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NEW DIMENSION IN LEAKAGE CURRENT

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ABSTRACT

The leakage current flows at reverse biased condition. According to the present concept the transistor leakage current is directly proportional to the junction temperature. But the experiment designed in this study reviles that amount of leakage current decreases with the increase of temperature from 30^0C to 125^0C. At 125^0C - 130^0C the leakage current is minimal. Above 125^0C the leakage current increases with the increase of temperature and follow the proportionality law. Initially leakage current follows exponential decrement and then above 125^0C it follows linear increment. The reason behind this anomaly is the improper distribution of the supplied heat energy among the carriers. But Above the threshold temperature more electron-hole pair generated and there by the supplied energy will be distributed properly among the previously present electron-hole pair and the newly generated one due to the supplied heat.

KEYWORDS: Transistor, Leakage Current, Temperature, Proportionality Law

INTRODUCTION

The minority carriers are electrons for P-type material and holes for N-type material. Due to the opposite applied voltage they get depleted at the P-N junction. As the minority carries are at the junction they can easily exchange charge among themselves and hence the current flow [1]. Based on the above fact it can be easily inferred that at reversed biased condition the leakage current flow solely depends on the amount of depleted minority carriers at the junction. Again higher will be the temperature more leakage current will flow across the transistor [2]. As a result more junction temperature means more electron-hole pair at the junction. Again it is known that at higher temperature the randomness of every particle is increased. So the already depleted electrons at junction will be scattered due to the supplied heat. If the carriers do not get a chance to accumulate at the junction the leakage current flow due to the minority carriers will be decreased. It is also well known that after receiving the threshold amount of energy (here heat energy) the electrons at lower energy level will move to the higher energy level and there by forming more no of electron-hole pair which will lead to more leakage current. Based on above condition it may assumed that leakage current will not flow proportionality law starting from room temperature to higher temperature such as 180^0C. With this assumption an experiment was designed to confirm this assumption.

METHODS AND MATERIALS

Materials

The material used in this experiment are a 3904 (NPN) transistor one 1K resistance (5% tolerance), one red coloured LED, one 10 volt DC source, connecting wires, one heater, one hot chamber with temperature sensor, and one AVO meter for measuring the voltage drop across the 1K resistance.

Experimental Arrangements and Circuit Explanation

The basic characteristic of the transistor is it acts like a switching device. If we apply a small voltage at the base terminal current will flow across the emitter- collector terminal, otherwise no current will flow. But due to the minority carriers a small amount of leakage current will flow with the open base configuration due to minority carrier depletion [1].

In the designed (Figure - 1) circuit transistor is configured in open base connection. The 1K resistance is used as a current limiter for the transistor. The red LED is included as a circuit indicator. The temperature sensor (thermometer), heater, and the transistor all are placed within that same hot chamber. The junction temperature will increase due to the heater temperature and the thermometer will sense the instantaneous temperature. By this arrangement voltage drop across the 1K resistance can easily be measured at any temperature and so the amount of leakage current. The readings have been taken from 30^0C to 180^0C at the interval of 5^0C. The LED, 1K resistance and transistor all are connected in series as shown Figure-1. So the leakage current flowing in the transistor (collector-emitter terminal) will also flow through the 1K resistance. At open base condition only leakage current will flow. According to the ohm's law (V=I*R) we know that current and voltage is directly proportional. Since the resistance is constant, by the value of voltage drop at any temperature the amount of leakage current can easily be calculated.

RESULTS AND DISCUSSIONS

The measured voltage drop across the 1K resistance from 30^0C to 180^0C at an interval of 5^0C is plotted in figure-2. A perusal of Figure 2 clearly exhibited that the leakage current is not directly proportional with the junction temperature as advocated by B.Van Zeghbroeck. The experimental data showed that at 30^0C (almost room temperature) the voltage across the 1K resistance is 22.19 mV. Then with the increment of heater temperature the voltage across the 1K resistance decreases. Finally at temperature 125^0C the voltage is 0.92 mV which is the minimal. Again further increment of temperature the voltage drop across the resistance increases. Finally at temperature 180^0C the voltage drop is 8.91 mV. So the leakage current up to 125^0C exponentially decreases and then linearly increases.

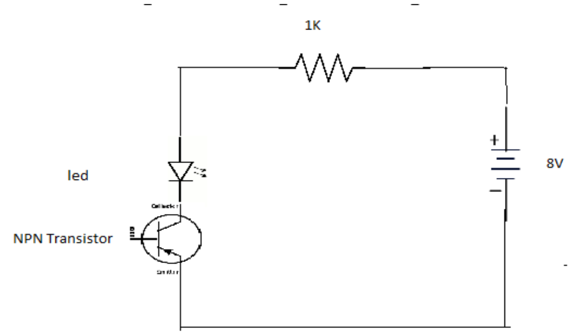

Figure 1

The main reason behind this anomaly is the improper energy distribution of the generated carriers by the supplied heat. At normal condition or steady state the electrons are at the lower energy state. If we supply sufficient amount of energy in any form the electrons will absorb that supplied energy and jump to the higher energy state. That sufficient amount of energy is called the threshold energy. Below that threshold energy the electrons will not be able to jump to the higher energy state. So the total supplied energy will be converted to any other form of energy mainly kinetic energy. Now in case of transistor the same thing happens. Supplied heat energy will be absorbed by the electrons. Until 125^0C the electrons will not be able to achieve the threshold energy. Therefore no more electron hole pair will be generated. The total supplied energy will be distributed among the less no carriers present at the junction. The amount of energy absorbed by individual existing carriers will be more. As state transition dose not occurs the total absorbed energy will be converted to kinetic energy. The probability of collision among the carriers due to the high kinetic energy will be increased. More will be the collision less will be the leakage current flow. But after 125^0C the supplied energy will be high enough to attain the threshold value. At threshold energy level more electron hole pair will be generated. As the no of carriers also increases the amount of energy absorbed by individual carriers will be less. More over most of the energy absorbed will be used for the state transition. The remaining energy left will be converted to kinetic energy which will be very low. Thus the probability of collision among the carriers will be low. Less will be the collision more will be the leakage current. So basically due to the collision of the carriers the leakage current decreases up to 125^{0}C but after the threshold value again increases due to the increment of the number of carrier.

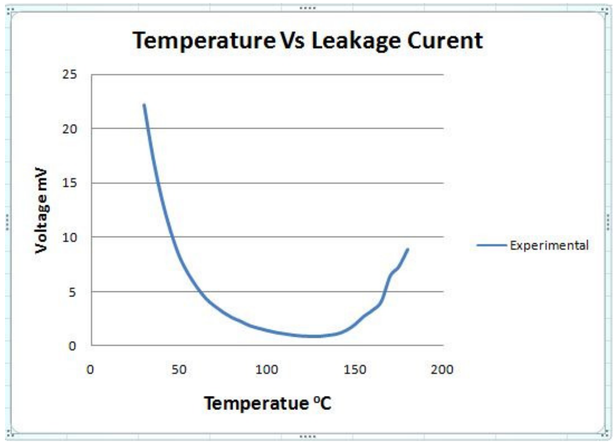

Figure 2

CONCLUSIONS

According to the previous concept the amount leakage current is directly proportional with the junction temperature. This experiment reveals that the proportionality law is applicable only after the threshold temperature, therefore this study explore the new dimension of leakage current.

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