HYDROTHERMAL SYNTHESIS OF YTTRIUM ORTHOVANADATE (YVO_4) AND ITS APPLICATION IN PHOTO CATALYTIC DEGRADATION OF SEWAGE WATER

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Abstract: *In this paper, YVO_4 powder was successfully synthesized from Vanadium Pentaoxide (V_2O_5), Yttrium Oxide (Y_2O_3) and ethyl acetate as a mineralizer by hydrothermal method at a low temperature (T=.230°C, and P=100bars).The as-prepared powders were characterized by X-ray Diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM), UV-V Spectroscopy and Chemical Oxygen Demand (COD) of the sewage water, respectively. The results show that hydrothermal method can greatly promote the crystallization and growth of YVO_4 phase. XRD pattern clearly indicates the tetragonal structure and crystallanity. An FTIR spectrum of the YVO_4 shows the presence of Y-O and V-O bond, respectively. The presence of these two peaks indicates that yttrum vanadate has been formed. UV-V is absorption spectra suggesting that YVO_4 particles have stronger UV absorption than natural sunlight and subsequent photocatalytic degradation data also confirmed their higher photocatalytic activity.*

Keywords: *XRD, FTIR, SEM, Hydrothermal Growth, Photocatalysis, COD.*

1. INTRODUCTION

Water is one of the primary natural resourcess and a necessity for sustaining life on earth. Supplying an adequate amount of potable water to the population worldwide for the sake of growing industrial and domestic needs is a gigantic task. The threats of global [1] warming and climate change which aggravate the problem of water shortage, are of particular concern to India as this country largely depends on glaciers and rainfall for water supply.

Water pollution is the contamination [2] of water bodies such as lakes, rivers, oceans and ground water. Water pollution affects organisms and plants that live in these water bodies and, in almost all cases, it damages not only individual species and population but also natural biological communities. It occurs when pollutants are discharged directly or indirectly into water bodies without adequate treatment to remove harmful contaminants.

Environmental contamination, [3] which is growing around the world and in our daily life, is a serious social problem which cannot be neglected. Examples of such contaminations can be listed as fallows:

1. Water pollution by household waste water discharge and industrial discharge.
2. Respiratory diseases causeds by air pollutants such as Sox or Nox.
3. Global warming, climate change, glacier melting etc.

The fact is that using energy to eliminate such environmental contamination increases the emission of CO_2 resulting in more global warming. Therefore, it leads to a dilemma of using energy to achieve the anti-pollution goal. Under such circumstances, it can be concluded that a material is needed which can gently [4] harmonize the contaminated environment in order to restore original conditions using natural energy which is a part of the environment and low cost energy which is supplied to the daily life. One solution to this problem which is presented in this research is photo catalysis. YVO_4, an important [5] optical material, has many wonderful characteristics and optical properties. The Yttrium Orthovandate (YVO_4) as an important metal [6]. Rare earth vanadates

(MVO_4,where M=Y,Bi,Fe,In, etc) has found some wide and practical applications., such as excellent laser host materials in single crystal form, which make it play [7] an important role in almost any devices involving the artificial production [8] of light and display [9] fields, such as excellent [10] polarizer and laser host material. This system has shown an excellent performance in the production [11] of both hydrogen and oxygen in UV and visible light, however its photo catalytic property is poorly understood.

The band gap of YVO_4 is about 3.5eV, [12] which is wider than that of $InVO_4$, though both have a V element in their structure. As heterogeneous Y^{3+} introduced, the crystal structure is modulated to the tetragonal zircon-type consequently. Therefore the electronic structure is also changed and, the band gap is widened.

Hence in this study, an attempt is made to study the photo catalytic application of pure Yttrium Orthovanadate (YVO_4).

