PHOTOCATALYTIC PHENOL REMOVAL
IN PHENOL-UREA-FORMALDEHYDE SOLUTION
ON CYANAMIDE MODIFIED IRON (III) OXIDE

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This work is dedicated to my beloved parents, Roslan and Noratipah,
as well as my little sister, Nur Aina Nabilah, who has always been there for me,
and has never doubted my dreams, and also to all my friends,
who has shared the joyful tears and get through the storms that we have
weathered. I love you all.

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ABSTRACT

Phenolic resin waste contains harmful chemical compounds such as phenol, urea, and formaldehyde that need to be treated before disposal. In this study, a series of cyanamide modified Fe_2O_3 was prepared from $FeCl_2.4H_2O$ as the iron precursor and cyanamide (CYA) as the carbon and nitrogen source. The cyanamide modified Fe_2O_3 was used for photocatalytic removal of phenol in the mixture of phenol-urea-formaldehyde. X-ray diffractometry patterns showed the formation of Fe_2O_3 peak. The peak intensity decreased with the increased of cyanamide mol ratio. The addition of cyanamide decreased the band gap energy of Fe_2O_3, showing that carbon and nitrogen-based material might act as a dopant. The presence of carbon species was confirmed by diffuse reflectance UV-visible and Fourier transform infrared spectroscopy, as well as thermogravimetric analysis, especially on sample with high mol ratio of cyanamide precursor. Photoluminescence study revealed that addition of low mol ratio of cyanamide successfully decreased the electron-hole recombination, while the addition of high mol ratio of cyanamide might block the emission sites of Fe_2O_3. Scanning electron microscope images of the samples also confirmed that samples with high mol ratio of cyanamide have a flake-type structure that coated the surface of Fe_2O_3. In the photocatalytic removal of phenol both under UV and visible light irradiation, all prepared samples gave better photocatalytic activity than the bulk Fe_2O_3. The best activity was achieved on Fe_2O_3-CYA(6) catalyst with the mol ratio cyanamide to iron precursor of 6, in which the percentage of phenol removal was 75 and 80% under UV and visible light, respectively. The high activity would be due to the success suppression of electron-hole recombination, decrease of the band gap energy, and the good interaction between phenol and emission sites of Fe_2O_3-CYA(6) catalyst, as supported by the fluorescence quenching study. The photocatalytic activity for phenol removal decreased in the presence of urea, formaldehyde, and urea-formaldehyde since there were adsorption competition as well as reaction competitions, such as oxidation of formaldehyde and formation of phenolic resin.

ABSTRAK

Sisa resin fenolik mengandungi kandungan bahan kimia merbahaya seperti fenol, urea dan fomaldehid yang perlu dirawat sebelum dibuang. Dalam kajian ini, suatu siri ferum(III) oksida (Fe_2O_3) terubahsuai sianamida telah disediakan daripada $FeCl_2.4H_2O$ sebagai pelopor ferum dan sianamida (CYA) sebagai sumber karbon dan nitrogen. Ferum(III) oksida terubahsuai sianamida digunakan untuk fotopemangkinan penyingkiran fenol dalam campuran larutan fenol-urea-formaldehid. Corak teknik pembelauan sinar-X menunjukkan pembentukan Fe_2O_3, di mana keamatan puncak berkurang dengan meningkatnya nisbah mol sianamida. Pertambahan sianamida mengurangkan tenaga ruang jalur Fe_2O_3, menunjukkan bahawa bahan berasaskan karbon dan nitrogen berkemungkinan bertindak sebagai dopan. Kehadiran spesies karbon telah disahkan dengan menggunakan pantulan serakan ultra lembayung-cahaya nampak dan spektroskopi inframerah transformasi Fourier, serta analisis termogravimetri terutama pada sampel dengan nisbah mol sianamida yang tinggi. Kajian pendarcahaya menunjukkan bahawa pertambahan nisbah mol sianamida yang rendah berjaya mengurangkan penggabungan semula elektron-lubang, sementara penambahan nisbah mol sianamida dalam jumlah yang tinggi berkemungkinan menyekat tapak pemancaran Fe_2O_3. Imej sampel daripada mikroskop pengimbas elektron juga telah mengesahkan bahawa sampel dengan nisbah mol sianamida yang tinggi mempunyai struktur berbentuk kepingan yang menyaluti permukaan Fe_2O_3. Dalam fotopemangkinan penyingkiran fenol di bawah sinaran UV dan cahaya nampak, semua sampel memberikan aktiviti fotopemangkinan yang lebih baik daripada Fe_2O_3 pukal. Aktiviti terbaik diberikan oleh mangkin Fe_2O_3-CYA(6) dengan nisbah mol sianamida kepada ferum 6, yang memberikan peratusan penyingkiran fenol masing-masing 75 dan 80% di bawah cahaya UV dan cahaya nampak. Aktiviti yang tinggi oleh mangkin ini disebabkan kejayaan penyekatan elektron-lubang, pengecilan aras jalur tenaga dan interaksi yang baik antara fenol dan tapak pemancaran mangkin Fe_2O_3-CYA(6), seperti yang disokong dalam kajian pelindap kejutan pendarfluor. Aktiviti fotopemangkinan untuk penyingkiran fenol menurun dengan kehadiran urea, formaldehid dan urea-formaldehid kerana terdapat persaingan penjerapan dan juga persaingan tindak balas seperti pengoksidaan formaldehid dan pembentukan resin fenolik.

