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AN ANALYSIS OF D BAND SCHOTTKY DIODE FOR MILLIMETER WAVE APPLICATION

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ABSTRACT
A Schottky Diode for millimeter wave application proposed in this paper. The proposed model includes the n-well thickness as a variable to explain the operational behavior of a planar Schottky Barrier Diode which is firstly introduced in this paper. This paper shows the differentiation the length of the n-well thickness with three lengths which are 1.6 µm, 1.4 µm and 1.2µm. Then, the size of the Schottky Diode becomes too small with dimension 2.0µm x 2.0µm. The suitable materials that used in this diode are silicon where it has a more advantages than other materials. The Schottky Diode was designed by using the Silvaco TCAD tools software whereas it's also produced the IV and CV Characteristics graph. The both of graph was be analyzes after the three comparison the length of the n-well thickness was specified the values.

Keywords: schottky diode, n-well thickness, silicon, silvaco software.

INTRODUCTION
The Schottky diode is an important device which is widely used in radio-frequency (RF) applications. It possesses many similarities to the point-contact diode. In fact many of the early devices were made in the same way as a point-contact diode, although today's devices are made with totally different manufacturing technique. Unlike conventional semiconductor diodes, which consist of a PN junction, the Schottky diode is made from a metal semiconductor junction. This offers a number of advantages in some circumstances as the diode has a very low forward-voltage drop, and secondly it has a very fast switching speed. Both of these properties make it ideal for many RF applications as well as giving it uses in many other areas (What is a Schottky Diode, 2011).

The Schottky diode is what is called a majority carrier device. This gives it tremendous advantages in terms of speed. Schottky Diode has been alert for possible requests in imaging, encompassing that for concealed weapon detection, aviation assistance, cancer detection, chips card in CMOS, secured high speed data communications and others (Chen *et al*., 2010). Primarily as vital microwave and gesture sources of millimeter wave changing the manage present into wireless frequency output manipulation (Hashim *et al*., 2011). Actually, for the D Band group in this scrutiny, the scope of wireless frequencies from 110 GHz to 170 GHz in the electromagnetic spectrum. The D Group is in the VHF scope of the wireless spectrum. The D Group lies at the way to higher frequency check of present electronic oscillator knowledge, between 110 and 170 GHz.

The structure of Schottky Diode had three type regions which are the n+, n-well and the P-substrate. Each type had values of concentration to design this structure. The suitable materials that used in diode are silicon. It is focusing to the silicon materials because it had more some advantages than the other materials such as GaAs materials. The Silvaco TCAD is some software that are use to create and design structure of Schottky Diode and produce also generate the IV and CV Characteristic graph. The graph is to be observed the current, voltage and the capacitance effects on the graph characteristics. Form the graph, as can see that the how Schottky Diode performances can be applying in industries.

STRUCTURE DESIGN
Figure-1 shows the schematic of a planar SBD in CMOS technology. Planar SBD has rectangular structure while dot-matrix diode has circular structure. In Figure-1, the polysilicon separates the anode and cathode of the SBD. The schematic shows the n+, n-well and the P-substrate. That is also known as a three type of region (Lee *et al*., 2013).

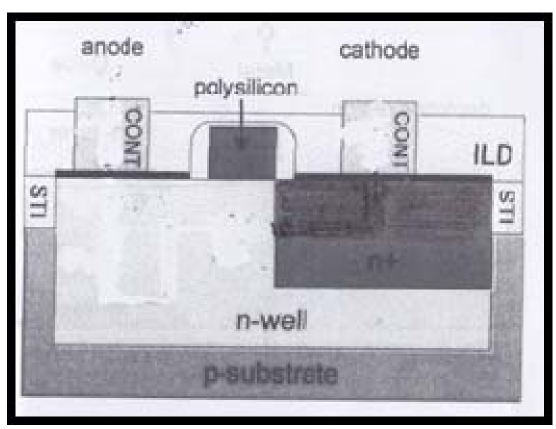

Figure-1. Schematic of Schottky Diode (Lee *et al*., 2013).

Figure below displays the construction and equivalent route of a planar Schottky Diode in CMOS technology. Planar schottky diode has rectangular construction as dot-matrix diode has a circular structure. Figure above, the poly silicon separates the anode and cathode of the schottky diode. A construction proposal is a minimum spreading resistance. In this construction, the R of the schottky diode can be delineated by the combination of the vertical spreading confrontation (Rvs) and horizontal spreading confrontation (RHs) in the n-well span and the link confrontation (Rc) (Hashim *et al*., 2011).

