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A Scope of Using Carbon Nanobeads Prepared from Castor Seeds as Biosensors

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ABSTRACT

This paper presents the possibility of development of biosensors from Carbon Nano beads (CNBs) prepared from castor seeds as a precursor by CVD method. The semiconducting nature of prepared nanobeads is confirmed by photoluminescence (PL) technique. The required study for determining the hormone content of the urine sample in the presence of CNBs as a sensing material has been carried out using a capacitance and resistor circuit. The variations found in the voltage across the capacitor give the scope for developing the biosensors from CNBs. This can be further calibrated and modified to measure the percentage of concentration of hormones by a non-invasive and simple method.

Keywords: Carbon Nano beads, photoluminescence technique, band gap, Biosensors.

I. INTRODUCTION

Carbon nanomaterials are getting popularized because of their special properties and possibility of their unique applications. Diverse nature of carbon bonding in organic molecules allows carbon to form some of the interesting nanostructures, particularly carbon nanotubes.. It's so called extraordinary properties like manifold stronger than steel, harder than diamond, electrical conductivity higher than copper etc. are turning it into a material of great demand in the near future. So there is a need to develop the process of synthesis using precursors which are not derived from sources like petroleum products so that in the event of the sources getting depleted the production of carbon nanomaterials is not adversely affected. Therefore plant based precursors are preferred over petroleum based precursors. The idea is, these precursors could be harvested as and when needed and even in the event of scarcity of petroleum derived precursors, the production of CNMs would not be affected.Therfore, seeds of Castor plant (*Ricinus communis*) was used as a precursor. Carbon nanobeads were prepared by Chemical vapour deposition method using the above mentioned precursor and Iron **(**Fe) as a nanocatalyst at a pyrolysis temperature of 900^0C with Argon as a carrier gas.

The term photoluminescence describes any process in which light is absorbed, generating an excited state, and then light of lower energy is re-emitted upon relaxation to a ground state. Photoluminescence absorption spectra of synthesized CNBs have been obtained in order to study their semiconducting nature. The absorption peak was found to occur at a particular wavelength (at around 600nm.). The analysis of this peak and the calculation of band gap show that CNBs prepared by above mentioned method are semiconductor in nature.

Endocrine system consists of various glands located throughout the body, hormones produced by the glands, receptors in various organs and tissues that recognize and respond to hormones. Nanomaterials are used in designing novel sensing systems and enhancing their performance. Use of nanotechnology in sensors and sensor hardware is resulted in development of a number of miniaturized, ultrasensitive and inexpensive methods. The surface chemistry and electronic properties make the use of carbon nanomaterials ideal for chemical and biochemical sensing. Carbon nanomaterials have the ability to enhance the binding of biomolecules and increase the electrocatalytic activities. With carbon Nanomaterials, the detection of several analytes is possible at low applied potential. No need to use electronic mediators and hence interferences are reduced.

After confirming the semiconductor nature of CNBs, a circuit is designed by using capacitor, resistor and 9 volt battery for determining the hormone content of the urine sample in the presence of CNBs which act as a sensing device.The variation in the voltage with change in the concentration of hormone gives the scope for the development of biosensors.

II. MATERIALS AND METHODS

2.1. Preparationof Carbon Nano beads

2.1.1. Precursor: Seeds of Castor (*Ricinus communis*) was collected from the wild plants growing in Navi Mumbai (Vashi, Nerul). These seeds are rich in oil and carbohydrates, thus a good source of hydrocarbons. Oil and carbohydrates are stored in seeds in storage cell having a specific anatomy of their own. Inherent morphology of plant materials have been found to give rise to very complicated porous carbon nanomaterials which would be extremely difficult to synthesize in the laboratory and might be having very useful applications (Sharon & Sharon 2013). Keeping these facts in mind castor seed was selected as the precursor. An initial elemental analysis of seeds was done to get an idea about the Carbon content. Castor seeds were found to contain 55.728%carbon.Castor seeds contain 12 – 15% water, to remove the water from seeds they were kept in a hot air oven at 100^0 C for one hour, and then crushed to form powder.