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LIST OF ABBREVIATIONS

arb.u	-	Arbitrary unit
cm	-	centimetre
DR UV-Vis	-	Diffuse Reflectance Ultra Violet-Visible
eV	-	Electron volt
FTIR	-	Fourier Transform Infra-Red
g	-	Gram
GC-FID	-	Gas Chromatography-Flame Ionization Detector
h		Hour(s)
K	-	Kelvin
kV	-	Kilovolt
min	-	Minute(s)
mL	-	Millimetre
nm	-	Nanometre
ppm	-	Part per million
s	-	Second
SEM	-	Scanning Electron Microscopy
TGA	-	Thermogravimetric Analysis
UV	-	Ultra Violet
XRD	-	X-Ray Diffraction

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CHAPTER 1

INTRODUCTION

1.1 General Background

Phenolic resin is one type of thermosetting resins containing phenol, formaldehyde and also urea. Phenolic resins have been used in vast applications, such as plastic industry (Whitehouse *et al*., 1967), wood adhesives (Peshkova & Li, 2003), and communication equipment (Hirano & Asami, 2013). As one of the compositions in the phenolic resins, phenol has been recognized as the most common organic pollutants, which can be easily found in the industrial waste. Since phenol can act as a carcinogenic compound to the human being, the permissible exposure limit (PEL) stated by Occupational Safety and Health is around 5 ppm (United States Department of Labour, 1996). Due to the toxicity of the phenol, many studies have been focused on the degradation of phenol. There have been many researches conducted on various methods suitable in dealing with this pollutant, such as biodegradation (El-Naas *et al*., 2009), adsorption (Caetano *et al*., 2009), thermal decomposition (Chen *et al*., 2008), catalytic conversion (Katada *et al*., 1997), and emulsion liquid membranes (Correia & Carvalho, 2003) and emulsion pertraction technology (Urtiaga *et al*., 2009). Another method that can be acknowledged is photocatalytic degradation method that is still stands as one the preferred methods in most of the studies, owing to its clean and environmentally safe process.

Photocatalysis has been proven to be one of the efficient methods in mineralization or removal of organic pollutant (Bandara *et al*., 2001; Yang *et al*., 2000; Zhang *et al*., 2010). While there have been many reports on photocatalytic removal of phenol as a single target pollutant, less attention has been made on the removal of phenol in the presence of other organic pollutants, such as in the case of phenolic resins, which contained of phenol, urea, and formaldehyde. Furthermore, most studies reported that the efficiency of the photocatalyst was restricted only to the low concentration of phenol (Araña *et al*., 2001). Therefore, photocatalytic removal of phenol in the presence of urea and formaldehyde was investigated in this study. For this purpose, development of a highly active heterogeneous photocatalyst that able to degrade phenol even in high concentration in the presence of other pollutants is very important.

On the other hand, iron (III) oxide (Fe_2O_3) has been recognized as a good catalyst for various chemical reactions. As it also has paramagnetic properties, it can be used as a good recyclable catalyst in heterogeneous catalysis. As example, Fe_2O_3 can be reused easily for at least five cycles by collecting the catalyst using magnet (Drbohlavova *et al*., 2009). In addition to the paramagnetic properties, Fe_2O_3 is a semiconductor that has a band gap of 2.1 eV, suggesting that it might be a potential photocatalyst under visible light irradiation. Unfortunately, it was confirmed that even though Fe_2O_3 showed its efficiency in removing phenol from water under ultra-violet (UV) light irradiation, it was not active under visible light irradiation (Roslan, 2011). Since sunlight emits more visible than the UV light, development of visible light-driven photocatalysts is a very important approach in photocatalysis study. Therefore, the photocatalytic activity of Fe_2O_3 under visible light irradiation should be improved, such as by introducing other material that is active under visible light. One of such potential materials is carbon nitride (C_3N_4) that has been reported to have band gap of 2.66 eV and absorb light up to 460 nm (Wang *et al*., 2009a).

The C_3N_4 can be prepared by a simple thermal polymerization method using various molecular precursors reported to prepare the g-C_3N_4, such as melamine (2,4,6-triamines-triazine) (Zhang *et al*., 2001), $C_3N_3(NH_2)_3$ (Gillan, 2000), s-triazine (cyanuric; C_3N_3) ring compounds such as $C_3N_3X_3$ (X= Cl, N, OH, NHCl) (Khabasheshku *et al*., 2000), cyanamide (Thomas *et al*., 2008) and urea (Lee *et al*., 2012). There are several hypothetical phases of carbon nitride, which are alpha (α), beta (β), cubic, pseudocubic and graphitic. Among of these phases, graphitic carbon nitride (g-C_3N_4) is the most stable phase at ambient conditions and possesses the smallest bad gap due to the sp^2 hybridization of carbon and nitrogen forming the π-conjugated graphitic planes (Molina & Sansores, 1999). Since C_3N_4 has been reported to show good photocatalytic activity under visible light irradiation for various reactions such as water splitting (Yan *et al*., 2012) and selective oxidation of alkene (Li *et al*., 2011), several studies on the preparation of metal oxides modified by C_3N_4 have been investigated, such as In_2TiO_5 (Liu *et al*., 2011) and ZnO (Wang *et al*., 2011). These prepared metal oxides modified by C_3N_4 showed better photocatalytic activities under visible light irradiation than the non-modified metal oxides.

