Fabrication and Characterization of Schottky Gate-Field Effect Transistor Utilizing pyromallitic 3, 4 benzoic acid di imide

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Abstract

Schottky gate-Field Effect Transistor was fabricated using pyromallitic 3, 4-benzoid acid as an effecting layer. Cast method was employed in depositing the polymeric material.

Electrical characteristic including output and transfer characteristic was carried out at room temperature. Electrical analysis howed that the device has a normally on mode with relatively high threshold and pinch off voltage.

Introduction

Semiconducting polymers have attracted much attention from both fundamental and practical viewpoint. Many studies were carried out on synthesis polymers and investigated their electrical properties as a substitutes to inorganic semiconductor and insulating materials for utilization in electronic applications. ([Ramamurthy *et al,* Kumar and

Sharma, 1998;Chirvase etal,2003; Rao and Sathyanarayana,2002 and Gan etal,1999)

Plastic materials were incorporated into several electrical components as resistor, capacitors Schottky diodes and also envisioned as the material comprising the conducting traces which interconnecting these components.

Abdul Ghafor,1996 and Abdul Ghafor etal,1996,1997,2000 have investigated the electronic properties of some condensation polymers such as poly (α-Naphthyl acrylate), pyromellitic 1,2 Naphthalene di Imide and pyromellitic 3,4 benzoic acid di-Imide (PPBD) and including them in the fabrication of field effect transistor and Schottky diode. Polymer materials in these electronic devices play an essential active role in controlling the source-drain current. These applications would be limited to low-speed devices because of the low carriers mobilities of semiconducting polymers compared to those of conventional semiconductors.

During the review in the researches carried out in the field of polymeric electronic devices, one can summerrised it into two main branches, first is synthesis conducting polymers and then trying to improve its physical and chemical properties (including thermal stability as important parameter). Seconde is synthesis highly thermal stability polymers, then trying to improve its electrical conductivity. It is well known that pyromellitic dianhydryde and di-Imide polymers have high thermal stability (Knop&etal,1985).They have also some other useful characteristics (candidates their utilization in the electronic devices fabrication) such as easy processing and required fewer processing in their fabrication, high capability to introduce active species in their matrix via suitable doping, and the nueomeroes derivatives that can be constructed via condensation polymerization. (Seymour *eta*l,1988).

Field Effect Transistor is unipolar device because its operation depends on the flow of major carriers. Many benefits are come from some available characteristic such as high input impedance, thermal stability, uniform temperature distribution and a low possibility to expose to thermal runaway that occurs in bipolar transistor. (Taylor *etal*,1991 & Yang ,1978).

This study presents the fabrication and characterization of Schottky gate - Field Effect Transistor including pyromellitic 3,4 benzoic acid di-imide. Device characteristics at room temperature were investigated include the out put and transfer characteristics. Other essential device parameters such as threshold voltages (V_T) channel conductance (g_d) and transconductance (g_t) were also measured.

Experimental Procedure

Schottky gate-FET was fabricated according to the following procedure (Abdul Ghafor,1996). Nickel metal as drain and source electrodes were deposited on glass substrate using evaporation technique under low vacuum pressure through a mask of finger shape as shown in figure (1).

Pyromellitic 3, 4- benzoic acid di-imide was casted on the nickel electrodes from polymeric solution and conditioned in temperature and vacuum environment as mentioned previously (Abdul Ghafor,1996).Gate electrode as a final step in the processing was deposited on the polymer surface made of aluminum to form Schottky contact with polymer surface. The device was kept at 70°C under vacuum (10^{-3}torr) for 24 hr's before starting measurements. Electrical characteristics of device were measured at room temperature. Steady state current was recorded by current amplifier model Electrometer Keithely 417 nr1516. All measurements were carried out in dark and shielded box under D.C. bias conditions provided by power supply model 6516A.H.PCO figure (2): shows schematic diagram of the measuring electrical circuit. The optimum working temperature range of the device was estimated from thermal analysis thermograms which includes two techniques i.e. differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA) (Abdul Ghafor,1997)

Result and Discussion

Drain current was recorded after 10 minutes from applying the drain voltage (for non-zero gate voltage). This value of current was corresponding to steady state current that is necessary for reproducible results.

The prepared polymer device is a long channel characteristic, therefore the procedures employed to calculate transistor parameters was similar to that used in silicon-FET (Sze ,1981& Antoun etal,1986).
The principle of transistor operation is to use the gate bias to modulate the conductance of channel which carriers pass through from source to drain .

The output characteristics of SG-FET measured at room temperature are shown in figure (3). The conducting channel between source and drain consists only of the pyromellitic 3, 4-benzoic acid di Imide, therefore low saturation drain current was observed as in figure (3) due to the low channel conductance which was about $2x10^{-8}$ (S / cm). When a positive (negative) bias was applied on the gate, drain current (I_d) increased (decreased) significantly with increasing drain voltage. The drain current varied from 2.0 $x10^{-8}$ to 4.5 $x10^{-8}$ when gate voltages increased from (-150 to +150) volt.

