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TEMPERATURE DETECTION BY CARBON NANO PARTICLE BASED SENSOR

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ABSTRACT: - In the presented work carbon Nano particle is fabricated by the arc discharge method and it is concluded that two factors of temperature rise and gas absorption are profound effect on the CNP current voltage characteristic. The effect of temperature variation on the electrical property of carbon nanoparticles with the adsorption of liquid gas is examined. It seems that the temperature rise causes an increase in the resistance and this is primarily because of increased scattering.

Keywords: Carbon Nano Particle (CNP), Sensor, conductivity, temperature, gas adsorption, shottky contact.

1. INTRODUCTION

Nowadays nanomaterial application, including Carbon nanoparticles (CNP) has considerable potential especially on sensor technology. Nanotechnology and nanomaterial application improvement including Carbon nanoparticles (CNP) has considerable potential for the production of sensors with special features is needed. The ratio of surface to volume is high and the hollow structures of CNP are highly appropriate for the adsorption of gas molecules as well. On the other hand Carbon nanoparticles can show semiconducting or metallic behavior which makes them suitable for gas sensor application. Semiconducting Carbon nanoparticles are utilized in manufacturing of gas sensors for detecting Ar, N2,NH2,CH2,H2O,O2,NO2,CO2 and H2 gases with high accuracy and low power consumption[1-4]. Generally there are two types of CNP based gas sensors: Resistive and Capacitive sensors.

The function of sensors is in a way that with the change of gas present in the environment, through the measurement of nanoparticles conductivity, the conductivity value of nanoparticles changes and as a result, the gas concentration can be realized[5,6]. Accordingly, the change in conductivity is primarily as a result of molecular adsorption[7].There are two fundamental processes involved in the detection mechanism of partial discharge by CNP gas sensor. First: The load transfer between CNP and gas molecules that change the electrical conductivity of the gas sensor. Second: The adsorption of the gases on the surface of CNP. under the study is tested by electric arc in which the electrodes used in it are made of copper in which synthesized. Figure 1 shows the number of CNP in which the first one is before the adsorption of gas and the second one is after the adsorption of gas and as a , the conductance has changed by Δg in size. Showing in Figurer (1) .

2. MODELING

Sensitive part of the sensor band structure is one of the most important parameters on sensor study because it is useful in the mechanisms of gas sensor applications [7] .For the carbon based materials band energy in terms of wave vector is[8]:

$$E(\mathrm{k}) = \frac{E_g}{2}\left(1 + \frac{9k_x^2 d^2}{8}\right) \quad \text{........ (1)}$$

Where the following values are used[9] :

$$E_g = 3a_{c\_c} t \beta \quad \text{........ (2)}$$

Where $a_{c\_c} = 0.142nm$ is the carbon-carbon (C-C) bond length , t=2.7 ev is the nearest neighbor C–C tight binding overlap energy[10,11].
where β is quantized wave vector given by [12]:

$$\beta = \frac{2\pi}{a_{c-c}\sqrt{3}}\left(\frac{p_i}{N+1} - \frac{2}{3}\right) \quad \text{......... (3)}$$

here *pi* is the subband index and *N* is the number of dimmer lines which determine the width of the ribbon.

The following formula shows the electronic structure of CNT atoms in terms of the wave vector $\overrightarrow{k_y}$, $\overrightarrow{k_x}$ As it is previously mentioned, CNP possesses ballistic conductivity and have higher conductivity comparing to other conductors. By the use of electronic transmission model of low bias in conductivity ballistic, the conduction of CNT can be given by the following formula[9]:

$$G = \frac{2q^2}{h}\int_{-\infty}^{+\infty} dE\, M(\mathrm{E}) T(\mathrm{E})\left(-\frac{df}{dE}\right) \quad \text{........ (4)}$$

$$f(\mathrm{E}) = \frac{1}{1 + e^{\frac{E - E_F}{k_B T}}} \quad \text{.. ...... (5)}$$

Where h is Planck's constant , M(E) is the number of modes , F(E) is Fermi function and T is transition probability which are considered equal to one of the ballistic limit [9,13].

$$G = \frac{3q^2 E_g d}{hLk_B T}\int_{-\infty}^{+\infty} \sqrt{\frac{1}{1 + \left(\frac{3k_x d}{2}\right)^2}}\left(\sqrt{\frac{4E^2}{E_g^2} - 1}\right)\left(\left(f(\mathrm{E})\right)^2\left(e^{\frac{E - E_F}{k_B T}}\right)\right) dE \quad (6)$$

Temperature changes cause changes in the conductivity which can be used as a sensing parameter as well. Our observation indicates that conductance fluctuates by temperature and this phenomenon is basically used in CNP based sensor analyzes.