Among the precursors of C_3N_4 mentioned above, cyanamide is of interest. In addition to formation of carbon nitride, cyanamide has been reported as a good carbon and nitrogen source in the preparation of metal nitrides (Buha *et al*., 2007), metal carbides (Li e*t. al*., 2008) and metal cyanamide (Zhao *et al*., 2013). Therefore, in this study, Fe_2O_3 was modified by cyanamide for the first time. During the thermal calcination process, cyanamide could be converted to C_3N_4 or other carbon and nitrogen-based materials, which would help enhancing the photocatalytic activity of Fe_2O_3.

1.2 Statement of Problem

Even though Fe_2O_3 has been recognized as potential photocatalyst in the photocatalytic degradation of phenol under UV light irradiation, it was reported that Fe_2O_3 suffered from the inability to work under visible light irradiation. Since visible light dominates 46% of solar light spectrum, the development of visible light-driven photocatalyst is highly desirable. Therefore, further modification needs to be conducted in order to improve the photocatalytic activity of Fe_2O_3 under visible light irradiation. Unfortunately, there is still no established method to modify the Fe_2O_3 due to the lack understanding on how to design the Fe_2O_3-based photocatalysts.

Modification of Fe_2O_3 so that it can act as visible light-driven photocatalyst is still one challenging problem. Cyanamide is used in this study since the polycondensation process of cyanamide may lead to the formation of C_3N_4 as well as other carbon and nitrogen-based materials such as CN and NCN. This study is the first investigation on the effect of cyanamide modifier on the properties and phocatalytic activity of Fe_2O_3. Therefore, it is still unclear and needs to be clarified if cyanamide precursor may improve the efficiency in the electron charge transfer process of Fe_2O_3 under visible light irradiation. Some parameters, such as effect of the ratio of cyanamide to Fe_2O_3 need to be explored in order to get fundamental understanding on designing the Fe_2O_3-based photocatalysts.

While the potential ability of Fe_2O_3 photocatalyst has been recognized for photocatalytic removal of phenol, the potential photocatalytic activity of Fe_2O_3-based photocatalysts to remove phenol in the presence of other compounds is still needs to be clarified. In addition, efficiency of phenol removal in high concentration remains unclear and further investigations need to be conducted. In the present study, the first photocatalytic degradation of phenol in the presence of urea and formaldehyde over novel Fe_2O_3-based photocatalysts is carried out. Effect of some parameters, such as the ratio of urea or formaldehyde to phenol, on the photocatalytic activity of the Fe_2O_3-based photocatalysts to remove phenol is still unclear and needs to be revealed.

1.3 Objectives

The main objectives of this study are:

1. To synthesize novel Fe_2O_3-based photocatalysts that are active in the visible light region.
2. To investigate the properties of the new Fe_2O_3-based photocatalysts.

3. To study the photocatalytic activity of the Fe_2O_3-based photocatalysts for phenol removal under UV and visible light irradiation in the presence of urea and/or formaldehyde.

1.4 Scope of the Study

The scope of this study is shown below. For preparation of Fe_2O_3-based photocatalysts, iron precursor used was $FeCl_2.4H_2O$. As the modifier, cyanamide was used with the mol ratio of cynamide to iron precursor within the range of 2 to 10. The synthesis of Fe_2O_3-based photocatalysts was carried out using one pot oxidation method at temperature of 823 K with rate of heating of 2.2 K min^{-1}. The prepared Fe_2O_3-based photocatalysts were characterized by X-ray diffraction (XRD), diffuse reflectance (DR) UV-visible spectroscopy, photoluminescence spectroscopy, Fourier transform infrared (FT-IR) spectroscopy, scanning electron microscopy (SEM), thermogravimetric analysis (TGA) and elemental analyzer. The photocatalytic activity of the prepared Fe_2O_3-based photocatalysts was tested for removal of phenol in the presence of urea, formaldehyde, and urea-formaldehyde at room temperature. The mol ratios of phenol to urea and formaldehyde used were 1:1 and 1:300, while for phenol-urea-formaldehyde were 1:1:1 and 1:300:300. All of the reactions were conducted under both UV and visible light irradiation for 25 h. The products of photocatalytic reactions were analysed and determined by a gas chromatography equipped with flame ionization detector (GC-FID).

1.5 Significance of Study

Modification of Fe_2O_3 with cyanamide would result in a novel series of materials. Therefore, this study is important in the point of view of material science. Since Fe_2O_3-based materials were used as a photocatalyst, this study will also give contribution in the photocatalysis science. The study on the ability of Fe_2O_3-based photocatalysts to remove phenol into non-hazardous compound will be a stepping stone for other researchers to explore the use of Fe_2O_3-based photocatalysts for other reaction such as conversion as well as the use of other photocatalysts for removal of phenol. Therefore, this study will give better knowledge and understanding on both photocatalyst and photocatalytic reaction.

Study on the removal of phenol in the absence and presence of other organic pollutants, such as urea and formaldehyde by photocatalytic reaction is very important in the point of view of green technology to reduce environmental problems. As we know, phenol is one of the most toxic compounds found in industrial waste water. It is expected that the findings from this research will enrich our knowledge on the fundamental studies of converting toxic organic compound in industrial waste water into non-hazardous compound, thus minimizing the harmful effects towards human being.