2.1.2. Catalyst Preparation: Iron (Fe) was used as catalyst for Carbon Nano beads (CNBs) synthesis because of their high solubility in carbon at high temperature and high carbon diffusion rate. Nano sized catalyst can be prepared using nitrates of these metals, because oxides of nitrogen escape leaving behind metal oxides. Known weight of nitrate salt of iron metal was mixed with urea in the ratio 1:5 and was ground thoroughly till it became liquid while grinding. Liquid mixture was heated in the muffle furnace by gradually increasing the temperature from 100^0C to 600^0C until the entire liquid was charred and turned into metal oxide. Reduction of oxide was carried out by keeping the oxide in a quartz boat at 900^0C for 1hr in a split furnace, flushed with Argon (Ar) gas. Then Hydrogen gas was passed to convert entire oxide into pure metal.

2.1.3. CVD set-up used for pyrolysis: A Horizontal CVD furnace was used for synthesis of CNMs from castor seeds. One gram dried crushed seeds mixed with catalyst to be tested were kept in quartz boat and inserted in quartz tube which was then kept in CVD furnace. Ar gas was flushed inside for the quartz tube for 10 minutes to create inert atmosphere. After that the flow of Ar gas was maintained at 50 cc/minute throughout the experiment. Furnace was then heated to 900^0 C and kept at this temperature for 2 hours. The furnace was then cooled to room temperature and the carbon was collected from the quartz boat.

2.1.4. Purification of CNM: Pyrolysed product, along with carbon also contains remnants of metal catalyst, some amorphous carbon, possibly same as and other impurities. To get pure CNM, the product obtained from pyrolysis was suspended in 1N HCl and kept on stirrer overnight. Then it was filtered through Buckner funnel with the help of Whatman filter paper and finally dried in a muffle furnace at 60^oC for 30 min.Purified CNMs were weighed.

2.1.5. Characterization of CNM: The morphological observations of as-synthesized and purified CNM were carried out by Scanning Electronic Microscope (SEM). SEM was conducted using a Hitachi (S-4700) SEM by placing the as-prepared samples on conductive carbon tape. SEM results showed that CNM prepared by above method is chain of Carbon Nano beads. The SEM images of CNB are shown in Fig.1 and Fig.2.

2.2. Photoluminescence study of Synthesized CNBs:-

The detection of band gap of nanobeads prepared by CVD method is carried out by photoluminescence (PL) technique. Photoluminescence is a highly sensitive spectroscopic method to investigate optical transition energies of semiconductors.CNBs are luminescent The ISS PC-1Spectrofluorometer has been used for the photoluminescence study of CNBs, since this Spectrofluorometer covers a large range of excitation and emission energies.

The spectra of three samples prepared in three experiments keeping all the parameters constant have been studied. All the three samples showed the absorption peak at same wavelength at around 600nm.

The band gap energy of the CNBs was found to be 2 eVolts.It is calculated by using formula: - Band gap

Energy (E) = hc/λ. A Sample PL spectra are shown in Figure 3.

The analysis of these peaks and the calculation of band gap showed that CNBs prepared by above mentioned method are semiconductor in nature.

2.3. Experimental study of CNB as a biosensor:
Hormones are the substances produced by the body that have chemical effect on the other parts of the body. Women produce hormones like estradiol (estrogen), Follicle Stimulating Hormone (FSH), Luteinizing Hormone (LH) and progesterone. Certain hormones rise at the various times of menstrual cycle and during pregnancy. Estrogen is the predominant female hormone.Estrodiol is the major form of estrogen produced in ovary. On the first day of Menstrual cycle, estrogen and progesterone levels are low which signal the pituitary gland to produce FSH.FSH begins the process of maturing a follicle. Follicle produces more estrogen to prepare uterus for preganancy.At ovulation, usually around 12th to 14th day ,increased estrogen level triggers a sharp rise in LH from pituitary gland causing release of egg from the follicle. Ruptured egg secretes progesterone and estrogen to continue to prepare uterus for pregnancy. If egg is not fertilized, estrogen and progesterone levels drop on 28th day and menses begin.The Female hormone cycle showing the estrogen and progesterone level is shown in Figure 4.

