2022「中技社科技獎學金」
2022 CTCI Foundation Science and Technology Scholarship
境外生生活助學金
Living Grant for International Graduate Students

Effect of growth temperature on morphology and photocatalytic properties of TiO_2@Carbon-modified nanowires

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Abstract

Photocatalysis is an accelerated chemical reaction in present of light which occurs when electron-hole pair created by photon can interact with molecules. Semiconductor photocatalysis is an efficient method for chemical utilization of solar energy. TiO_2 are widely popular because of good UV-absorption, low cost and good stability[1]. However, the large band gap (3.0eV)[2] becomes a disadvantage for TiO_2 as photocatalyst. on this work, we report the modification of TiO_2 by introducing acetone (as a carbon source) at certain temperature. The amount of carbon from acetone can be produced by controlling the temperature. The morphology of TiO_2@Carbon-modified has been determined as nanowires by SEM, the mean diameter of nanowires are increased from 95.3 nm to 798.4 nm with increasing the growth temperature from 650°C to 950°C, respectively. The rutile phase of TiO_2@Carbon-modified has confirmed by Raman spectroscopy, and the chemical composition of TiO_2@Carbon-modified has studied by XPS, it shows the appearance of the C1s, Ti2p, and O1s peaks at the core level. Based on the First-order kinetic equation, degradation the rate of TiO_2@carbon can be estimated, the sample grown at 850°C has better degradation rate ($2.3x10^{-4}$ min^{-1}) from other samples, it can reduce the MB molecule up to 36.5% in 8 hours.

Experimental set-up

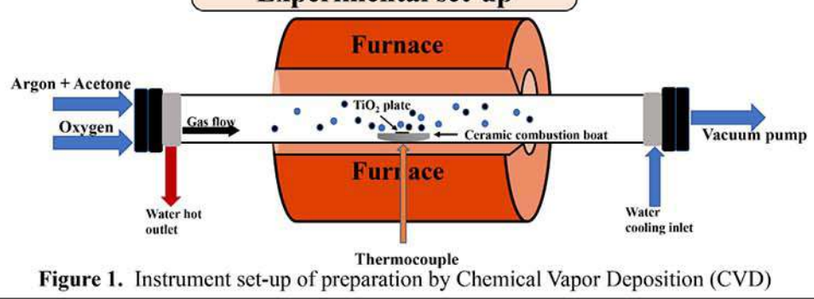

Figure 1. Instrument set-up of preparation by Chemical Vapor Deposition (CVD)