REFERENCES

Abdelwahab, O., Amin, N. K., & El-Ashtoukhy, E. S. Z. (2009). Electrochemical removal of phenol from oil refinery wastewater. *Journal of Hazardous Materials,* **163** (2-3), 711-716.

Addiego, W. P., Liu, W., & Boger, T. (2001). Iron oxide-based honeycomb catalysts for the dehydrogenation of ethylbenzene to styrene. *Catalysis Today,* **69** (1-4), 25-31.

Agarwal, S., Ferreira, A. E., Reis, M. T. A., Ismael, M. R. C., Ferreira, L. M., Machado, R. M., & Carvalho, J. M. R. (2009). A study on a combined process for the treatment of phenolic resin plant effluents. *Journal of Hazardous Materials,* **169** (1–3), 659-666.

Ahmed, S., Rasul, M. G., Martens, W. N., Brown, R., & Hashib, M. A. (2010). Heterogeneous photocatalytic degradation of phenols in wastewater: A review on current status and developments. *Desalination,* **261** (1-2), 3-18, and references therein.

Akpan, U. G., & Hameed, B. H. (2009). Parameters affecting the photocatalytic degradation of dyes using TiO_2-based photocatalysts: A review. *Journal of Hazardous Materials,* **170** (2-3), 520-529.

Anpo, M. (1997). Photocatalysis on titanium oxide catalysts: Approaches in achieving highly efficient reactions and realizing the use of visible light. *Catalysis Surveys from Japan,* **1** (2), 169-179.

Araña, J., Tello Rendón, E., Doña Rodríguez, J. M., Herrera Melián, J. A., González Díaz, O., & Pérez Peña, J. (2001). Highly concentrated phenolic wastewater treatment by the Photo-Fenton reaction, mechanism study by FTIR-ATR. *Chemosphere,* **44** (5), 1017-1023.

Asahi, R., Morikawa, T., Ohwaki, T., Aoki, K., & Taga, Y. (2001). Visible-light photocatalysis in nitrogen-doped titanium oxides. *Science,* **293** (5528), 269-271.

Baekeland L. H. (1909). Method of making insoluble products of phenol and formaldehyde. United States Patent Number 383,634.

Bakardjieva, S., Stengl, V., Subrt, J., Houskova, V., & Kalenda, P. (2007). Photocatalytic efficiency of iron oxides: Degradation of 4-chlorophenol. *Journal of Physics and Chemistry of Solids,* **68** (5–6), 721-724

Bandara, J., Mielczarski, J. A., Lopez, A., & Kiwi, J. (2001). Sensitized degradation of chlorophenols on iron oxides induced by visible light: Comparison with titanium oxide. *Applied Catalysis B: Environmental,* **34** (4), 321-333.

Bard, A. J., & Lund. H (1978). *Encyclopedia of Electrochemistry of the Elements*, **6**, Marcel Dekker, New York.

Billing, R., Zakharova, G. V., Atabekyan, L. S., & Hennig, H. (1991). Luminescence quenching of $*[UO_2F_4]^{2-}$ in aqueous solutions by anions. *Journal of Photochemistry and Photobiology A: Chemistry,* **59** (2), 163-174.

Budavari, S., O' Neil, M. J., Smith, A., and Heckelman, P. E., (1989). *In: The Merck Index,* 11th ed., Merck & Co., Inc., Rahway, NJ, 15.

Buha, J., Djerdj, I., Antonietti, M., & Niederberger, M. (2007). Thermal transformation of metal oxide nanoparticles into nanocrystalline metal nitrides using cyanamide and urea as nitrogen source. *Chemistry of Materials,* **19** (14), 3499-3505

Busca, G., Berardinelli, S., Resini, C., & Arrighi, L. (2008). Technologies for the removal of phenol from fluid streams: A short review of recent developments. *Journal of Hazardous Materials,* **160** (2–3), 265-288.

Caetano, M., Valderrama, C., Farran, A., & Cortina, J. L. (2009). Phenol removal from aqueous solution by adsorption and ion exchange mechanisms onto polymeric resins *Journal of Colloid and Interface Science,* **338** (2), 402-409.

Chatterjee, A., & Nicolais, L. (2011). Thermoset resins. *Wiley Encyclopedia of Composites.* New York: John Wiley & Sons, Inc.

Chatterjee, D., & Dasgupta, S. (2005). Visible light induced photocatalytic degradation of organic pollutants. *Journal of Photochemistry and Photobiology C: Photochemistry Reviews,* **6** (2-3), 186-205.

Chen, D., Jiang, Z., Geng, J., Wang, Q., & Yang, D. (2007). Carbon and nitrogen co-doped TiO_2 with enhanced visible-light photocatalytic activity. *Industrial & Engineering Chemistry Research*, **46** (9), 2741-2746.

Chen, Y., Chen, Z., Xiao, S., & Liu, H. (2008). A novel thermal degradation mechanism of phenol–formaldehyde type resins. *Thermochimica Acta,* **476** (1–2), 39-43.

Cheng, C. J., Lin C. C., Chiang, R. K., Lin, C. R., Lyubutin I. S., Alkaev, E. A., & Lai, H.Y. (2008). Synthesis of monodisperse magnetic iron oxide nanoparticles from submicrometer hematite powders. *Crystal Growth & Design*, **8** (3), 877–883.

