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Silver Nanoparticulate Matter Reinforced Conducting Polymer Polyaniline Nanocomposite: Sol-Gel Processing, Schottky-Diode Making and Electronic Worthiness Testing

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Abstract: Polyaniline nanoparticles is synthesized by chemical oxidation of aniline by copper sulphate. Chemical reduction of silver nitrate by sodium citrate yileds silver nanoparticles. Both aforesaid nanomaterials are mixded with polyvinyl alcohol to get nanocomposite gel. Nanoparticles are characterized by ultraviolet-visible absorption spectroscopy. Schottky diode is made by applying nanocomposite with copper wire on one side of aluminium foil and on other side attaching copper wire for another electrical contact. Current-voltage electrical characterization is analyzed by making simple circuit encompassing polyaniline/silver nanocomposite diode.
Keywords: Nanoelecttronics, Nanoparticles, Polyaniline, Nanocomposite, Schottky-diode

I. INTRODUCTION

Nano-electronics and nano-electro-mechanical systems are promising trendy research areas in engineering and technology, and applied electronics. Many molecular nano-scale devices (diodes, switches, wires, etc) are made and tested inresearch centers [1-5]. Amongst various nano-devices, considerable significance is making and testing Schottky diodes using conducting polymer and metal foils. This diode offers several advantages over conventional ones, viz., less voltage drop, low heating problem, greater efficiency, high current density levels and minimum capacitance [1, 5-10]. Poly-anilines (PA) are excellent conducting polymer. Because of its rich chemistry, poly-aniline is one of most researched polymers of past century. To tell elaborately, poly-aniline and its derivatives possess high chemical stability, easy preparatory scheme, high electrical conductivity and for being cheapest material choice [1, 6-12]. On other hand, silver possesseshighest electrical conductivity, and is excellent metal for making conducting composites [1, 6-10, 13]. Electronics applications, such as photovoltaic cells, power supply units, radio-wave detection, etc need Schottky diode. Current nano-article is on making custom nanocomposite (NC) with polyaniline / silver, and fabricating Schottky diode out of it and testing for current-voltage characteristics [1, 6-10].

II. MATERIALS AND METHODS

Analar grade chemicals are used to produce nanoparticles (NP). Aniline and hydrated copper sulphateare reactants used to synthesize polyaniline nanoparticles. Silver nitrate and sodium citrate are reactants used to synthesize silver nanoparticles (10nm). First of all, making PA Nanoparticles is viachemical oxidation.To a solution of aniline in methanol, aqueous copper sulphate solution is added drop by drop with constant stirring. After 45min boiling, dark-green particles (poly-aniline) settles down [1, 6-11]. Secondly, making Ag Nanoparticles is via chemical reduction. To boiling aqueous silver nitrate, aqueous sodium citrate solution is added with vigorous stirring. After 1h boiling, solution is cooled to 25ºC to precipitate light-brown particles (Ag) [1, 6-10, 13]. Next, making PA/Ag Nanocomposite is via colloid formation. Solution of PA nanoparticles in poly-vinyl alcohol (PVA) and that of silver nanoparticles in methanol are mixed and stirred for 2h to obtain PA/Ag nanocomposite gel [1, 6, 8-10]. Finally, Schottky-diode is fabricated by depositing PA/Ag nanocomposite at one side of the Al substrate. Electrical contact Cu wires are attached to Al fresh surface and PA/Ag nanocomposite. Characterisation is done using Ultraviolet-Visible spectra and Current-Voltage plots [1, 6-10].

III. RESULTS AND DISCUSSION

A. Nanocharacterization with UV-Vis Spectra

UV-Visible spectra gives distinct absorption peaks for PA nanoparticles and Silver nanoparticles (**Figures 1 & 2**). Optical absorbance spectra are recorded in 300-600nm region at room temperature. Absorption peak is observed at 335-405nm for PA dispersed in methanol [1, 6-11]. And, absorption peak is observed at 410nm for Ag nanoparticles [1, 6-10, 13].