3. EXPERIMENT

In order to investigate the effects of temperature variation on the electrical resistance of carbon nanoparticles and their sensitivity, a growth set up is designed. For this purpose a driver is designed where the output voltage is extremely high. The second part of this device is called reactor, which consists of a glass container that completely stops air penetration. From one side of the glass container a tube is connected, in which the liquid gas enters into the reactor and in the other side of it a tube is embedded to let the gas stream exit. Also, two wires from the two ends of the reactor are used to conduct electrical current into the glass container. As it has been previously pointed out, the desired goals for performing nanoparticle growth action is the liquefied gas. The gas is a mixture of propane, butane and ISO-butane that is liquid and is for domestic consumption in small capsules. The liquid gas is obtained from the separation of propane and butane present in the natural gas. The electrode used in this experiment is made of copper where the distance between them is 0.7mm. For the synthesis, the oxygen must be removed so that it wouldn't cause explosions, and accordingly gas capsule should be opened for 30 seconds to let the oxygen exit through the outlet tube and also there is no need to use pump.

After being sure of the removal of oxygen from the reactor, the driver should be turned on so that the nanoparticle growth takes action. Because of the high potential difference between the copper electrodes an electric field is formed which causes gas carbon bond to be broken, and the produced carbon actions move toward the cathodes they sit on the cathodes. This operation is repeated so much that the nanoparticles grow fully and the produced lights of the electric arc are cutoff. The effect of temperature rise on the electrical resistance of the nanotubes is investigated by two ways: 1). with the absorption of liquid gas 2). Without the adsorption of liquid gas by carbon nano-particles.

The experiment was performed in a different temperature namely: 28, 8, 108, 125,145 and 160 degrees Celsius and a heater are used to reach these temperatures in which the heating time for glass container is 15 minutes.

Ultimately, by obtaining the accurate amount of current in the circuit, current diagram can be drawn in terms of potential difference.

Figurer(2) is drawn in two ways, one way considers drawing it without the adsorption of liquid gas and the other one deals with the adsorption of liquid gas. So as to provide the gas adsorption mode, gas flow is passed for 15 minutes on the nanoparticle. As mentioned before, at the time of the adsorption of gas molecules by nanoparticle, heater keeps the chamber temperature constant and accordingly the temperature is measured by a thermometer. As it is shown in figure 3, it represents i-v diagram for carbon nanoparticle in 28°C in either gas adsorption and without gas adsorption.

The diagram shows that in the absence of gas, the voltage of 0 to 0.6 of nanoparticles show Ohmic behavior and with the increase of voltage in nanoparticles the linear current increases as well. At voltages of 0.6 to 1.2 the steep slope of electric current in nanoparticles highly increases and then non-ohmic behavior appears. It is crucial to mention that this behavior is dependent upon the changes in temperature.

From voltage 1.2 on the slope steepens and sounds to be exponential. By the entrance of gas to the system voltage current at the ohmic and non-ohmic part changes and also ohmic behavior continues up to 1.2 volt potential difference in nanoparticles and then in 2.3 volts the current slope is partially steep, but higher than this voltage current increases with higher slope. Apparently, the presence of gas with factor 2 is effective in current changes. Also it is inferred that with the presence of gas electrical resistance of nanoparticles increases and its conductivity decreases. As shown in figure (4), at 87c° without the presence of gas, the potential difference of 0 to 0.3 volts, the current curve would be perfectly linear and will behave like an ohmic body. From voltage of 0.3 to 0.86 current slope steepens and seems to be exponential, but from 0.86 volts on, nanoparticles show ohmic behavior and the current diagram become linear in which its slope is considerably high compared to previous section. In the next case, nanoparticles are examined in the presence of gas, with the absorption of gas by nanoparticles the obtained diagram represents the complete ohmic behavior of nanoparticles and its current diagram is linear. It can be deduced that two factors of temperature rise and gas absorption have a profound effect on having a linear diagram. Not only these two factors leads to a reduction in the conductivity of nanoparticle, but they also cause an increase in the resistance of the nanoparticles.