Cheng, K., He, Y. P., Miao, Y. M., Zou, B. S., Wang, Y. G., Wang, T. H., Zhang, X. T., Du, Z. L. (2006). Quantum size effect on surface photovoltage spectra: Alpha-Fe_2O_3 nanocrystals on the surface of monodispersed silica microsphere. *The Journal of Physical Chemistry B,* **110** (14), 7259-7264.

Chernyshova, I. V., Ponnurangam, S., & Somasundaran, P. (2010). On the origin of an unusual dependence of (bio)chemical reactivity of ferric hydroxides on nanoparticle size. *Physical Chemistry Chemical Physics,* **12** (42), 14045-14056.

Chiavari, G., Fabbri, D., Mazzeo, R., Bocchini, P., & Galletti, G. C. (1995). Pyrolysis gas chromatography-mass spectrometry of natural resins used for artistic objects. *Chromatographia,* **41** (5-6), 273-281.

Chiou, C. H., Wu, C. Y., & Juang, R. S. (2008). Influence of operating parameters on photocatalytic degradation of phenol in UV/TiO_2 process. *Chemical Engineering Journal,* **139**, 322–329.

Cho, S. H., Shim, J., Yun, S. H., & Moon, S. H. (2008). Enzyme-catalyzed conversion of phenol by using immobilized horseradish peroxidase (HRP) in a membraneless electrochemical reactor. *Applied Catalysis A: General*, **337** (1), 66-72.

Choi, J. S., Kim, T. H., Choo, K. Y., Sung, J. S., Saidutta, M. B., Ryu, S. O., Song, D. S., Ramachandra, B., Rhee, Y. W. (2005). Direct synthesis of phenol from benzene on iron-impregnated activated carbon catalysts. *Applied Catalysis A: General,* **290** (1-2), 1-8.

Choi, W., Termin, A., & Hoffmann, M. R. (1994). Effects of metal-ion dopants on the photocatalytic reactivity of quantum-sized TiO_2 particles. *Angewandte Chemie International Edition in English,* **33** (10), 1091-1092.

Cieśla, P., Kocot, P., Mytych, P., & Stasicka, Z. (2004). Homogeneous photocatalysis by transition metal complexes in the environment. *Journal of Molecular Catalysis A: Chemical,* **224** (1–2), 17-33.

Correia, P. F. M. M., & de Carvalho, J. M. R. (2003). Recovery of phenol from phenolic resin plant effluents by emulsion liquid membranes. *Journal of Membrane Science,* **225** (1–2), 41-49.

Cui, Y., Huang, J., Fu, X., & Wang, X. (2012). Metal-free photocatalytic degradation of 4-chlorophenol in water by mesoporous carbon nitride semiconductors. *Catalysis Science & Technology*. **2** (7), 1396-1402.

Dalrymple, O. K., Stefanakos, E., Trotz, M. A., & Goswami, D. Y. (2010). A review of the mechanisms and modeling of photocatalytic disinfection. *Applied Catalysis B: Environmental,* **98** (1-2), 27-38.

David M, S. (2005). Electronic structures of iron(III) and manganese(IV) (hydr)oxide minerals: Thermodynamics of photochemical reductive dissolution in aquatic environments. *Geochimica et Cosmochimica Acta*, **69** (13), 3249-3255.

Derrick, M. (1989). Fourier transform infrared spectral analysis of natural resins used in furniture finishes. *Journal of the American Institute for Conservation,* **28** (1), 43-56.

Dong, F., Wang, H., & Wu, Z. (2009). One-step “green” synthetic approach for mesoporous C-doped titanium dioxide with efficient visible light photocatalytic activity. *The Journal of Physical Chemistry C*, **113** (38), 16717-16723.

Dong, S., Chen, X., Zhang, X., & Cui, G. (2013). Nanostructured transition metal nitrides for energy storage and fuel cells. *Coordination Chemistry Reviews,* **257** (13–14), 1946-1956.

Drbohlavova, R. H., Vojtech A., Rene K., Oldrich S. and, & Hubalek, J. (2009). Preparation and properties of various magnetic nanoparticles. *Sensors,* **9**, 2352-2362.

Edwards, H. G. M., Farwell, D. W., Heron, C. P., Croft, H., & David, A. R. (1999). Cats' eyes in a new light: Fourier transforms Raman spectroscopic and gas chromatographic–mass spectrometric study of Egyptian mummies. *Journal of Raman Spectroscopy,* **30** (2), 139-146.

El-Naas, M. H., Al-Muhtaseb, S. A., & Makhlouf, S. (2009). Biodegradation of phenol by *Pseudomonas putida* immobilized in polyvinyl alcohol (PVA) gel. *Journal of Hazardous Materials,* **164** (2–3), 720-725.

Feih, S., & Mouritz, A. P. (2012). Tensile properties of carbon fibres and carbon fibre–polymer composites in fire. *Composites Part A: Applied Science and Manufacturing*, **43** (5), 765-772.

Fiebach, K., & Grimm, D. (2000). *Natural resins: Ullmann's Encyclopedia of Industrial Chemistry*. Weiheim: Wiley-VCH Verlag GmbH & Co. KGaA.

Fink, J. K. (2005). 4 - Phenol/formaldehyde resins. *Reactive Polymers Fundamentals and Applications*, Norwich, New York: William Andrew Publishing, 241-281.