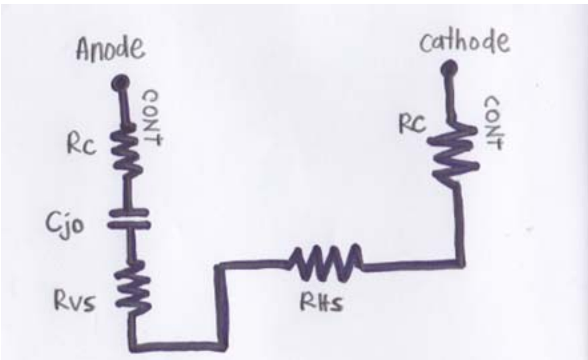

Figure-2. Equivalent circuit of the Schottky Diode (Lee *et al*., 2013).

THEORY AND IV AND CV CHARACTERISTICS

Figure below show the formulae of the IV and CV Characteristics. Actually, there are two ways to generate the IV and CV graph. Firstly, to find it is by using the formulae given and from the simulation.

$$\phi_b = V_t \cdot \ln\left(\frac{A \cdot A^* \cdot T^2}{I_s}\right)$$

Figure-3. Equation IV of the Schottky Diode (Hashim *et al*., 2011).

Analysis of the reverse saturation current of the material is used to count the Schottky barrier heights (SBHs) by employ the Richardson-Dushman calculation for the thermionic current. Anywhere, the barrier height in volts, Is is the reverse saturation present, A* is the competent Richardson steady (8.16 Acm−2 K−2), A is the span of the metal-semiconductor link, T is the definite temperature and Vt is the thermal voltage. The computed Schottky barrier height is 0.4349 eV (Lee *et al*., 2013).

$$C_{j0} = \frac{\pi a^2}{4}\sqrt{q\varepsilon_s N_D/2\phi_{bi}}$$

Figure-4. Equation CV of the Schottky Diode (Lee *et al*., 2013).

Here, as is the diameter of the anode, b is the diameter of the cathode, q is the electron price, μn is the mobility of n- layer, Nd is the doping compression of the n- layer, t is the thickness of the n-layer, d is the thickness of the depleted n-layer, δ is the skin depth of the n- layer, εs is the permittivity of the layer, and ϕbi is the Schottky barrier height.

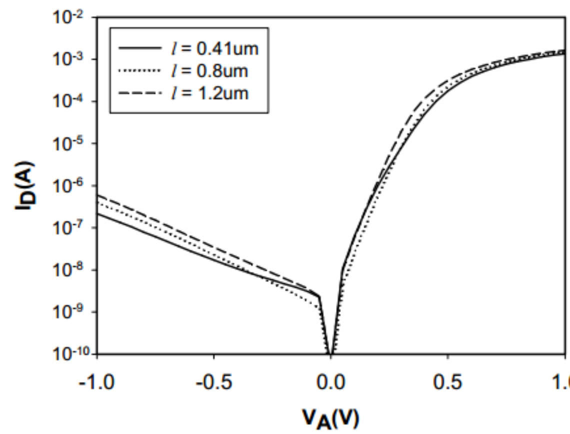

Figure-5. IV graph of the Schottky Diode (Lee *et al*., 2013).

The Figure above is about an analysis of the reverse saturation current of the material is used to count the Schottky barrier heights (SBHs) by employ the Richardson-Dushman calculation for the thermionic current (Hashim *et al*., 2011).

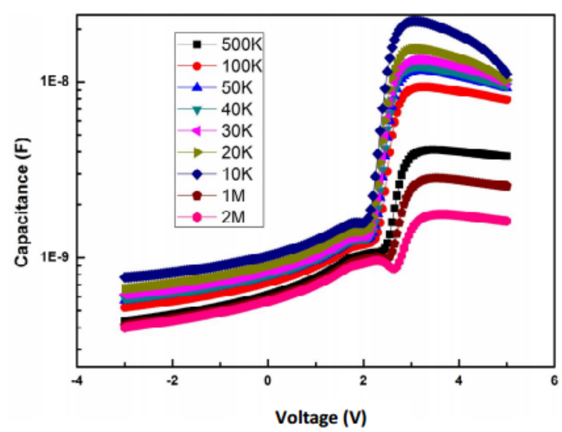

Figure-6. CV graph of the Schottky Diode (Asghar *et al*., 2013).

Figure above is normal C-V characteristics of Au/ZnO/Si Schottky diode amid voltage scope of -4 V to +5 V at room temperature and at disparate frequencies fluctuating from 10 kHz to 2 MHz. The graph displays that the worth of capacitance is cutting alongside rising frequency and plot exhibits a top in affirmative voltage. This top is softly vanished as frequency increased from 10 kHz to 2 MHz. The probable reasons of this top could the attendance of deep states in the band gap, sequence confrontation and interface density states (Asghar *et al*., 2013).