As it is represented in figure 5, by the variation of temperatures at 108°c, 125°c,145°c and160°c, nanoparticle reaction to the used voltage up to 0.5 voltage without gas and also in the presence of the gas is amiss, therefore, the current curve is perfectly linear .

As it is presented in figures(5. a,b,c,d) linear behavior is expanded by temperature and non-Ohmic behavior is occurring in the high voltages which can be discussed in the form of threshold voltage in the contacts as well. In addition the temperature effect is compared as shown in figure (6).

4. Comparison study

Without the presence of gas the potential difference in the range of 0 to 0.7 volts, the current curve was found to be linear and shows Ohmic behavior approximately in all temperatures . Also the obtained diagram represents the complete ohmic behavior of nanoparticles and its current diagram goes linear as well. It can be deduced that two factors of temperature rise and gas absorption have a profound effect on having a linear diagram. By gas continuation of the system a linear response is increased.

Not only these two factors lead to a reduction in the conductivity of nanoparticle, but they also cause an increase in the resistance of the nanoparticles, It can be deduced that two factors of temperature rise and gas absorption have a profound effect on having a linear behaviour. Finally obtained results are tabulated as shown in table 1, which indicates by temperature increment the Ohmic behavior is increased. Also as shown in table.2 the nano particle resistance decreased by gas absorption as well.

As shown in figure(7) , it is found that as the temperature increases the resistance of nano particle decreases as well. This is while the experimental results are fully compatible with temperature effect on semiconductor materials. As it has been mentioned before, with the absorption of gas by carbon nano particles the resistance of carbon nano particles would increase in double at each temperature. But after the temperature was increased, electrical resistance decreased as well..

5. CONCLUSION:

The unique geometry and electrical properties of CNT has made it ideal in the manufacturing of sensors. In the presented CNP is grown with arc discharge method and the temperature on the fabricated shottky contact sensor is investigated.
It is found that carbon nano particles are sensitive to the temperature and the experimental results are well-matched with semiconductor materials behavior as well.

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Table 1: Resistance without absorption gas

Temp(°C)	Ohmic behavior(Volt)	Non ohmic behavior(Volt)
28	0 to 0.44 (**V**)	0.44 to 1.8 (**V**)
87	0 to 0.49 (**V**)	0.49 to 1.5 (**V**)
108	0 to 0.55 (**V**)	0.55 to 1.5 (**V**)
125	0 to 0.55 (**V**)	0.55 to 1.5 (**V**)
145	0 to 1.43 (**V**)	--------------
160	0 to 1.40 (**V**)	--------------

Table 2: Resistance with absorption

Temp(°C)	Ohmic behavior(Volt)	Non ohmic Behavior(Volt)
28	0 to 0.42 (**V**)	0.42 to 3.5 (**V**)
87	0 to 2.23 (**V**)	--------------
108	0 to 2.26 (**V**)	--------------
125	0 to 2.27 (**V**)	--------------
145	0 to 2.06 (**V**)	--------------
160	0 to 2.04 (**V**)	--------------

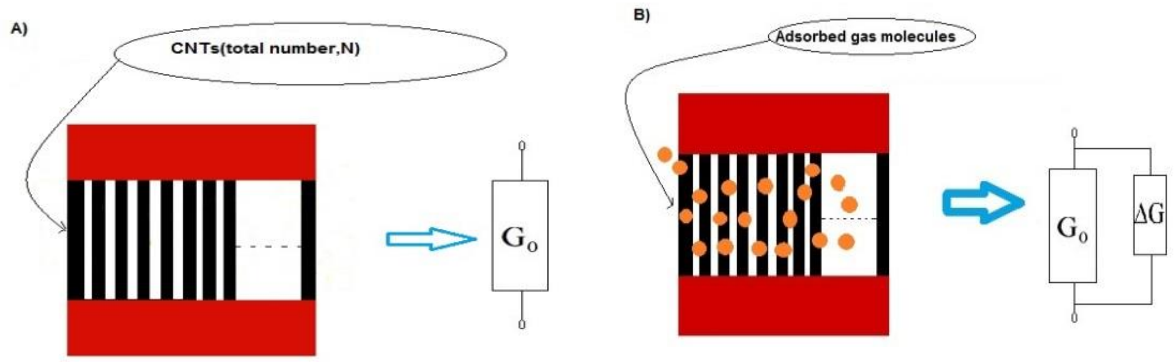

Figure 1: A: Sensor before the gas adsorption, **B**: Sensor after the adsorption of gas molecules