Fujishima, A., & Honda, K. (1972). Electrochemical photolysis of water at a semiconductor electrode. *Nature,* **238** (5358), 37-38.

Gardziella, A., Pilato, L. A., & Knop, A. (2010). *Phenolic Resins: Chemistry, Applications, Standardization, Safety and Ecology*. Berlin, Germany: Springer.

Ghosh, A. K., & Maruska, H. P. (1977). Photoelectrolysis of water in sunlight with sensitized semiconductor electrodes. *Journal. Electrochemical. Society,* **124** (10), 1516-1522.

Ghosh, H., Yella, R., Ali, A. R., Sahoo, S. K., & Patel, B. K. (2009). An efficient synthesis of cyanamide from amine promoted by a hypervalent iodine(III) reagent. *Tetrahedron Letters,* **50** (20), 2407-2410.

Gillan, E. G. (2000). Synthesis of nitrogen-rich carbon nitride networks from an energetic molecular azide precursor. *Chemistry of Materials,* **12** (12), 3906-3912.

Goerlitz, D. F., Troutman, D. E., Godsy, E. M., & Franks, B. J. (1985). Migration of wood-preserving chemicals in contaminated groundwater in a sand aquifer at Pensacola, Florida. *Environmental Science & Technology,* **19** (10), 955-961.

Goglio, G., Foy, D., & Demazeau, G. (2008). State of art and recent trends in bulk carbon nitrides synthesis. *Materials Science and Engineering: R: Reports,* **58** (6), 195-227.

Grenier-Loustalot, M. F., Raffin, G., Salino, B., & Païssé, O. (2000). Phenolic resins Part 6. Identifications of volatile organic molecules during thermal treatment of neat resols and resol filled with glass fibers. *Polymer,* **41**(19), 7123-7132.

Groenewolt M., & Antoniette, M. (2005). Synthesis of g-C_3N_4 nanoparticles in mesoporous silica host matrices. *Advanced Materials,* **17**, 1789-1792.

Hara, M., Hitoki, G., Takata, T., Kondo, J. N., Kobayashi, H., & Domen, K. (2003). TaON and Ta_3N_5 as new visible light driven photocatalysts. *Catalysis Today***,** **78** (1–4), 555-560.

Hargreaves, J. S. J. (2013). Heterogeneous catalysis with metal nitrides. *Coordination Chemistry Reviews,* **257** (13–14), 2015-2031.

Hawley G.G. (1981). *The condensed chemical dictionary*. 10th ed. New York, NY: Van Nostrand Reinhold Co, 796.

He, G., & Yan, N. (2004). ^{13}C NMR study on structure, composition and curing behavior of phenol–urea–formaldehyde resole resins. *Polymer,* **45** (20), 6813-6822.

Herrmann, J. M. (2005). Heterogeneous photocatalysis: State of the art and present applications. *Topics in Catalysis,* **34** (1-4), 49-65.

Herrmann, W. A., & Kohlpaintner, C. W. (1993). Water-soluble ligands, metal complexes, and catalysts: Synergism of homogeneous and heterogeneous catalysis. *Angewandte Chemie International Edition in English,* **32** (11), 1524-1544.

Hirano, K., & Asami, M. (2013). Phenolic resins—100 years of progress and their future. *Reactive and Functional Polymers*, **73** (2), 256-269.

Hock, H., & Lang, S. (1944). Autoxydation von Kohlenwasserstoffen, IX. Mitteil.: Über Peroxyde von Benzol-Derivaten. *Berichte der deutschen chemischen Gesellschaft (A and B Series),* **77** (3-4), 257-264.

Huang, C.-H., Lin, Y.-M., Wang, I.-K., & Lu, C.-M. (2012). Photocatalytic activity and characterization of carbon-modified titania for visible-light-active photodegradation of nitrogen oxides. *International Journal of Photoenergy,* **2012**, 13 pages.

Huang, Y. H., Huang, Y. J., Tsai, H. C., & Chen, H. T. (2010). Degradation of phenol using low concentration of ferric ions by the photo-Fenton process. *Journal of the Taiwan Institute of Chemical Engineers,* **41** (6), 699-704.

Ji, M., Chen, G., Wang, J., Wang, X., & Zhang, T. (2010). Dehydrogenation of ethylbenzene to styrene with CO_2 over iron oxide-based catalysts *Catalysis Today,* **158** (3-4), 464-469.

Jun, M.-C., & Koh, J.-H. (2012). Effects of NIR annealing on the characteristics of Al-doped ZnO thin films prepared by RF sputtering. *Nanoscale Research Letters,* **7** (1), 294.

Katada, N., Doi, T., Shinmura, T., Kuroda, S., & Niwa, M. (2003). Catalytic activity of gallium-loaded ZSM-5 zeolite for synthesis of aniline from phenol and ammonia. *Studies in Surface Science and Catalysis*, **145**, 197-200.

Katada, N., Iijima, S., Igi, H., & Niwa, M. (1997). Synthesis of aniline from phenol and ammonia over zeolite beta. *Studies in Surface Science and Catalysis,* **105**, 1227-1234.

Katada, N., Kuroda, S., & Niwa, M. (1999). High catalytic activity for synthesis of aniline from phenol and ammonia found on gallium-containing MFI. *Applied Catalysis A: General*, **180** (1-2), L1-L3.