This behavior can be used to distinguish the type of the prepared device. Because of the non-zero drain current at zero gate voltage, the device showed (normally - on) mode. In this device, gate polarity has a great influence on determining the mode type. The negative gate polarity creates depletion layers in the channel surface for negative gate polarity, the gate to channel Schottky junction is being a reversed biased which gives rise to junction potential barrier and cause a built-in depletion region. The depletion region will penetrate into the conducting channel, narrower it and decreased its conductance, the matter that makes the device be in a depletion mode. Enhancement mode is exist in satisfying the reverse case. Threshold voltage was calculated from the relationship between $(I_{ds})^{1/m}$ Vs Vg .It was observed that best linear fitting to the above data was m=2.2 corresponding to V_T = -150V.The negative value of V_T is also confirming the normally - on mode . Fig (4) shows the transfer characteristics of the device. The behavior of the drain current was similar to the metal-oxide semiconductor-FET utilizing conductive polymer (Kamat and Fox,1984).

The pinch off voltage & transconductance were calculated from the following equations: (Sze and Sons,1981)

$$g_{m1} = \left.\frac{g_{ID}}{gV_G}\right|_{V_D \text{ constant}} = g_D(V_D/V_P) \quad \text{[in the linear region before pinch off voltage]}$$

$$g_{m2} = g_D(1+V_G/V_P) \quad \text{[in the saturation region beyond pinch off voltage]}$$

Comparing these results with other Schottky devices utilizing poly (1-4 Naphthalene vinylene) PNV and poly (p-phenylene vinylene) PPV (Gibson and Frejlich,1985) have been listed in the following table.

Table: The calculated electrical parameters for Schottky - gate FET.

parameters	Present work	PNV	PPV
g_D ,(s)	1.7×10^{-10}		
g_{m1}	9×10^{-12}	7×10^{-11}	
I_{dat},(A)	3.2×10^{-8}	7×10^{-11}	1.4×10^{-9}
V_T,(V)	-125		
V_P,(V)	190	5.5	3
σ_{chan} ,(s.cm^{-1})	1.7×10^{-8}		
mode	Normally on	Normally on	Normally on

From above results, one can concluded, that the present device has a value of transconductance nearly similar to that in poly naphthalene vinylene Schottky gate Field Effect Transistor inspit of its high saturation drain current. Other results can be observed in the present device is the high value of threshold and pinch-off voltage which is mainly due to the high value of channel resistance.