2. MATERIALS AND METHOD

For preparing YVO_4 particles, appropriate amounts of Y_2O_3,V_2O_5 in 1:1molar ratio were dissolved in ethyl acetate as a mineralizer solution, and the entire mixture was stirred in a magnetic stirrer for 15 minutes till a homogeneous solution was obtained and the solution was completely transferred into the Teflon liner of 25ml capacity provided with general purpose autoclaves of SS316. The use of Teflon liners helps in overcoming the entry of inclusions from the autoclave material into the crystals. The temperature and pressure were kept constant at T-230°C and P-100 bars, respectively, and the experimental duration was 6 hr. After the experimental run the autoclave was taken out from the hot air oven and was cooled naturally at room temperature. The, synthesized material from the Teflon liner was collected and washed with distilled water for 3 to 4 times; then it was dried for 1hr at 60°C in hot air oven in order to eliminate the moisture content form the obtained material. The obtained materials from the hydrothermal method were characterized using X-ray Diffraction (XRD) analysis, which was performed using a Rigaku miniflex2,copper target,(λ=1.5405Å) and in the scanning range of 10- 800 (2θ), Fourier Transform Infrared Spectroscopy (FTIR 460 plus Jasco) Scanning Electron Microscopy (SEM Hitachi model S-3500N), UV-V spectroscopy (minispectroscp SL171,Elco) and Chemical oxygen demand (COD).

The photocatalytic property of the YVO_4 was tested, at first, 0.1601mg of hydrothermally synthesized YVO_4 powder was dispersed into five beakers, which were filled with 40 ml of sewage waste water separately. Prior to irradiation, the suspension were magnetically stirred in a dark condition for 30 min to establish adsorption/degradation equilibrium. The suspensions were then irradiated under the UV

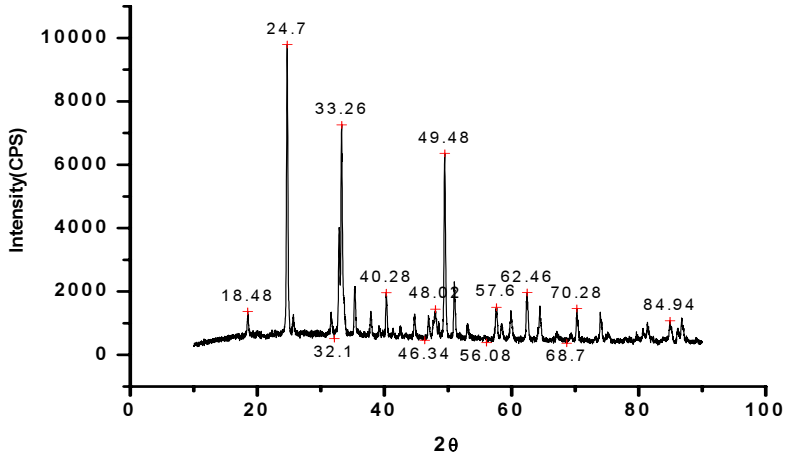

Fig.1. Shows the XRD pattern of the YVO_4 crystal prepared by hydrothermal method

light and sun light. A 400w high-pressure Hg lamp with a maximum emission at about 360 nm was used as a light source.

3. RESULTS AND DISCUSSION

YVO_4 crystal has a zircon type structure and belongs to the tetragonal space group of $I4_1/amd$ with cell dimensions of. a=7.119Å, c=6.289Å [13]. Fig.1 shows the XRD pattern of YVO_4 crystals prepared by hydrothermal method. All the diffraction peaks could be identified as belonging to the tetragonal zircon-type lattice structure of YVO_4. (JCPDS: 17-0341).The tetragonal-phase YVO_4 can be easily obtained even at T- 230°C. Three predominant diffraction peaks of 2θ =24.7, 33.26 and 49.48 belongings to the crystalline YVO_4 were observed clearly which indicate the relative high crystallinity. It can be concluded that YVO_4 single phase was formed successively by the hydrothermal method.