Katritzky, A. R., Meth-Cohn, O., & Rees, C. W. (1995). Comprehensive organic functional group transformations: Synthesis: carbon with two attached heteroatoms with at least one carbon-to-heteroatom multiple link: *Elsevier.*

Keav, S., Martin, A., Barbier Jr, J., & Duprez, D. (2010). Deactivation and reactivation of noble metal catalysts tested in the catalytic wet air oxidation of phenol. *Catalysis Today,* **151** (1-2), 143-147.

Kennedy, M., Maguire, A. R., & McKervey, M. A. (1986). Organic synthesis with [alpha]-chlorosulphides. Conversion of phenols into [gamma]-lactones using methyl-2-chloro-2-(alkyl or arylthio) carboxylates. *Tetrahedron Letters,* **27** (6), 761-764.

Khabashesku, V. N., Zimmerman, J. L., & Margrave, J. L. (2000). Powder synthesis and characterization of amorphous carbon nitride. *Chemistry of Materials,* **12** (11), 3264-3270.

Khedr, M. H., Abdel Halim, K. S., & Soliman, N. K. (2009). Synthesis and photocatalytic activity of nano-sized iron oxides. *Materials Letters,* **63** (6-7), 598-601.

Kopf, P. W. (2002). *Phenolic resins: Encyclopedia of Polymer Science and Technology*. Cambridge, Massachusetts: John Wiley & Sons, Inc.

Krott, M., Liu, X., Fokwa, B. P. T., Speldrich, M., Lueken, H., & Dronskowski, R. (2007). Synthesis, crystal-structure determination and magnetic properties of two new transition-metal carbodiimides: CoNCN and NiNCN. *Inorganic Chemistry,* **46** (6), 2204-2207.

Lanouette, K. H. (1977). Treatment of phenolic wastes. *Chemical Engineering Journal.*, **84** (22), 99- 106.

Lee, S. C., Lintang, H. O., & Yuliati, L. (2012). A urea precursor to synthesize carbon nitride with mesoporosity for enhanced activity in the photocatalytic removal of phenol. *Chemistry – An Asian Journal,* **7** (9), 2139-2144.

Lee, S. G., Hong, S. P., & Sung, M. H. (1996). Removal and bioconversion of phenol in wastewater by a thermostable [beta]-tyrosinase. *Enzyme and Microbial Technology,* **19** (5), 374-377.

Li, C., & Hoffman, M. Z. (1999). One-electron redox potentials of phenols in aqueous solution. *The Journal of Physical Chemistry B,* **103** (32), 6653-6656.

Li, F. B., & Li, X. Z. (2002). The enhancement of photodegradation efficiency using Pt–TiO_2 catalyst. *Chemosphere,* **48** (10), 1103-1111.

Li, P. G., Lei, M., & Tang, W. H. (2008). Route to transition metal carbide nanoparticles through cyanamide and metal oxides. *Materials Research Bulletin,* **43** (12), 3621-3626.

Li, X. H., Chen, J. S., Wang, X., Sun, J., & Antonietti, M. (2011). Metal-free activation of dioxygen by graphene/g-C_3N_4 nanocomposites: Functional dyads for selective oxidation of saturated hydrocarbons. *Journal of the American Chemical Society,* **133** (21), 8074-8077.

Li, Y., Zhu, C., Lu, T., Guo, Z., Zhang, D., Ma, J., & Zhu, S. (2013). Simple fabrication of a Fe_2O_3/carbon composite for use in a high-performance lithium ion battery. *Carbon*, **52**, 565-573.

Lin, S.-H., Chiou, C.-H., Chang, C.-K., & Juang, R.-S. (2011). Photocatalytic degradation of phenol on different phases of TiO_2 particles in aqueous suspensions under UV irradiation. *Journal of Environmental Management,* **92** (12), 3098-3104.

Liou, R. M., & Chen, S. H. (2009). CuO impregnated activated carbon for catalytic wet peroxide oxidation of phenol. *Journal of Hazardous Materials,* **172** (1), 498-506.

Liptáková, B., Hronec, M., & Cvengrosová, Z. (2000). Direct synthesis of phenol from benzene over hydroxyapatite catalysts. *Catalysis Today,* **61** (1-4), 143-148.

Liu, A. Y., & Cohen, M. L. (1989). Prediction of new low compressibility solids. *Science,* **245** (4920), 841-842.

Liu, Y., Chen, G., Zhou, C., Hu, Y., Fu, D., Liu, J., & Wang, Q. (2011). Higher visible photocatalytic activities of nitrogen doped In_2TiO_5 sensitized by carbon nitride. *Journal of Hazardous Materials,* **190** (1-3), 75

Maeda, K., Wang, X., Nishihara, Y., Lu, D., Antonietti, M., & Domen, K. (2009). Photocatalytic Activities of Graphitic Carbon Nitride Powder for Water Reduction and Oxidation under Visible Light. *The Journal of Physical Chemistry C,* **113** (12), 4940-4947.

Magesh. G., Viswanathan, B., R. P., & Varadarajan, T. K. (2007). Photocatalytic routes for chemical. *Photo/Electrochemistry & Photobiology in the Environment, Energy and Fuel*, **2**, 1-37.