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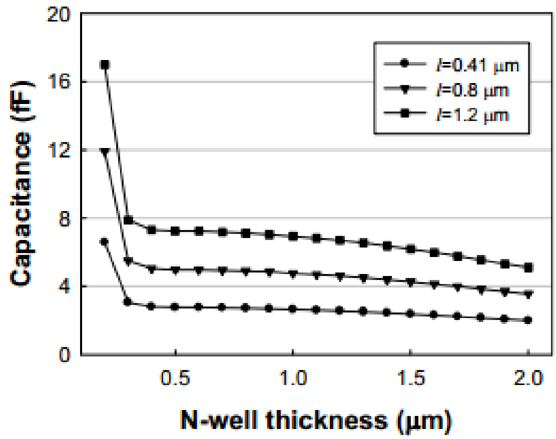

Figure-7. Capacitance Vs n-well thickness graph of the Schottky Diode (Lee *et al*., 2013).

Figure above displays the simulation aftermath of the resistance and capacitance removed from ATLAS simulator. In Figure above, the capacitance of the SBD becomes higher as the anode length increases. After the n-well is thicker than a certain point (0.4 μm in this case), the capacitance is nearly steady for every single anode length. Even though the capacitance seems to be altered by the n-well thickness, the degree of this result is far less momentous than that of the anode span. The higher the length of the N-well thickness, the value of the capacitance becomes increased (Hashim *et al*., 2011).

Model Verifications Using Atlas

Figure below shows the proposed design of structure Schottky Diode by using the SILVACO TCAD Software. In this software had two types that ATLAS and ATHENA. ATLAS for the device simulation whiles the ATHENA for the fabrication process. So, in this project just used the ATLAS because do not do the fabrication process. These papers just show the comparison of size structure diode, the differentiation of the length n-well thickness and the suitable materials. The Figure show the size structure of Schottky Diode is 2.0μm x 2.0μm with include the three type region which are the N+, n-well and the P-Sub. Each region had each their special concentration.

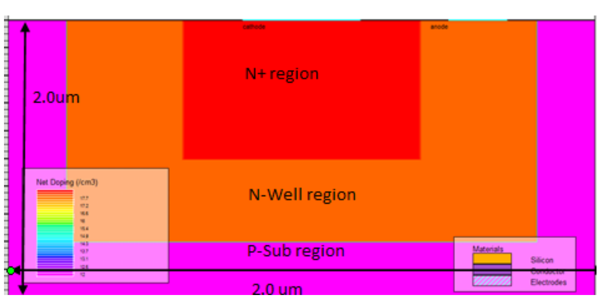

Figure-8. Structure design of the Schottky Diode.

To create this structure just used the SILVACO software. For their step is go to the DECKBUILD and followed by the ATLAS. To produce the structure just runs the coding by using this software with step by step.

Besides that, the materials that used in this project are Silicon. The major reason for such activity is because of the high quality, low cost and large wafer size offered by Si substrates. The GaAs substrate is much extra expensive than Si and the wafer scope is still significantly minor. The benefit of Si with GaAs is its extremely developed processing technology and the very great combination density of circuits' offered. The advantage of Si over GaAs is its highly developed processing technology and the very high integration density of circuits available (Hashim *et al*., 2011). Hence, the structure was produced with the 2.0μm x 2.0μm. Additional, the IV and CV Characteristics graph was produced.

Table-1. Structure of Schottky Diode (Lee *et al*., 2013).

Variable	Value
N_{D-} (for n-well)	$6.5 \cdot 10^{17}/cm^3$
N_{D+} (for n+ region)	$5 \cdot 10^{20}/cm^3$
x_j(n+ depth)	0.45 um
N_A (for p-substrate)	$1.5 \cdot 10^{17}/cm^3$
φ_B (Barrier height)	0.56 eV

The Table-1 shows the concentration of each doping that is used in diode. There are several process and dimension variables in the simulation. The doping concentrations of the p-substrate, n-well and n+ region and the barrier height of the Schottky junction belong to process variables (Lee *et al*., 2013).

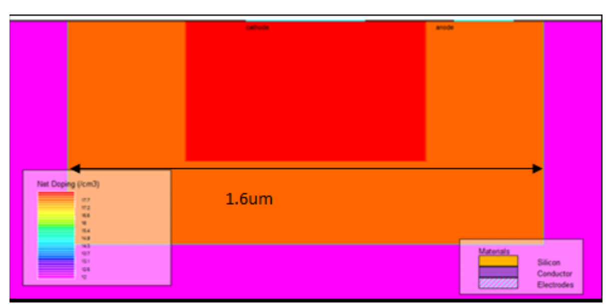

Figure-9. Length with 1.6μm (N-well thickness).