Fig.s 2.A.B.andC. shows the FTIR spectra of YVO_4 particle before and after phtodegradation. The infrared spectra of the YVO_4 were recorded in the range of 4000-400cm^{-1}, from the FTIR spectra,, It can be observed that a strong peak at 836 cm^{-1}, is apparently associated with the characteristic vibrating modes of the VO_4 group and a weak absorption peak of the Y-O (449.333 cm^{-1}). The presence of these two peaks indicates that yttrium orthovandate has formed and completed the crystallization of the YVO_4.The following reaction would have occurred during the synthesis:

$$Y_2O_3 + V_2O_5 + CH_3COOC_2H_5 \rightarrow Y_2O_3 + V_2O_7 + 4CH_3 + H_2 \rightarrow \text{Equation1}$$

$$Y_2O_3 + V_2o_7 + 4CH_3 + H_2 \rightarrow 2YVO_4 + 4CH_3 + H_2O_2 \rightarrow \text{Equation2}$$

The broad absorption band at 3095.19 cm^{-1} corresponds to the OH groups of H_2O while absorbing to the surface of the crystals. In addition, the FTIR spectra for hydrothermal product show the two bands at 2358.51 cm^{-1} and 1646.91 cm^{-1}, which are assigned to OH stretching vibration modes for coordinated water. No structural changes could be found in the Infrared spectra of the YVO_4, before and after photodegradation of the Sewage waste water, meaning that FTIR spectra of the YVO_4 were not changed even after the photodegradation. This

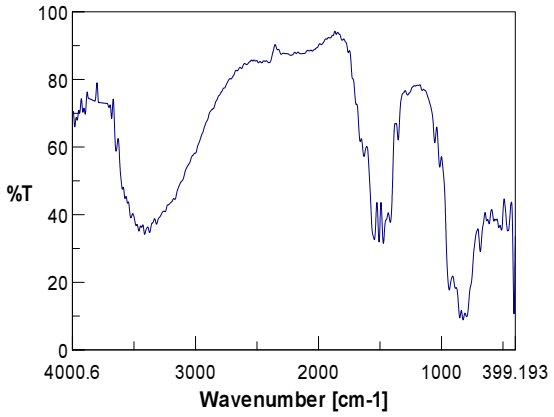

Fig. 2. A. FTIR of the YVO4

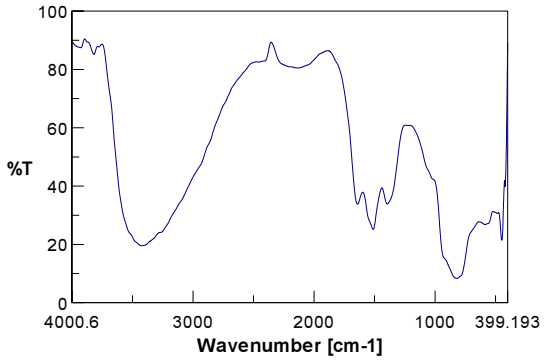

Fig. 2. B. FTIR of the YVO4 crystal after degradation of sewage waste water by sun light.

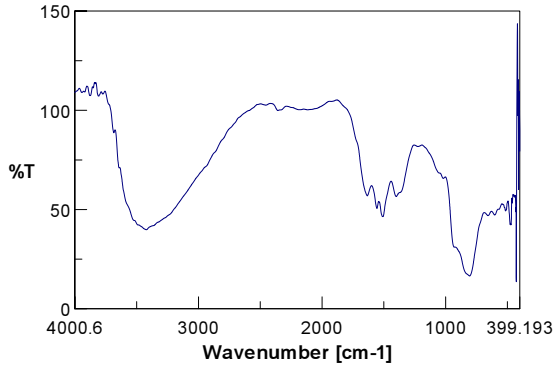

Fig. 2. C. FTIR of the YVO_4 crystal after degradation of Sewage waste water by UV light.