Morphology study

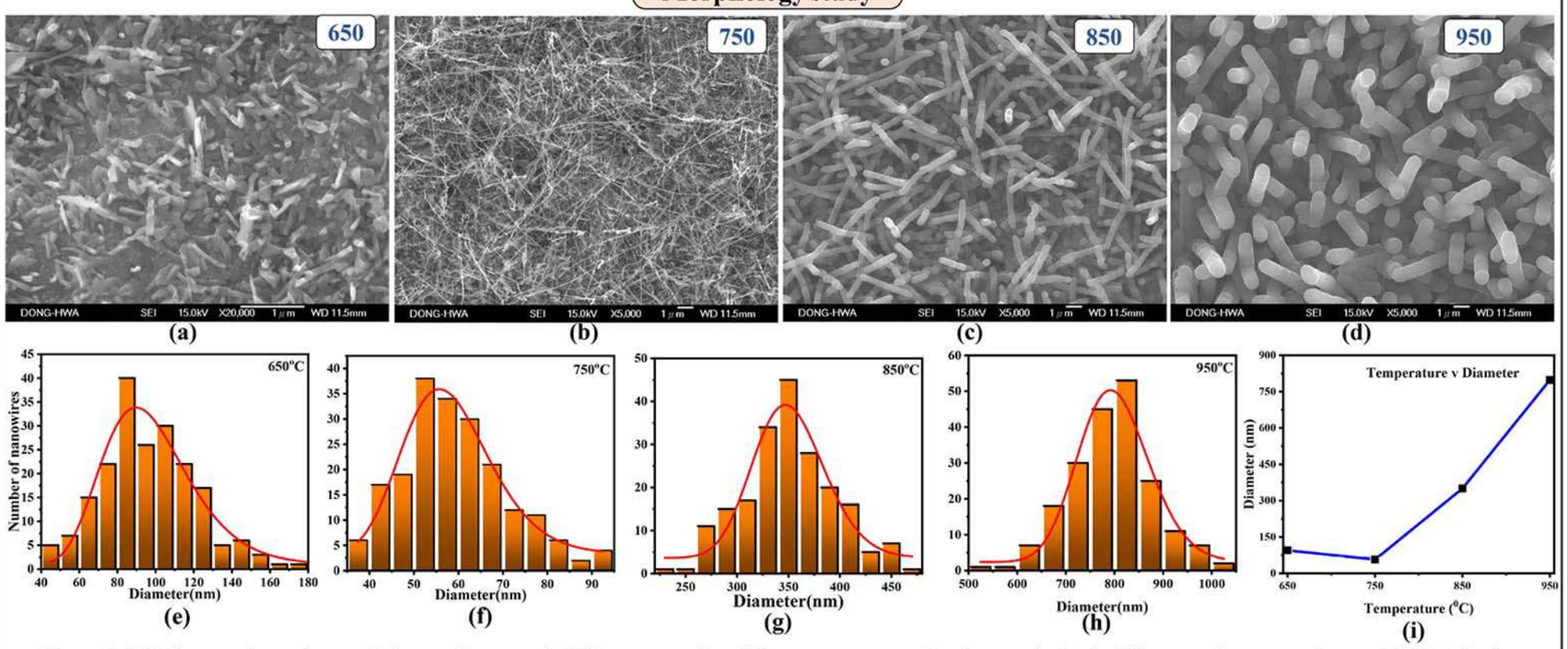

Figure 2. SEM images shows the morphology and structural of TiO_2 grown at four different temperatures (a - d) respectively, the TiO_2 nanowires start to form at 750°C; (e-h) shows the distribution of TiO_2 nanowires, the nanowires distribution is fitted using log-Normal distribution function; (i) average of diameter v temperature, it shown the diameter of nanowires increases as the temperature increasing.

Raman Analysis

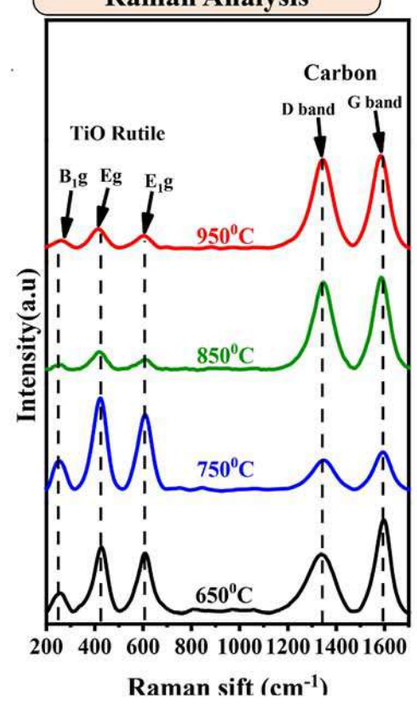

Figure 3. TiO_2@Carbon was analyzed by Raman spectroscopy. Appearance two peak at 415cm^{-1}(E_g mode) and 602cm^{-1}(A_{1g} mode), which indicates that TiO_2 has rutile phase. And peak at 1343cm-1 and 1583cm-1 corresponds to D and G band of carbon

