS and results were compared. The leakage current and capacitance at -10V are 20 nA and 17.7 pF for NÜR-PIN, 32 nA and 27 pF for BPW34. Even if NÜR-PIN has good results at low reverse voltage, it is unstable at high reverse voltage compared to BPW34 photodiodes.*

Keywords: *Silicon PIN photodiode, BPW34, Current – Voltage, Capacitance – Voltage*

1. INTRODUCTION

Silicon PIN photo diode structure (P^{++} - I- N^{++}) on floating zone high-resistivity substrate is generally operated full depletion mode or over depletion region. So, PIN photodiodes are widely preferred devices for microelectronic application [1]. In addition, Silicon PIN photodiode with its small size and good resolution under low dose radiation is alternative to thermo-luminescent dosimeters (TLD) to measure radiation dose [2]. Accordingly PIN photodiode usage for radiation detector applications has a lot of potential [3]. In recent studies, many silicon PIN photodiode was tested under gamma and X-ray radiation [4-5]. Especially, BWP34 PIN photo has tested for dosimeter system and obtained good result under low dose measurement [5]. In this study, Si-PIN photodiodes (NÜR-PIN) with 3.5 x 3.5 mm² active areas were previously fabricated and initial capacitance and current characteristics have already investigated. We compared the characteristics of NÜR-PIN with commercial product electrical characteristics of BWP34 photodiode.

2. EXPERIMENTAL METHOD

2.1. Si-PIN photodiode fabrication

A slightly doped (100) N-type floating zone silicon substrates that have almost 2.4-3.2 kΩ-cm surface resistivity was cleaned by the Standard America Cleaning Application (RCA) process to remove ionic ,oxide and organic contamination. Shortly after RCA process, Initial oxide layer (SiO_2) was grown by wet oxidation at 1100 °C. To pattern P^{++} and N^{++} regions, conventional photolithography and chemical etching process were carried out. Then, the doping was accomplished at 1100 °C in duffusion furnance by using Boron and Phosphorus to form P^{++} an N^{++} region respectively. After that, DC sputtering method was used to create Aluminum metal contacts, and the PIN structure annealed for 10 minute under forming gas to reduce resistivity of metal contact. Finally, The photosensitive regions of the fabricated NÜR-PIN photo diodes were coated with black epoxy and the photo diodes were made insensitive to light for leakage current measurement.

2.2. Electrical measurements of NÜR-PIN and BPW 34 photodiodes

I-V and C-V characteristics of NÜR-PIN and BPW34 photodiodes were measured by using the Keithley 4200-SCS characterization device at 24 °C.

3. RESULTS AND DISCUSSION

3.1. Results of I-V and C-V measurements

The I-V measurements of NÜR-PIN and BPW34 photodiodes are depicted in Fig.1. They were implemented at 24 °C. The leakage current (I_{leak}) measurement results of NÜR-PIN and BPW 34 photodiodes are depicted in Table. I_{leak} value increased with the increase of reverse voltage until breakdown occurs. The obtained I_{leak} values are in consonance with

* yilmaz@ibu.edu.tr

the reported mathematical model [6] that footing discloses relation of the diffusion current to photodiode's active area and the current that is occurred in the depletion region. Furthermore, The I_{leak} value of NÜR-PIN is lower than BPW34 at -10 V. But I_{leak} value increase to 100 nA at higher voltage than -10 V. On contrary, BPW 34 photodiode has I_{leak} value 32-60 nA and BPW34 operates more stable above -10 V. Active states in intrinsic region and tunnel effect are likely to reason of the leakage current [7]. When the applied voltage exceeds the break down voltage, the leakage current becomes independent of the voltage increase. Photodiodes' the voltage value that corresponds to 10 μA is determined as breakdown voltage (V_{br}).

