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# Synthesis of Carbonous Nano Adsorbents and Their Application in Methane Gas Storage

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**ABSTRACT:** In this research, adsorbed natural gas methods have been studied. The adsorbents used in this thesis are carbon-based nano-sorbents (activated carbon, pure and functionalized carbon nanotubes, and porous graphene) which were synthesized by the chemical vapor deposition method. The accuracy of synthesized results was examined using scanning electron microscopy, transmission electron microscopy, Fourier-transform infrared spectroscopy, X-ray diffraction, and Brunauer–Emmett–Teller analyses. The adsorption capacity of adsorbents for methane gas adsorption at three temperatures of 28, 45, and 60 ° C was calculated and matched with three isotherm equations of Langmuir, Freundlich, and Temkin. The R of the Langmuir isotherm for pure and functional nanotube adsorbents were 0.9963 and 0.9997, respectively, and for activated carbon was 0.9995, which is the closest isothermal equation for these adsorbents, while for the graphene adsorbent the closest prediction is Temkin isotherm with calculated R of 0.9986. It can be concluded that with increasing temperature, the amount of adsorbed gas decreases, and with increasing pressure, the amount of adsorbed gas increases. Therefore, the maximum adsorption for all adsorbents occurred at a temperature of 28°C and a pressure of 40 bar. Among the used adsorbents, porous graphene showed the best performance at a temperature of 28°C, and a pressure of 40 bar, which according to its high specific surface area, Brunauer–Emmett–Teller analysis (1200 m2/g), and significant pore size, such an outcome was predictable.

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## 1- Introduction

One of the effective methods to study the proper adsorbent for methane storage was to evaluate adsorbents for their equilibrium and kinetic properties. The commonly used methods for methane storage and separation from various gases contain an absorption process [1-2], dual-alkali absorption [3], a membrane separation process [4], and solid adsorption via carbon nanotube as adsorbents [5-7]. Methane adsorption via numerous nano adsorbents have expanded more interests in many several research papers. Many nano porous adsorbents have been synthesized for methane storage an adsorption application. In this investigation the synthesis of the highly porous carbonous adsorbents is described. The adsorption parameters effect such as pressure and adsorption temperature and adsorption time were considered. The capacity of the $CH_4$ storage of the synthesized adsorbents was also explored. Due to synthesized adsorbent high specific surface area, Brunauer–Emmett–Teller (BET) analysis (1200 m2/g), and significant pore size, it is a suitable adsorbent for methane storage.

## 2- Methodology

### 2- 1- Synthesis of carbon nanotube

Carbon Nanotube (CNT) was prepared by the chemical vapor deposition method. Methane was used as a carbon source in this method. The synthesis of CNT was done over zinc oxide nanocatalyst which was arranged by sol-gel method.

### 2- 2- Synthesis of functionalized CNT

In order to modify the adsorption property of the synthesized CNT and increase the surface area of the CNT, the functionalizing of the adsorbent was studied. For this aim, 4 g, of CNT was stirred by nitric acid for 4 hours at 700C. For the separation of the pure product, the brown nanoporous material was rinsed with deionized water till the pH is fixed at 6. After that, the functionalized CNT was carried to the oven under the nitrogen atmosphere for 24 h at 75 0C.

### 2- 3- Adsorption i

Adsorption experiments were shown in agreement with the volumetric method; the pressure was measured in a closed system. For calculation of the adsorption of the methane gas the adsorption cell apparatus was designed and used in this study. Fig. 1 exhibits the apparatus that was considered to perform the methane adsorption process. Preceding each test, the synthesized adsorbents were degassed at 1600C overnight to remove any adsorbed materials.