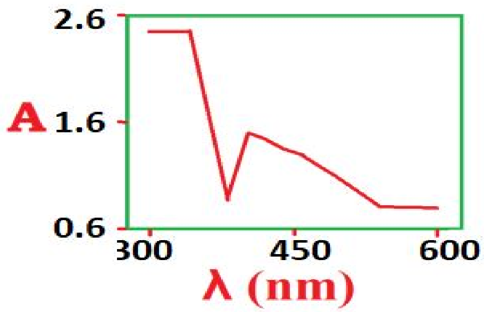

Figure 1. UV-Visible Spectral Peak for Polyaniline

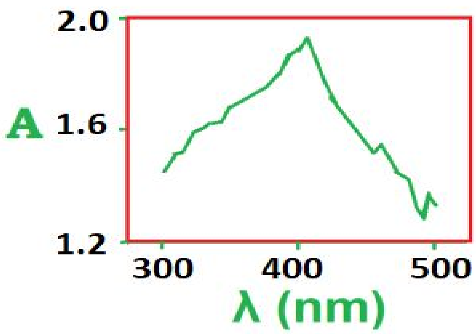

Figure 2. UV-Visible Spectra of Silver Nanoparticles

B. Basic I-V Characterization for Schottky Diode

In the second characterization of Schottky diode, current-voltage analysis circuitry and I-V plotting is done (are shown in **Figures 3 & 4**). Circuit with PA/Ag NC Schottky diode is made on breadboard, along with voltage source, multimeter, ammeter, wires, and resistor. I-V plot shows current flow definitely favoured only in one direction. Voltage drop across diode is only 0.12V. Resistivity changes with temperature. So, at higher voltages, there is substantial heating, current reading gradually goes up (for >5min @ 5V forward bias) indicating that lowering of resistance [1-3, 6-10]. If current is switched off for some time, resistance returns to its room temperature value. So when switched on again, current returns to its low starting value. It is noted that resistance of 3000Ω is quite high in comparison to normal diodes and power dissipation of 4.8μw is low in comparison to normal diode. For forward regions, forward voltage drop, V_F=0.12V; forward current, I_F=40μA; resistance of diode, R_F=3000Ω; and power dissipation of diode,ϕ=4.8μW.

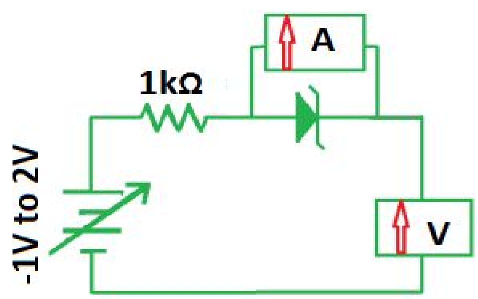

Figure 3. PA-Ag-PVA Schottky Diode in Circuit

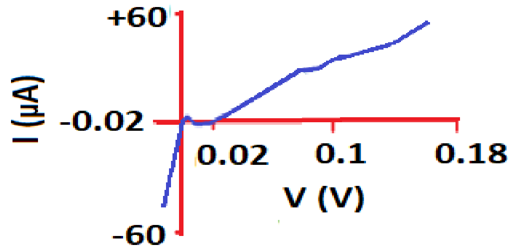

Figure 4. I-V plot for PA-Ag-PVA Schottky Diode

C. Primary MIM Characterization of Schottky Diode

In the second characterization of Schottky diode, application of square wave pulse is implemented with a Function Generator (at 2.2kHz) and voltage characteristics is studied using an Oscilloscope (**Figures 5 & 6**). For input voltage Vin= -10V to +10V for PA/Ag Nanocomposite Schottky diode based circuit; voltage drop across diode, V_F=10-0.005=9.9V; and resistance in forward bias, R_F=(9.9/0.005)x1kΩ=1980kΩ. As resistance is higher, voltage drop across diode is more and that across 1kΩ resistor is also more [1-3, 6-10].