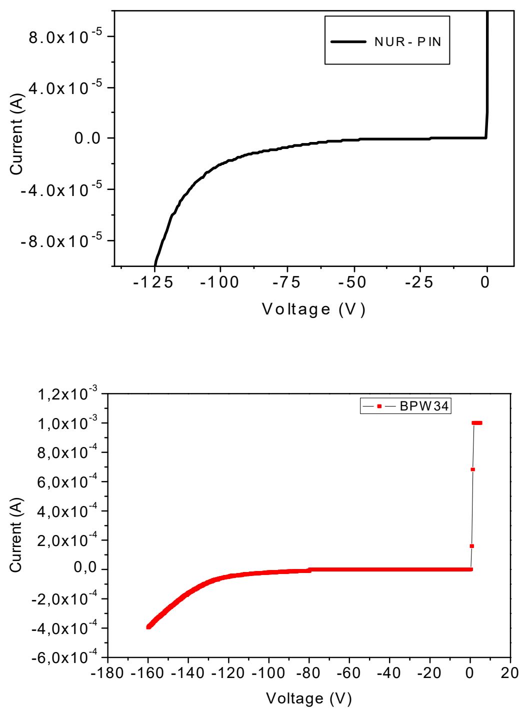

Figure 1. I-V measurement results

The C-V results of NÜR-PIN and BPW34 photodiodes are shown in Fig.2. Low capacitance is desired for high sensitivity and operational speed devices [8]. Full depletion voltage determined from $1/C^2$ versus voltage graph (not shown here). The capacitance values versus reverse bias voltage of NÜR-PIN and BPW34 photodiodes dropped sharply until full depletion voltage. But capacitance values of the photodiodes are negligibly low when the reverse voltage exceeds the full depletion voltage shown in Fig.2. This shows that NÜR-PIN and BPW34 photodiodes proceed to full depletion region and work in full depletion mode at -5 V and -15V respectively. Although the NÜR-PIN photodiode has a larger photo sensitive region, it has a lower capacitance value than the BPW34's capacitance value. The capacitance results of full depleted NÜR-PIN and BPW34 are shown in Table 1. The variations in capacitance values in Table are related to the active area of each Si-PIN photodiodes.

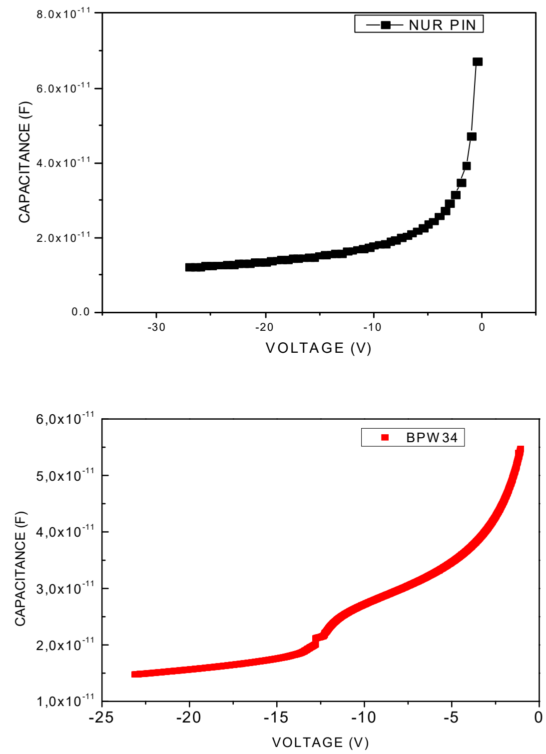

Figure 2. C-V measurement results

Table 1. I-V and C-V measurement results

PIN Photodiode	Active Area mm²	Dark Current (I_{dc}) @ -10V	Breakdown Voltage (V_{br}) (@10 μA)	Capacitance @ -10v
NÜR-PIN	3.5x3.5	- 20 nA	- 84	17.7 pF
BPW34	2.65x2.65	-32nA	-70	27 pF

4. Conclusion

NÜR-PIN photo diode has a low leakage current at nA level up to -10V. However, when a higher reverse voltage is applied to the NÜR-PIN photo diode, the leakage current value rises rapidly to the μA level. Leakage current at low voltage is due to the temperature dependence of the silicon and surface current of diode. When higher voltage is applied, the tunnel effect is the main cause of leakage current. Although NÜR-PIN photodiode performance at voltage is good compared to BPW34 photodiode, High reverse biased needed to measure radiation. So, NÜR-PIN photodiodes can be used for some microelectronic application but leakage current of fabricated NÜR-PIN photodiodes have to be reduced for radiation detection. For this purpose,

a) The thickness of boron doped region (P^{++}) could be optimized between 60 – 140 nm

b) Surface passivation should be used to eliminate surface current contribution.

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