In order to test the sensing ability of CNBs towards female hormones, urine sample of a healthy woman at different stages of menstrual cycle is used. Testing is carried out by designing a simple circuit containing capacitor, resistor and 9V battery which shown in Fig.5. The voltage across the capacitor with CNBs and without CNBs for various conditions of the subject has been measured and tabulated in Table.1. Observed variation of voltage in the presence of CNBs ensures the contribution of CNBs in sensing hormones in urine. Thorough analysis and calibration of this result in comparison with a normal menstrual cycle can be done in order to calculate the exact percentage of the hormone content in the urine.

III. RESULT AND DISCUSSION

From the above observations, the voltage in the absence of CNBs is same in all the cases whereas the voltage varies in the presence of CNBs and at the different stages of hormonal cycle. It is a well known fact that the female reproductive hormone levels are not constant throughout the menstrual cycle. Therefore, the observed voltage decreases with increase in the hormone content. This relation can be understood from Table.1.and Fig.4. This result gives the scope for developing biosensors from CNBs for measuring the quantity of female hormones by a non-invasive and a simple method. These voltage values can be further calibrated and modified so that it can be used for diagnosis of hormonal imbalance and related disorders.

IV. REFERENCES

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V. TABLES AND FIGURES

Table 1. Variation of voltage across the capacitor with and without CNB for various condition of the subject.

Sr.No	Materials	Voltage (v)	Condition of the subject
1	Without CNB	2.80	Menses
2	With thin layer of CNB	3.34	
3	With thick layer of CNB	4.9	
4	Without CNB	2.80	7th to 9th day of menstrual cycle
5	With thin layer of CNB	3.25	
6	With thick layer of CNB	4	
7	Without CNB	2.82	12th to 14th day of menstrual cycle
8	With thin layer of CNB	1.2	
9	With thick layer of CNB	1.7	