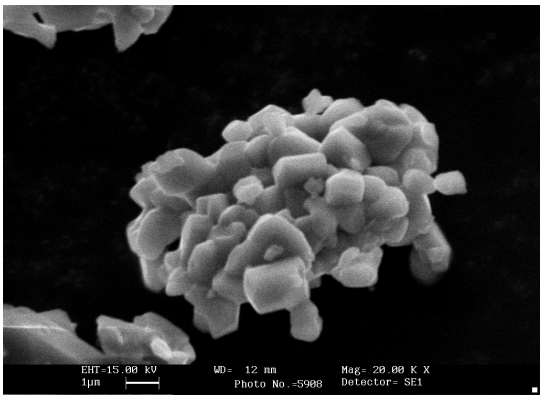

Fig. 3 .A

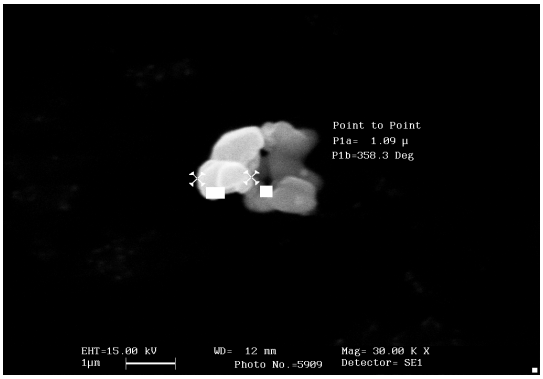

Fig.3.B

Fig. 3. Photo degradation of the Sewage waste water by YVO_4 crystal.

indicated that it performed as a photo catalyst without participation in the chemical reaction. In the present research, it can be conclude that YVO_4 acts as a photo catalyst by accelerating the rate of reaction in presence of sunlight and UV light without participating in the chemical reaction. In this study, YVO_4 shows more photocatalytic degradation for UV light than natural sunlight.

The morphology and grain size of the YVO_4 particles were characterized with SEM. Fig.3. A and B. shows the SEM images of the YVO_4.The SEM image shows that the products are composed of large quantities of 1D YVO_4 with typical lengths up to several micrometers. An YVO_4 particle, prepared at T-230°C, consists of homogeneous and tetragonal structures. The SEM images shows that YVO_4 particles which are agglomerated may be because of the hydrophobic nature of the mineralizer which is used as a precursor material for the synthesis.

YVO_4 is a semiconductor which turns to a high energy state by receiving light energy and releases electrons form its illuminated surface and jumped to the conduction band leaving a hole in valence band. The hole in the valence band has a strong oxidation power and takes the electron form the OH- (hydroxide ion) in the water at the time OH which takes the electron and, becomes OH radicals of very unstable condition. OH radical takes the electron by the strong oxidation from nearby the organic compound in order to become stable. In this way the organic compound is decomposed by the loss of electron and finally become CO_2 and water and released in to the atmosphere. Fig.4 indicates the photo catalytic process.

COD test is commonly used to measure the amount of organic compound in water; most

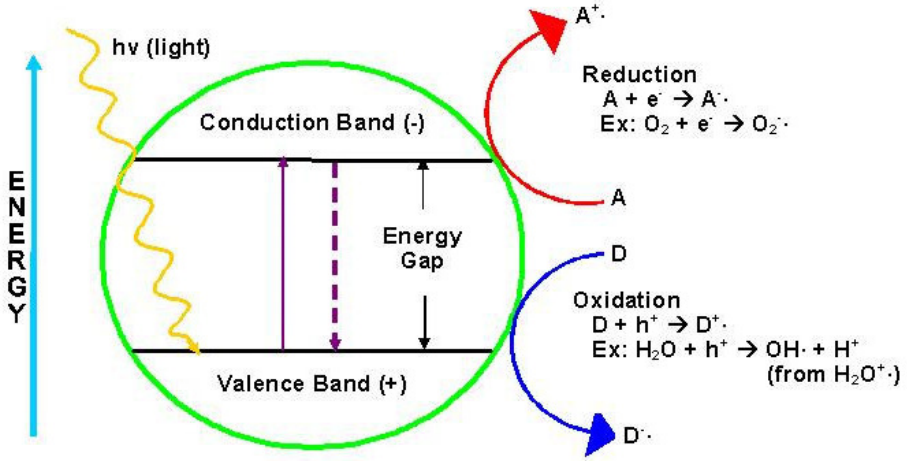

Fig. 4. The above figure shows basic Photo catalytic process (fujishima, 1972)

Table 1. Initial and final COD of the Photo degraded Sewage water by YVO_4 crystal.