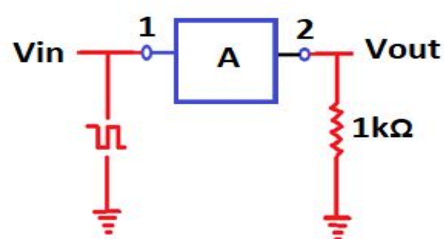

Figure 5. PA/Ag Diode in MIM Circuit (Mode I)

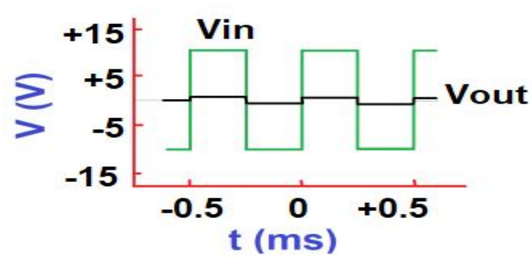

Figure 6. Vin-Vout of PA/Ag Diode for Vin(-10 to +10)

D. Secondary MIM Characterization of Schottky Diode

For input voltage Vin=-9V to +9V for an equivalent circuits (**Figures 7-9**);voltage drop across diode, V_F=9-5=4V; and resistance in forward bias, R_F=(4/5)x1kΩ=0.8kΩ. Hence, equivalent circuit one (in forward biased region), we get by circuit analysis; equivalent resistance, R_F=1.8kΩ, and capacitance, C=τ/R=0.27μF. Another equivalent circuit (in forward bias region), by circuit analysis, equivalent resistance R_F=(1x0.8)/(1+0.8)=0.44kΩ and capacitance C=τ/R=1.125μF. Based on this review, PA/Ag NC diode is suitable for application in photovoltaics and serving as sensors [1-3, 6-10]

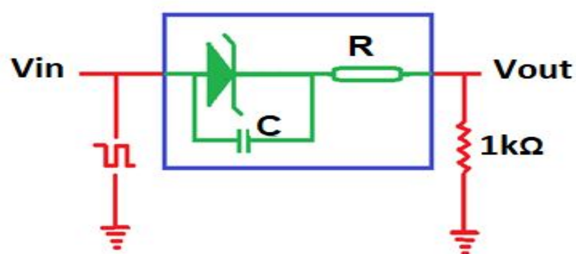

Figure 7: PA/Ag Diode in MIM Circuit (Mode II)

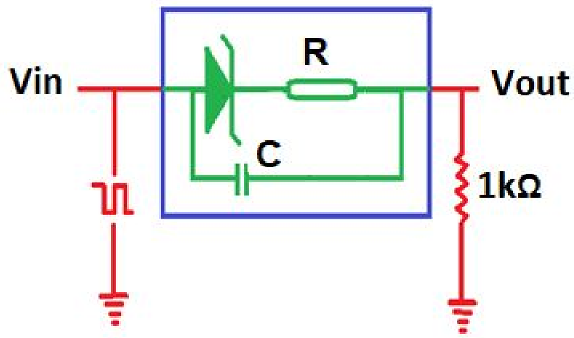

Figure 8: PA/Ag Diode in MIM Circuit (Mode III)

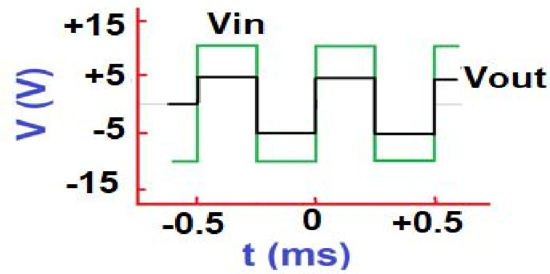

Figure 9 Vin-Vout of PA/Ag Diode for Vin(-9 to +9)

IV. CONCLUSION

Summarily, making PA/Ag nanocomposite Schottky diode, and verifying its I-V trend are done. UV-Vis spectra show presence of PA NP and Ag NP. Schottky diode is fabricated out of PA NP and Ag NP using PVA. Electrical circuitry with PA/Ag NC Schottky diode reveals high resistivity, and low capacitance and power dissipation. So, it is suitable for serving in photovoltaics.

