Sharp Edges Schottky Contact Electric Field Simulation

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Abstract

This paper reports investigation on effect of adding sharp edges to Schottky contact. Few studies suggested that sharp edge nanostructures produces high electric field which subsequently improve gas sensing performance on reversed biased mode. Three different shapes: circular-, hexagon- and star-shape were modeled by using COMSOL Multiphysics. The study on effects of different sizes sharp edges Schottky contact also reported. Electric field was observed and it shows that star-shape yields highest summation of electric field 2.79 x 10^9 V/m and lowest electric field observed at circular-shape 7 x 10^7 V/m. The results also revealed that distance of sharp edges from substrate edge affects the magnitude of electric field.

Keywords. Schottky contact; Electric field; Sharp edges; Hexagon-shape; Star-shape; Simulation

Introduction

Schottky diode has been used as power diode as well as a sensor. It consist of metal-semiconductor configuration structure. Platinum (Pt) or Palladium (Pd) usually was used as the Schottky contact metal. And then it was followed up with another interfacial layer of wide band-gap semiconductor such as Zinc Oxide (ZnO) or Titanium dioxide (TiO_2) on top of silicon (Si) substrate. Finally an ohmic contact deposited as bottom layer. In gas sensor application, the catalytic metals can dissociate molecular of hydrogen gas into atoms hence creating dipole charge at the metal-semiconductor interface thus changing the barrier height. It is known that sharp edges on Schottky contact was avoided in power application due to leakage current. However, researchers have reported that sharp edges nanostructure on Schottky diode enhance the performance of hydrogen sensor Schottky diode [1, 2]. The sharp tip of nanostructures induced a strong electric field at reverse biased condition. Consequently it affected the Schottky I-V characteristics and become a highly sensitive gas sensor in reverse biased condition. Conventionally a circular Schottky contact was utilized in Schottky diode. Therefore motivated by the nanostructure sharp edges effect, a study on sharp edges Schottky contact was investigated in this paper. An experiment was conducted with fabricated hexagon Pt/ZnO/Si Schottky diode sensor and can be read further in [3].

Methods

Three different shapes were modeled using COMSOL Multiphysics. Circular-, hexagon- and star-shape were modeled as Pt Schottky contact on 5 mm x 5 mm silicon substrate. Then, three different sizes 2, 3 and 4 mm diameter shapes were constructed by using the circular-shape diameter as the base. The dimension details is described in Table 1. Figure 1 illustrates the dimension and design of the modeled Schottky contact.

Table 9. Schottky contact dimension

Shape	No. of Sharp Edge	Area(mm^2)

	Diameter	2mm	3mm	4mm
Circular	Null	3.14	7.06	12.55
Hexagon	6	3.46	7.79	13.86
Star	10	1.71	3.86	6.86

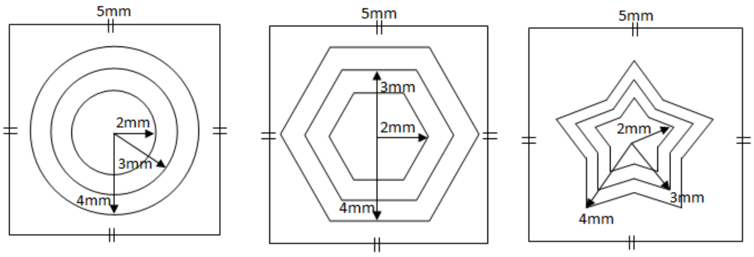

Figure 1. Circular-, hexagon- and star-shape Schottky contact design

Results and Discussion

Electric fields were measured as integral summation of electric field. Figure 2 depicts that 4 mm diameter star-shape gives highest electric field 2.79 x 10^9 V/m. Next highest electric field is 4 mm hexagon-shape and followed by 2 mm star-shape with 2.42 x 10^9 V/m and 1.85 x 10^9 V/m respectively. All circular-shape show lowest electric field. Although star-shape area is ~45% smaller than circular- and ~50% smaller than hexagon-shape, it shows higher magnitude of electric field. This is cause by acute angle of star-shape compared to hexagon-shape. Besides, from the simulation it was observed that only convex sharp edges of star-shape contribute to high electric field. The magnitude of electric field measured at convex (72˚) and concave (144˚) point are 4 x 10^4 V/m and 0.2 x 10^4 V/m respectively.