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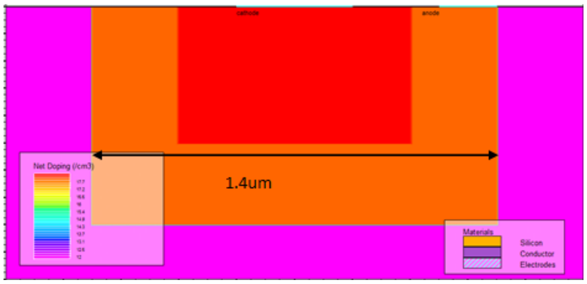

Figure-10. Length with 1.4μm (N-well thickness).

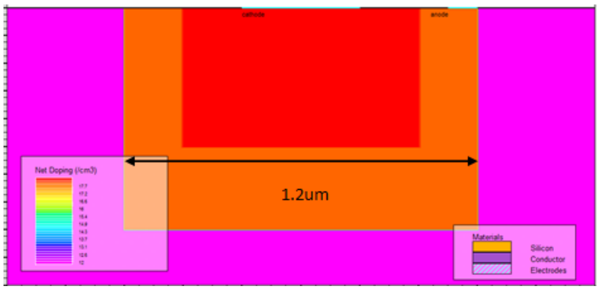

Figure-11. Length with 1.2μm (N-well thickness).

The three Figures above shows the comparison structure with the length of the n-well thickness. The length that is used in the n-well is 1.6μm, 1.4μm and 1.2μm. Each region had a special concentration to get a better graph. Additional, the structure of N-Well thickness length was produced after change their length and see the effect on the IV graph. To get the some effect in the IV graph, the comparison of the length of the N-Well thickness was being created and the results were observed. The results had some differentiation that can be seen.

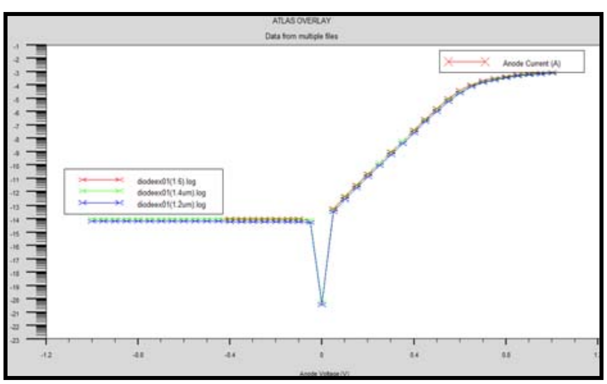

Figure-12. The tonyplot overlay of the IV Characteristics for Schottky Diode.

Figure above show the comparison the length of the n-well thickness. This graph shows the same voltage but its different current intrinsic. In this graph had three lines that are for the red line is 1.6μm, for the green line is 1.4μm while for the blue line is 1.2μm. This line shows the length of the N-Well thickness. Three lengths obtain from the structure as the previous results by coding in SILVACO. Noted, the results show when the lower the length of N-well thickness, the smaller the current produced.

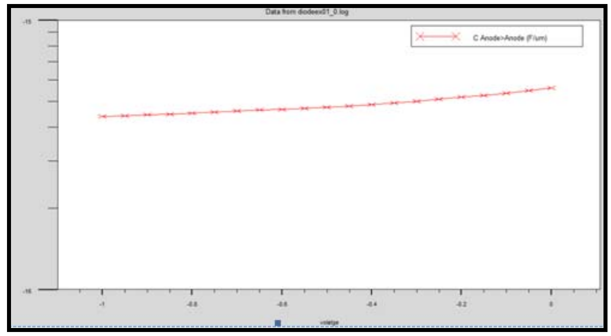

Figure-13. The CV Characteristics of the Schottky Diode.

Figure above show the CV characteristics of Schottky Diode. The graph show the capacitance for the x-axis while for the y-axis is voltage. So, the graph was produced not to be perform because had some problem. The predictions problem may be related with method that are used, the materials chosen, the size of diode, the value of the concentrations that are used and some error can be occurred. May be the materials that used are not suitable. The graph shows are not clearly. From the graph observations, when the high values of the capacitance, the voltage become higher too but not too much. Hence, the observations must be more do the researches why the graph produced like this. Finally, the observations of the graph have been recorded.

CONCLUSIONS

At the end of this project, some aspects had been learned in term of designing and analyzing the Schottky Diode by using Silvaco TCAD Tools. A Silicon-based Schottky Diode was designed with variation of length demonstrate for n-well thickness. As results, smaller size of the n-well thickness length corresponds to a smaller current. Silicon materials will bring a higher integration density for circuit available compared to GaAs materials. The new low-cost and high reliable devices will enhance the performances of the Schottky Diode which can be utilized in millimeter wave application. Finally, the objective of this project was achieved and successfully.

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