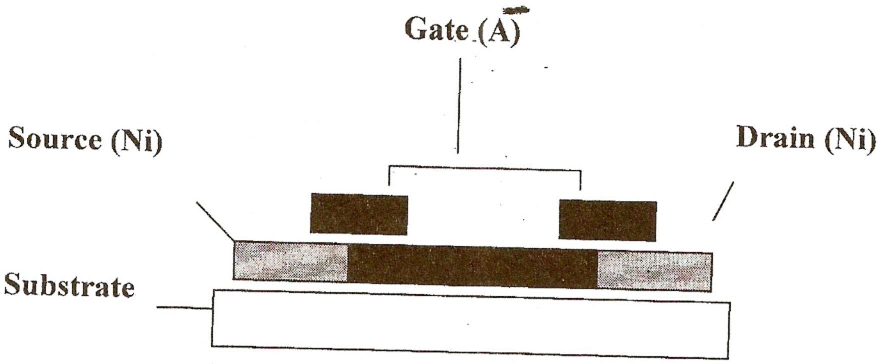

Fig (1): Schematic diagram of FET fabrication

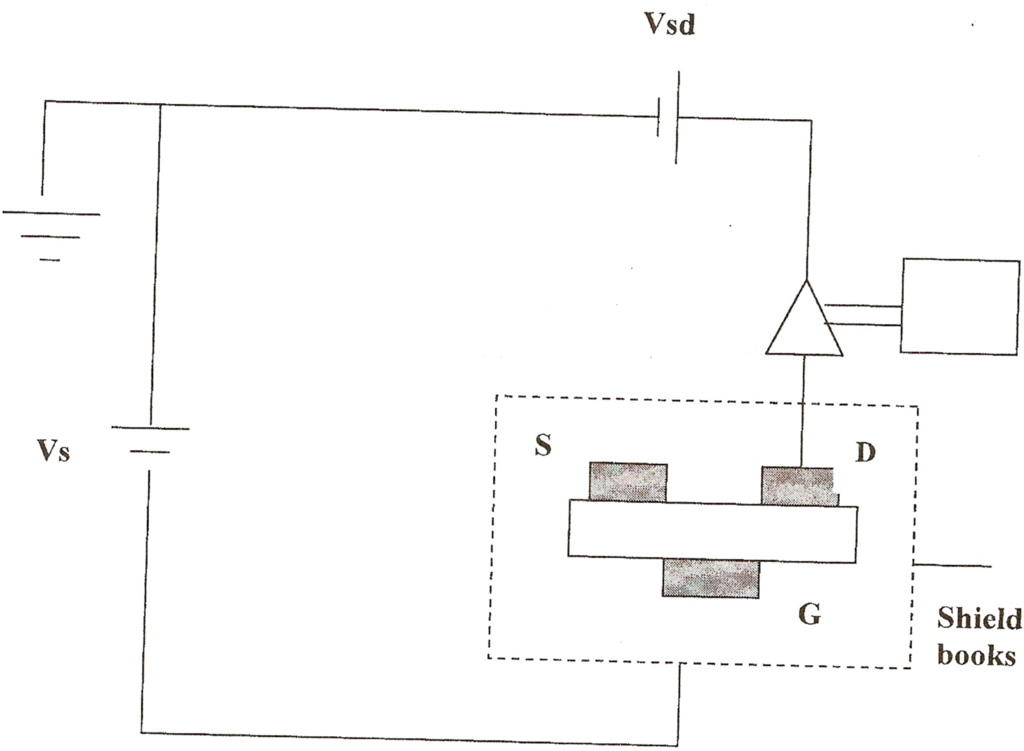

Fig (2): Schematic diagram of FET electrical circuit measurement

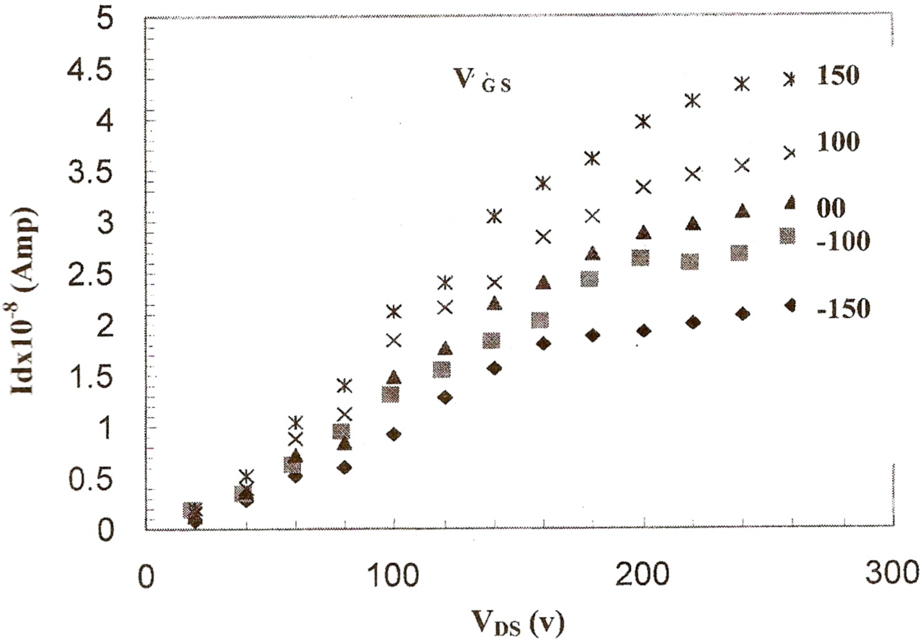

Fig (3): The out put characteristic for Schottky

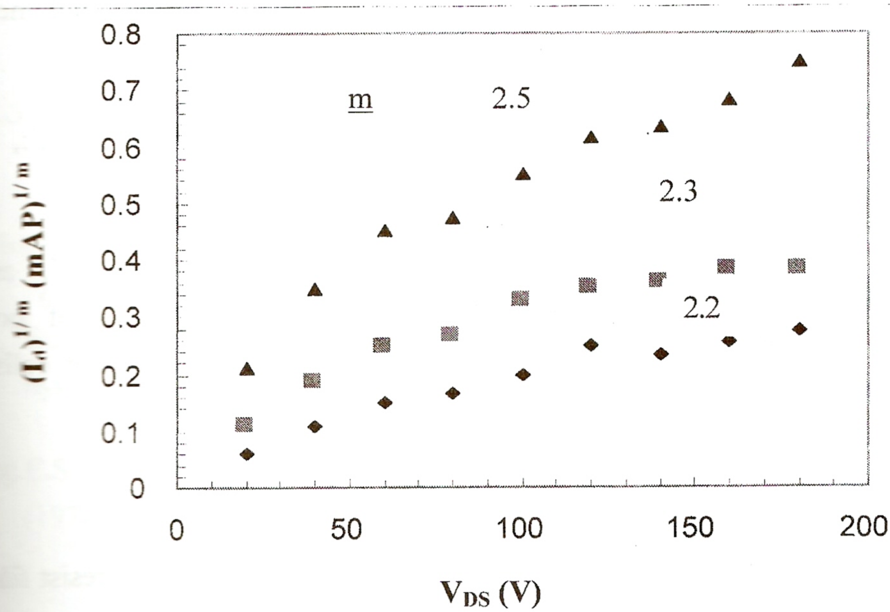

Fig (4): The drain current $(I_D)^{1/m}$ dependence on source-drain Voltage with gate and source connected together, for FET

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