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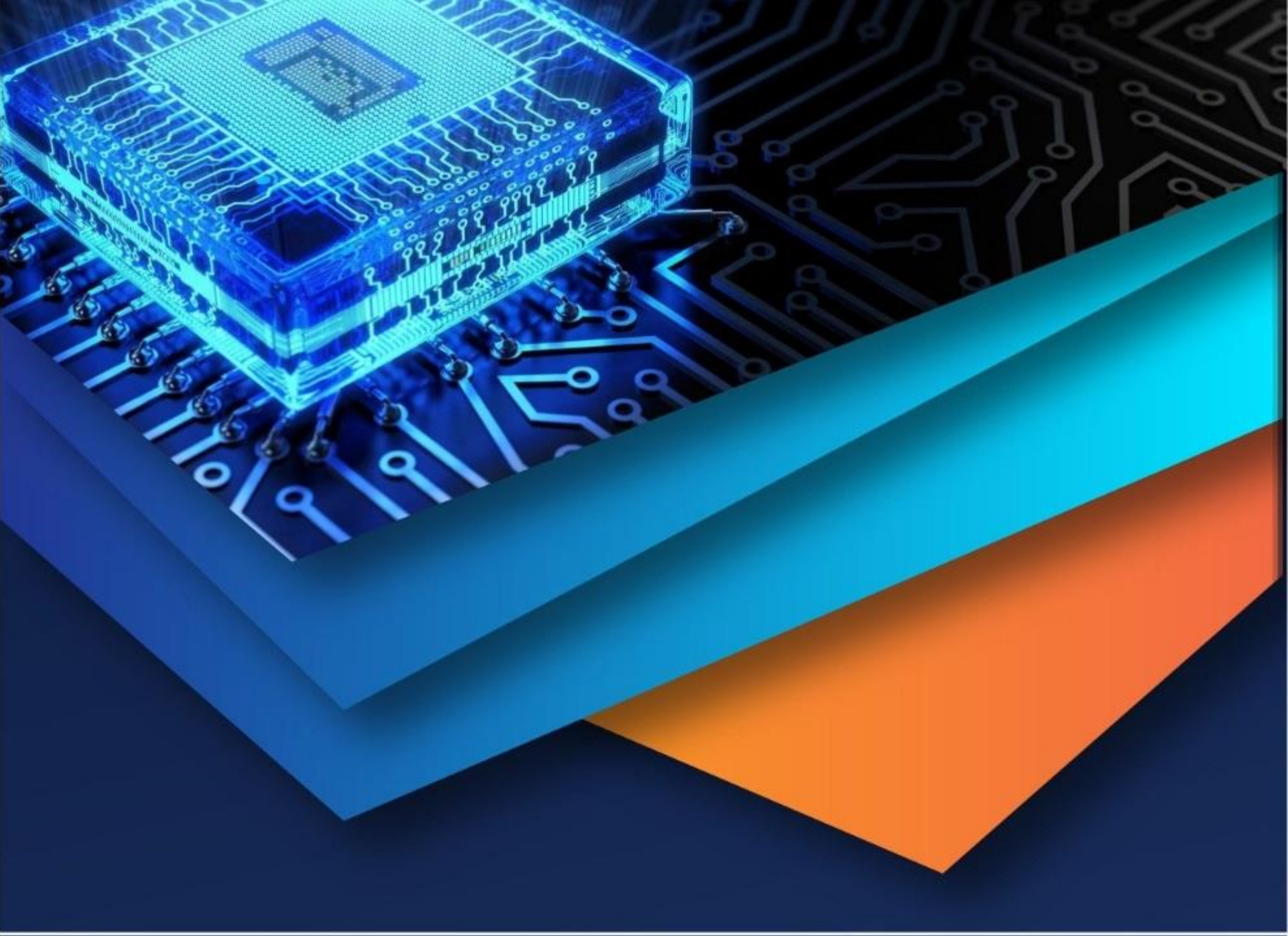

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