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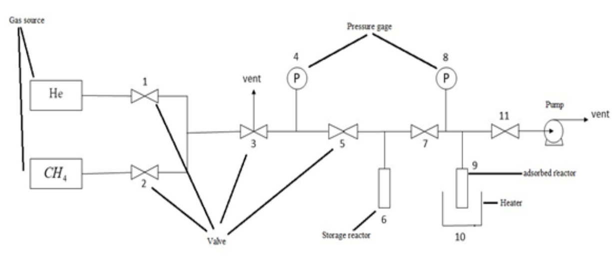


**Fig. 1. the schematic of the methane adsorption apparatus**

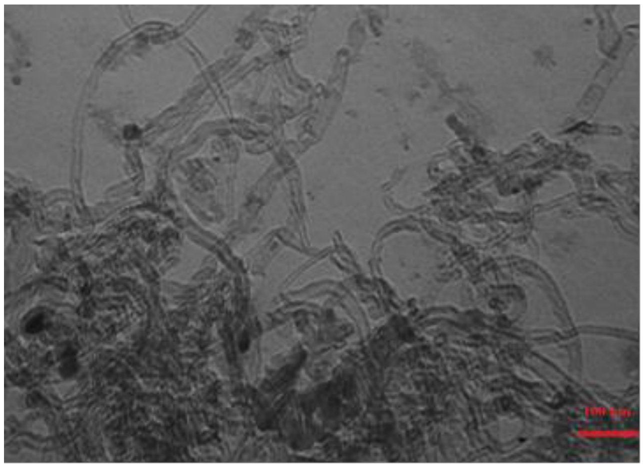

**Fig. 2. TEM image of the synthesized CNT**

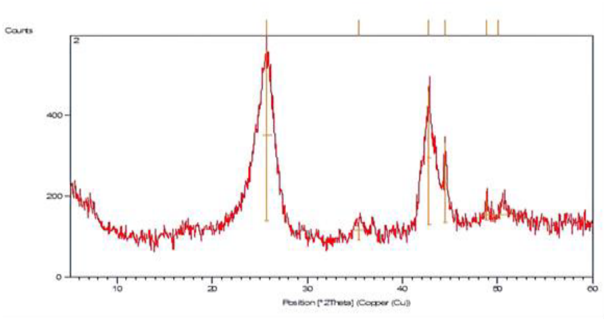

**Fig. 3. XRD pattern of the carbonous adsorbent**

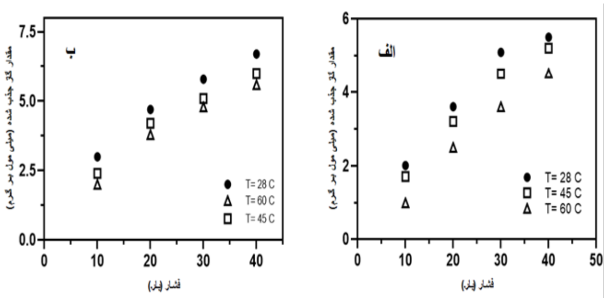


**Fig. 4. the isotherm of the a) CNT b) functionalized CNT**

## 3- Results and Discussion

### 3- 1- Characterization of the synthesized adsorbent

To analyze the morphology of the synthesized carbonous adsorbent Transmission Electron Microscopy (TEM) image was gained. It is concluded from the TEM image (Fig. 2) that, the CNTs had a size of 10 nm. The CNT nanoparticles' crystalline structure was calculated by X-Ray Diffraction (XRD) pattern (Fig. 3), in the diffraction range of 2θ=10-80°. It is stated from XRD results that, CNT nonabsorbent had various peaks at 23, 26.1, 44.5, 55.4, 63.4, and 68.

### 3- 2- Effect of the temperature

It is obvious from the adsorption results at 28, 45, and 600C which are reported in Fig. 4, the methane storage on carbonous adsorbent was an exothermic process and the adsorption capacity was decreased by increasing the temperature. It is also concluded that the capacity of the CNT and functionalized CNT were calculated at 280C and 40 bar, 5.5 mmol/g, and 6.7 mmol/g respectively. The results showed that the functionalized CNT had the highest capacity in methane adsorption in comparison with the other adsorbents.

## 4- Conclusions

Adsorbed Natural Gas (ANG) is one of the methods for energy saving in the world. In this study, various carbonous adsorbents were used to adsorb the methane gas as an ANG method. The nano carbonous adsorbent capacity as a nanoporous for storage of natural gas was calculated. The carboxylic CNT as an adsorbent was synthesized via the Chemical Vapor Deposition (CVD) method. Pressure and temperature were studied in this research as adsorption parameters. The optimum amount of them was about 40 bar and 280C. the carboxylic CNT modified the adsorption capacity from 5.5 to 6.7 mmol/g. This increase is about 22 %. In conclusion, carbonous adsorbents have a great potential for methane adsorption for natural gas storage.

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