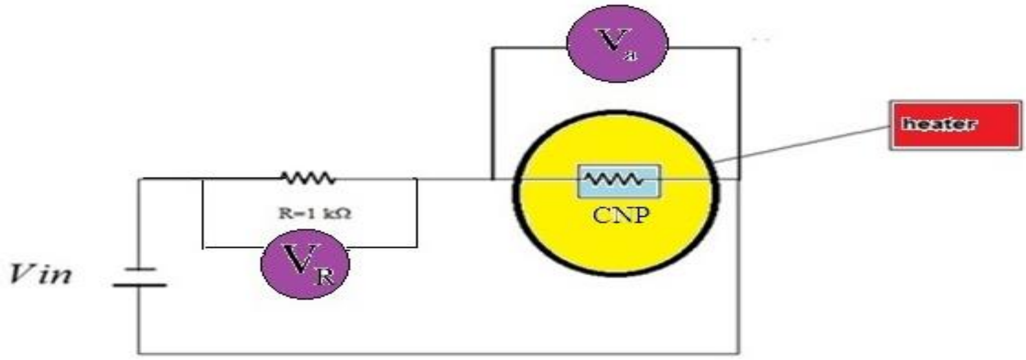

Figure 2: The circuit for the carbon nanoparticle electrical resistance measurement.

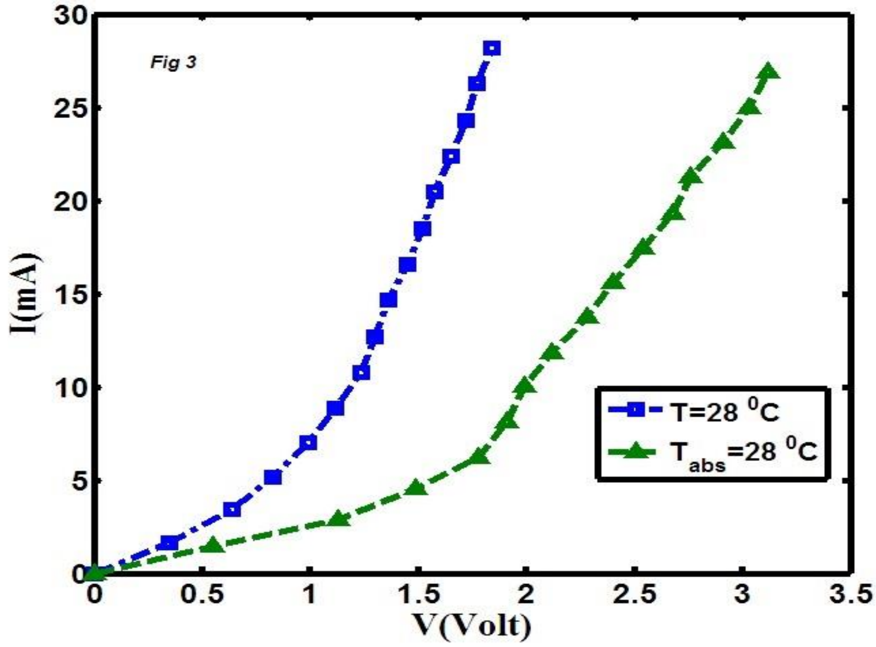

Figure 3: I-V diagram for carbon nanoparticle at 28 ^{o}C in both gas adsorption and lack of gas adsorption.