COD of the sewage water before photo degradation.	COD of sewage waste water after photo degradation by UV light.	COD of sewage waste water after photo degradation by sun light.
332.28 mg/L.	51.92 mg/L.	259.6 mg/L.

applications of COD determines the amount of organic pollutants found in the waste water making COD a useful measure of water quality.

In this research, 0.1601 gm of Hydrothermally synthesized YVO_4 powder are taken as a catalyst into the five cleaned beakers containing 40 ml of sewage waste water, then the beakers is irradiated to the sunlight and to the UV light for 6 hrs. After 6 hrs of exposure to the UV light and sunlight, the sewage water sample is immediately analyzed for Chemical Oxygen Demand (COD) and UV spectroscopy. Initial COD of the sewage waste water was 256.9 mg/l. However, after being irradiated to the UV light and sunlight reduction was observed in the COD level to 51.92 mg/l and 332.28 mg/l respectively. Spectroscopic measurement showed an increase in the percentage transmission of light. The initial percentage transmission of sewage waste water was 0% and, after the irradiation by sunlight and UV light, the percentage transmission increased to 90 to 100%. This means that YVO_4 degraded the organic chemicals in the sewage waste water at orbital level. Fig.5 indicates the UV spectroscopic data of the sewage water and Table.1 shows the initial and final Chemical Oxygen Demand (COD) of sewage water before and after photo degradation by YVO_4.

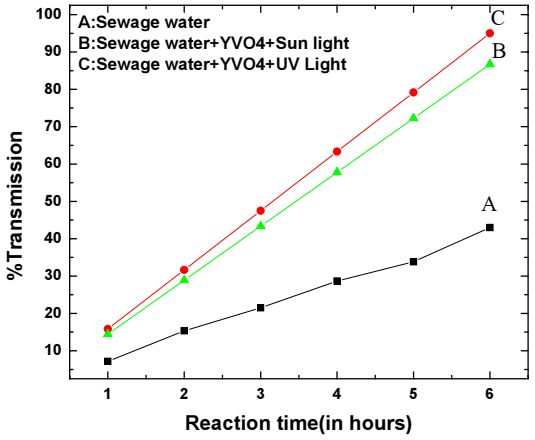

Fig. 5. Photo degradation of the Sewage waste water by YVO_4 crystal.

For the first time, an attempt was made to find the photo catalytic activity of the Yttrium Orthovanadate (YVO_4) in degrading sewage waste water. Therefore, the good crystallization and band gap can be considered as key factors, which enhance the photocatalytic performance of the YVO_4 powder.

4. CONCLUSIONS

Homogeneous particles can be easily prepared by a simple and convenient hydrothermal method. Their synthetic temperature can be lowered to T- 230°C and their pressure to P-100 bars, their tetragonal YVO_4 micro particles with 1μm in diameter can be obtained. Obtained results revealed that YVO_4 acts as a photo catalyst and playes a key role in degrading the organic pollutants in the sewage waste water. The major advantage of this research is that the photo degraded sewage waste water can be reused for the external purposes like cleaning and washing and the photo catalyst can be reused for the further research in photocatalytic activities. The influence of hydrothermal treatment temperature on micro particles YVO_4 was revealed by XRD and FTIR measurements. FTIR spectrometry data are in good agreement with XRD results which clearly indicates the VO_4 vibration. As a necessary condition for developing a photocatalyst with a high performance, it would

be important, that the system be designed in a way to produce short water catalyst. Considering the above mentioned results can be concluded that YVO_4 micro particles are promising alternative materials for phtocatalyst and may find potential applications in the related fields.

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