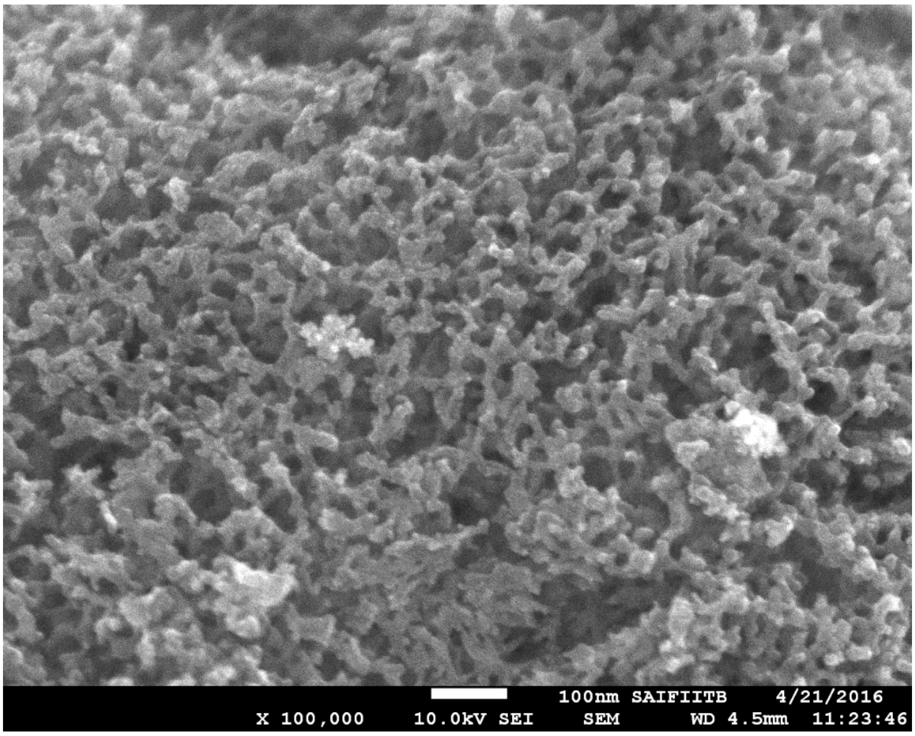

Figure 1. SEM image (1) of CNB

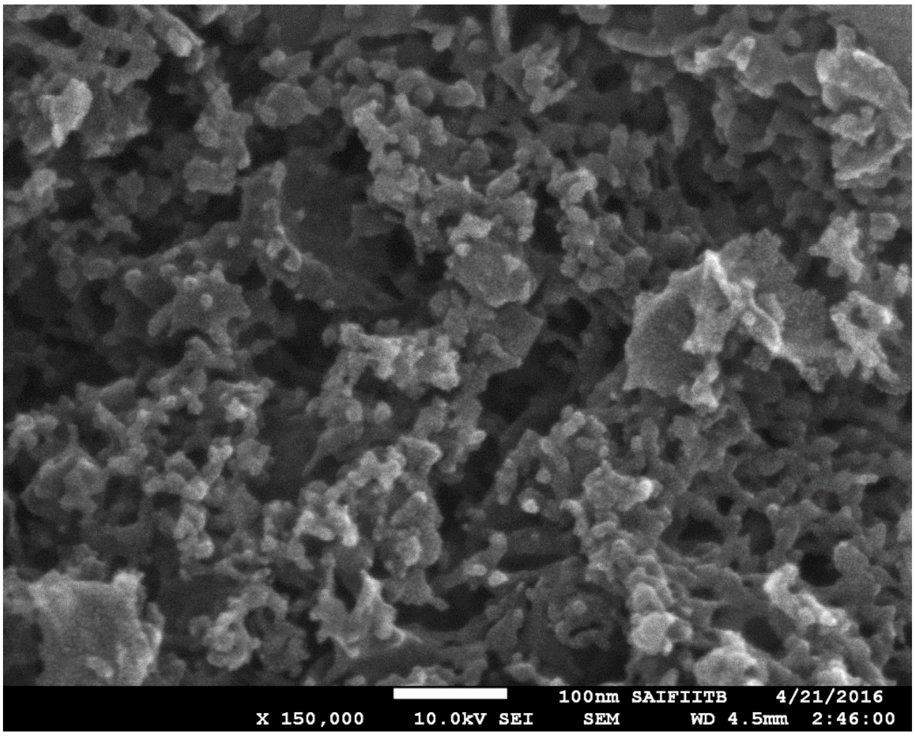

Figure 2. SEM image (2) of CNB

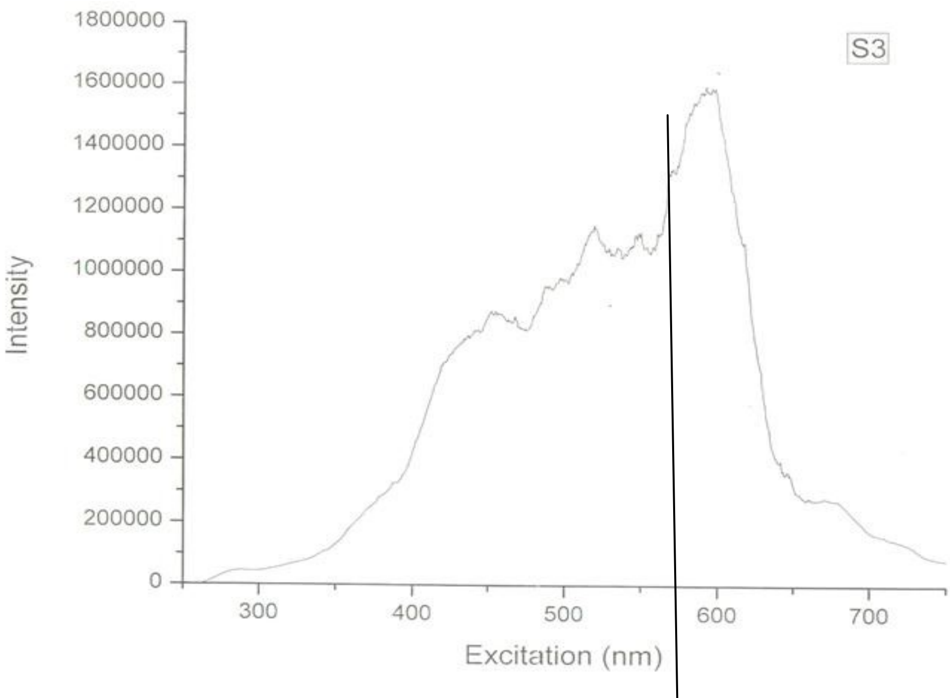

Figure 3. Photoluminescence spectrum of CNB