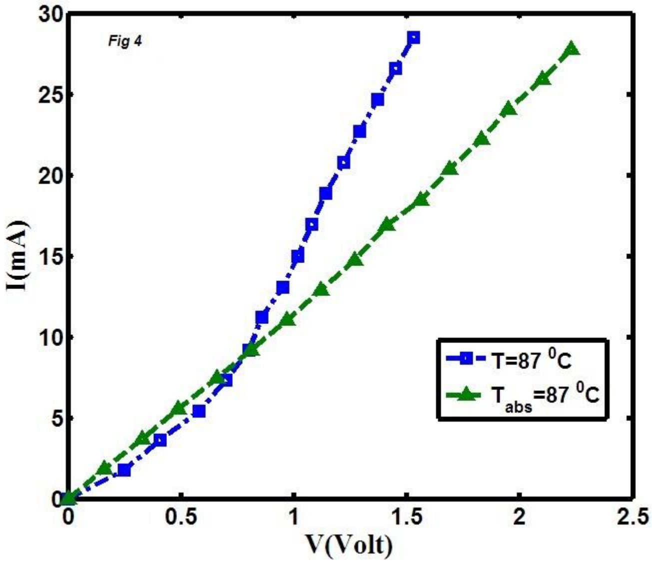

Figure 4: I-V diagram for carbon nanoparticle at 87 ^{o}C in either gas adsorption or lack of gas adsorption.