XPS characterization

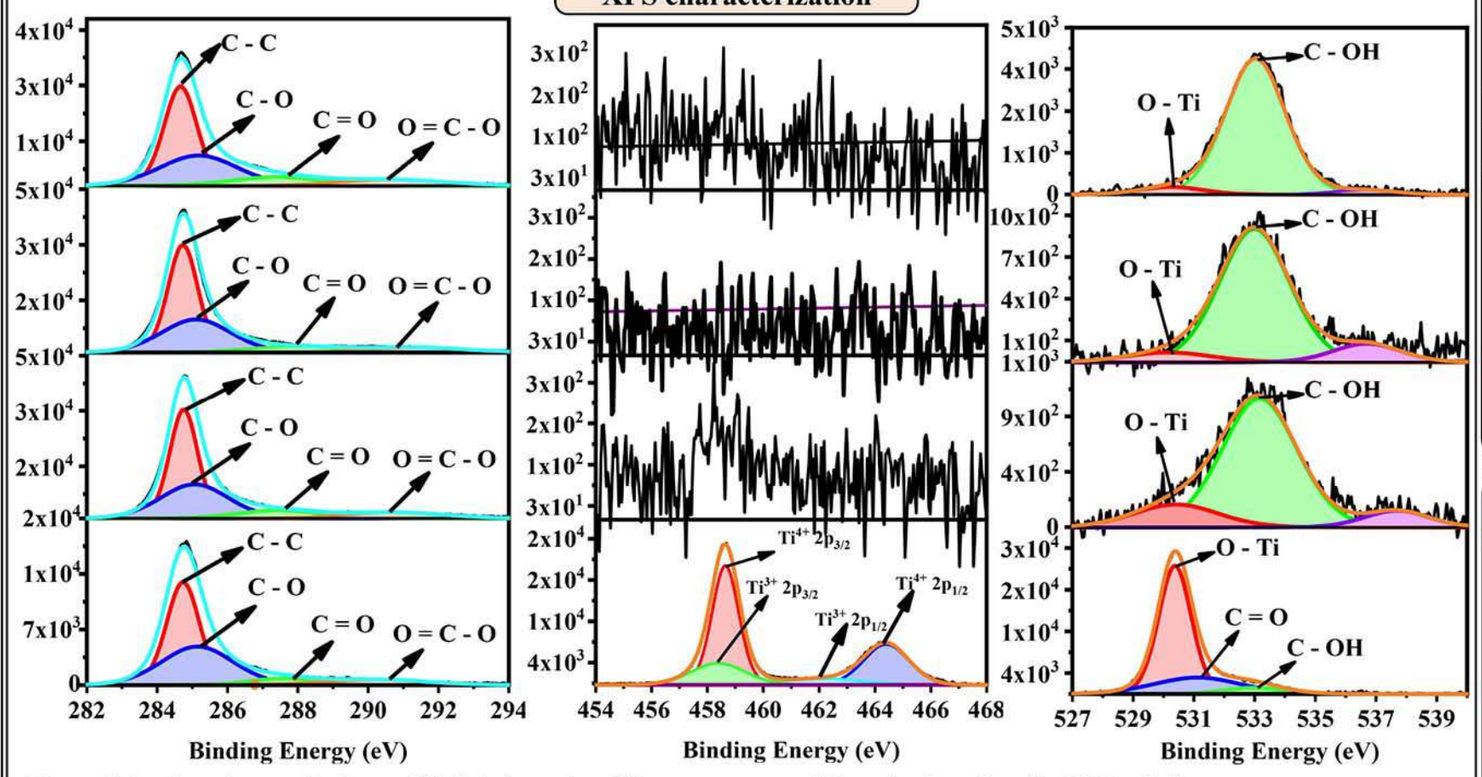

Figure (4.a). The existence of carbon on TiO_2@Carbon at four different temperatures different has investigated by XPS analysis.
Figure (4.b). Two peaks center at 458.8 eV and 464.6 eV correspond to the characteristic Ti $2p_{3/2}$ and Ti $2p_{1/2}$ peaks of Ti^{4+}, respectively. It was observed shoulder was observed at lower binding energies for the samples that contain defects, which can be ascribed to Ti^{3+} ions.
Figure (4.c). There is no TiO_2-C peak, suggesting that the carbon doesn't dope with TiO_2.

UV-Vis characterization

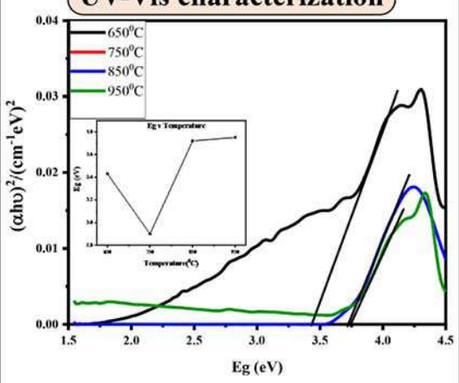

Figure 5. The UV-Vis spectroscopy shown the absorption ability of TiO_2@Carbon and was analyzed by using touch-plot method.

Constant rate

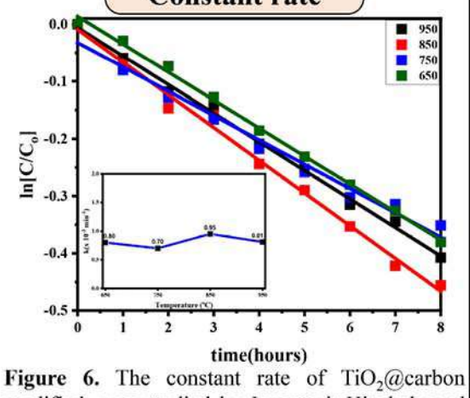

Figure 6. The constant rate of TiO_2@carbon modified was studied by Langmuir-Hinshelwood (L-H) model. The sample at 850 has highest constant rate compared to other samples.

Eg, Constant rate V Temperature

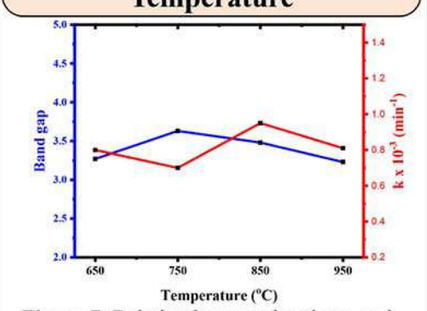

Figure 7. Relation between band gap and constant rate in each temperature.

Conclusion

- Mean diameter of nanowires increases by increasing the growth temperature.
- Raman spectroscopy result has confirmed that TiO_2@Carbon might be exhibit on rutile phase for all growth temperatures.
- XPS result shows the appearance of the Ti^{3+} peak, which means the samples has oxygen vacancy.
- The band gap of the samples decreases as the growth temperature increase from 750 to 950°C.
- The highest degradation efficiency for degradation of methylene blue dye was obtained at 850°C.
- The highest constant rate of degradation was obtained in 850°C at 0.95(S^{-1})

References

1. Nanocrystalline anatase TiO_2 photocatalysts prepared *via* a facile low-temperature nonhydrolytic sol-gel reaction of $TiCl_4$ and benzyl alcohol. Applied Catalysis B: Environmental. 2007, 76, 82-91
2. Obtaining titanium dioxide nanoparticles with spherical shape and antimicrobial properties using M.citrifolia leave extract by hydrothermal method. Journal of photochemistry and photobiology, B: Biology. 171 (2017) 117-124