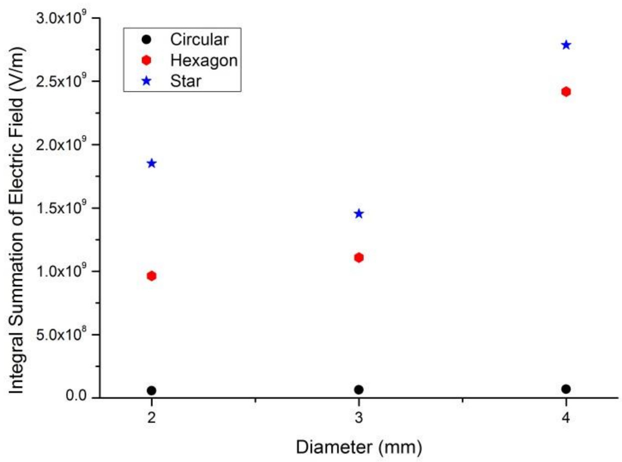

Figure 2. Integral summation of electric field for circular-, hexagon- and star-shape at different sizes.

Furthermore, it was observed that distance of sharp edges to the edge of the substrate affects the magnitude of electric field. Figure 3 illustrates electric field intensity of hexagon shape with different sizes. Each sharp edge points were labeled from one to six. Point 6 was fixed to study this substrate edge effect. Lighter blue color indicates higher intense of electric field. Figure 4 plotted measured electric field at each points. It reveals that Point 6 electric field magnitude declining upon increment of size. On the other hand, magnitude of electric field at Point 3 increased with increment of size. This is due to Point 3 distance from substrate edge reduced with enlargement of Schottky contact size.

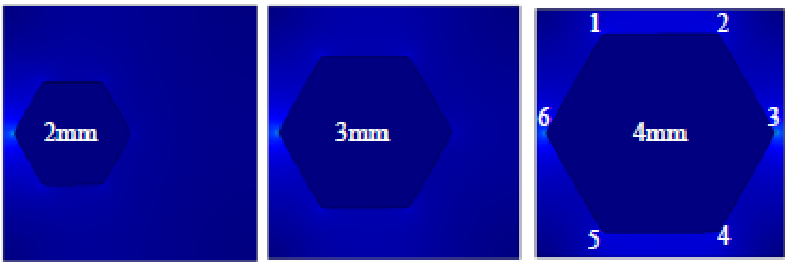

Figure 3. Electric field intensity at 2, 3 and 4 mm hexagon-shape with fixed corner at Point 6

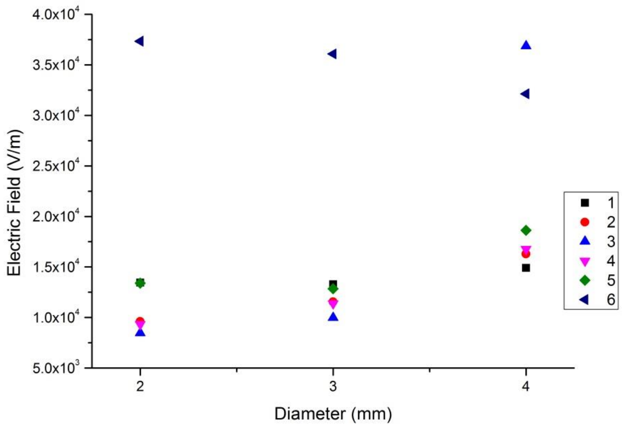

Figure 4. Electric field measured at six points of hexagon sharp edges

Conclusion

The simulation of circular-, hexagon- and star-shape Schottky contact reveals that highest electric field was observed at star-shape Schottky contact 2.79 x 10^9 V/m. Then it is followed by hexagon- and circular-shape with summation magnitude of electric field 2.42 x 10^9 V/m and 7 x 10^7 V/m respectively. It was also observed that distance of sharp edges to the substrate edge contributes to the electric field intensity. Magnitude of electric field increased when sharp edges approaching the substrate edge. On the other hand, magnitude of electric field decreased when the sharp edges far from the substrate edge.

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