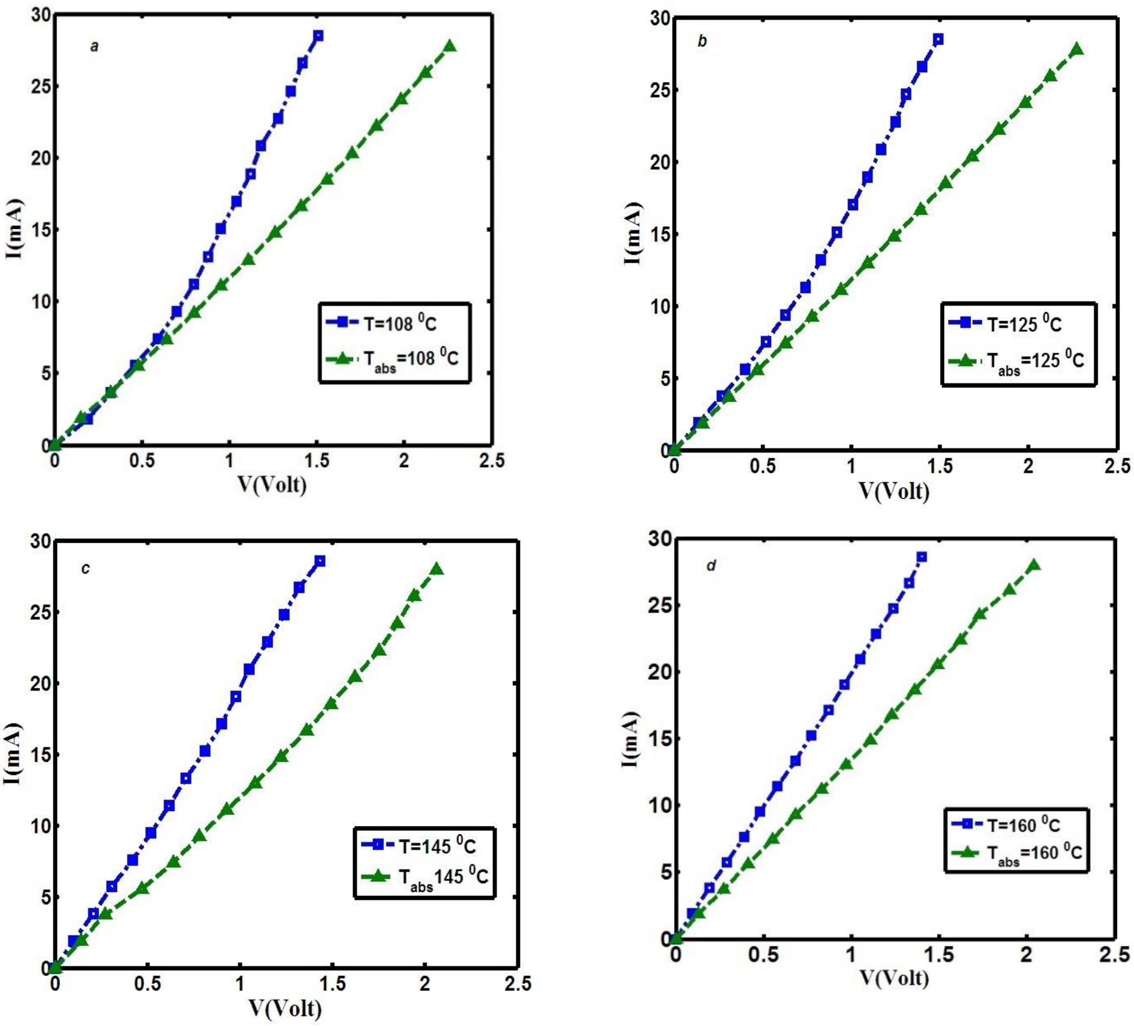

Figure 5: a). I-V diagram for carbon nanoparticle at 108 ^{o}C, b). at 125^{o}C, C).at 145^{o}C, d).at 160^{o}C in either gas adsorption and without gas respectively.

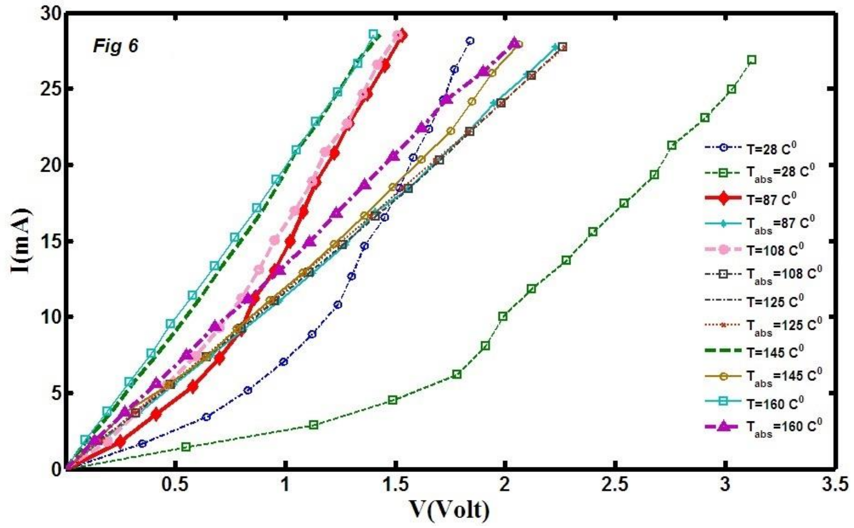

Figure 6: I-V charachtristic for different temperatures

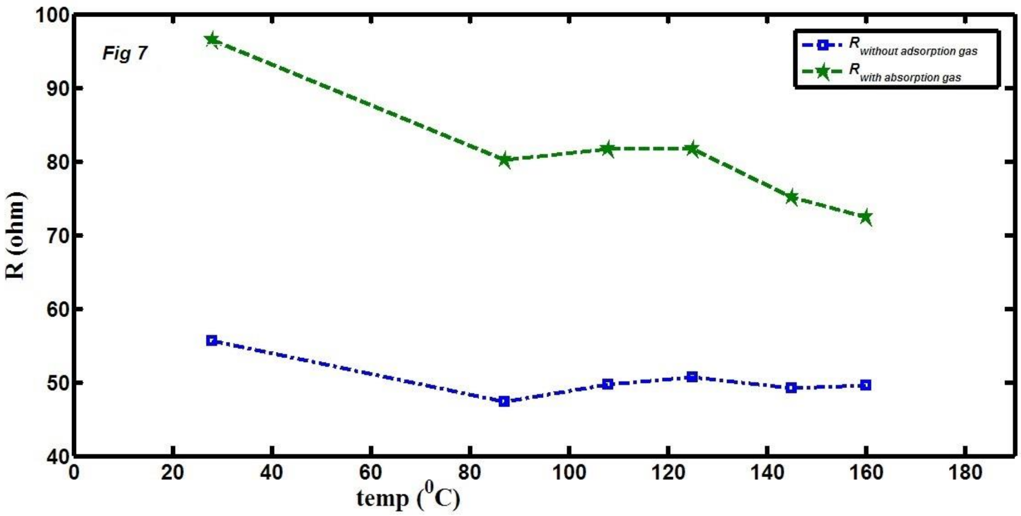

Figure 7: Resistance vrsuse temperature in the precence of gas(green line) and without gas,(blue line)