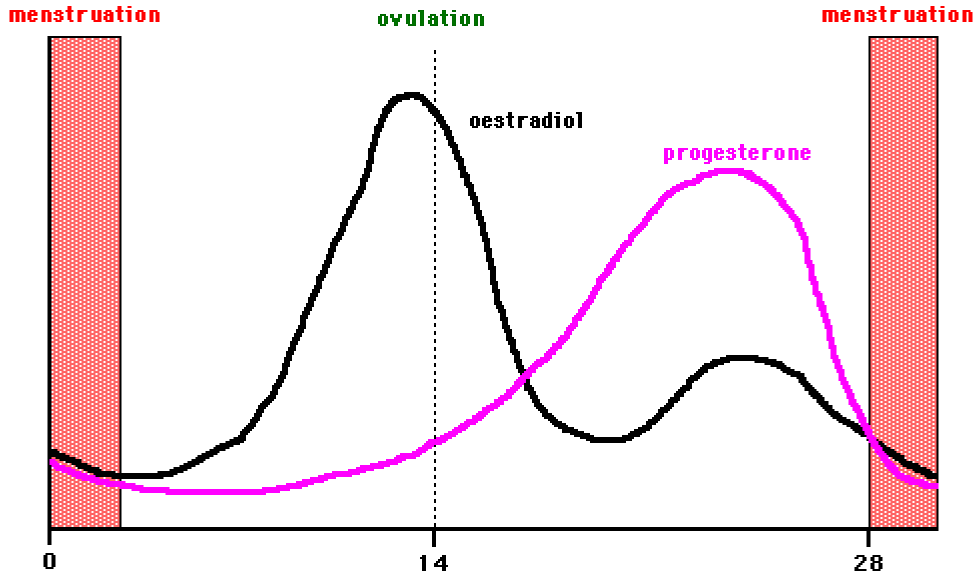

Figure 4. Estradiol and progesterone in the menstrual cycle.

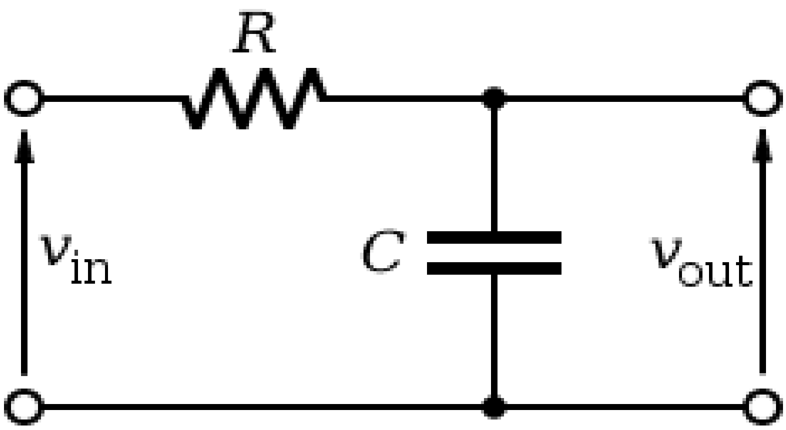

Figure 5. Circuit Diagram to test the sensing ability of CNBs towards female hormones