Maugans, C. B., & Akgerman, A. (2003). Catalytic wet oxidation of phenol in a trickle bed reactor over a Pt/TiO_2 catalyst. *Water Research*, **37** (2), 319-328.

Michałowicz, J., & Duda, R. O. W. (2005). Analysis of Chlorophenols, Chlorocatechols, Chlorinated Methoxyphenols and Monoterpenes in Communal Sewage of ŁÓDŹ and in the Ner River in 1999–2000. *Water, Air, & Soil Pollution*, **164** (1), 205-222.

Mimura, N., Takahara, I., Saito, M., Hattori, T., Ohkuma, K., & Ando, M. (1998). Dehydrogenation of ethylbenzene over iron oxide-based catalyst in the presence of carbon dioxide. *Catalysis Today,* **45** (1-4), 61-64.

Misra, R. A., & Sharma, B. L. (1979). Cathodic reduction of phenol to cyclohexanol. *Electrochimica Acta*, **24** (6), 727-728.

Molina, B & Sansores L.E. (1999). Electronic structure of six phases of C_3N_4: a theoretical approach. *Modern Physics Letters B*, **13** (6-7). 193-201.

Nath, J., Patel, B. K., Jamir, L., Sinha, U. B., & Satyanarayana, K. V. V. V. (2009). A one-pot preparation of cyanamide from dithiocarbamate using molecular iodine. *Green Chemistry,* **11** (10), 1503-1506.

Neri, G., Rizzo, G., Galvagno, S., Loiacono, G., Donato, A., Musolino, M. G., Pietropaolo, R., & Rombi, E (2004). Sol-gel synthesis, characterization and catalytic properties of Fe-Ti mixed oxides. *Applied Catalysis A: General*, **274** (1-2), 243-251.

Neukirch, M., Tragl, S., & Meyer, H. J. (2006). Syntheses and Structural Properties of Rare Earth Carbodiimides. *Inorganic Chemistry,* **45** (20), 8188-8193.

Niknam, K., Saberi, D., & Baghernejad, M. (2009). Silica-bonded S-sulfonic acid a recyclable catalyst for the synthesis of coumarins. *Chinese Chemical Letters,* **20** (12), 1444-1448.

Parayil, S. K., Kibombo, H. S., Wu, C.-M., Peng, R., Baltrusaitis, J., & Koodali, R. T. (2012). Enhanced photocatalytic water splitting activity of carbon-modified TiO_2 composite materials synthesized by a green synthetic approach. *International Journal of Hydrogen Energy*, **37** (10), 8257-8267.

Peng, W., & Riedl, B. (1995). Thermosetting resins. *Journal of Chemical Education*, **72** (7), 587.

Peng, W., Zhao, W., Zhao, N., Li, J., Xiao, F., Wei, W., & Sun, Y. (2008). Direct synthesis of salicylamide from phenol and urea over ZnO catalyst. *Catalysis Communications*, **9** (6), 1219-1223.

Peshkova, S., & Li, K. (2003). Investigation of chitosan–phenolics systems as wood adhesives. *Journal of Biotechnology*, **102** (2), 199-207.

Qiu, X., & Burda, C. (2007). Chemically synthesized nitrogen-doped metal oxide nanoparticles. *Chemical Physics*, **339** (1–3), 1-10.

Qiu, X., Zhao, Y., & Burda, C. (2008). ChemInform Abstract: Synthesis and characterization of nitrogen-doped group IVB visible-light-photoactive metal oxide nanoparticles. *ChemInform*, **39** (7).

Quintanilla, A., Casas, J. A., Mohedano, A. F., & Rodríguez, J. J. (2006). Reaction pathway of the catalytic wet air oxidation of phenol with a Fe/Activated carbon catalyst. *Applied Catalysis B: Environmental*, **67** (3-4), 206-216.

Rahman, M. M., Krishna, K. M., Soga, T., Jimbo, T., & Umeno, M. (1999). Optical properties and X-ray photoelectron spectroscopic study of pure and Pb-doped TiO_2 thin films. *Journal of Physics and Chemistry of Solids*, **60** (2), 201-210.

Raval, D. K., Narola, B. N., & Patel, A. J. (2005). Synthesis, characterization and composites from resorcinol-urea-formaldehyde-casein resin. *Iranian Polymer Journal*, **14** (9), 775-784.

Ravelli, D., Dondi, D., Fagnoni, M., & Albini, A. (2009). Photocatalysis. A multi-faceted concept for green chemistry. *Chemical Society Reviews*, **38** (7), 1999-2011.

Roslan, N. A. (2011). Sythesis of iron (III) oxides from mesoporous carbon nitride template for photocatalytic removal of phenol. Universiti Teknologi Malaysia, Johor Bharu.

Sahana, M. B., Sudakar, C., Setzler, G., Dixit, A., Thakur, J. S., Lawes, G., Naik, R., Naik, V.M., & Vaishnava, P. P. (2008). Bandgap engineering by tuning particle size and crystallinity of SnO_2—Fe_2O_3 nanocrystalline composite thin films. *Applied Physics Letters*, **93** (23), 231909-231903.

Seif El-Yazal, M. A., & Rady, M. M. (2012). Changes in nitrogen and polyamines during breaking bud dormancy in “Anna” apple trees with foliar application of some compounds. *Scientia Horticulturae*, **136**, 75-80.

Senturk, H. B., Ozdes, D., Gundogdu, A., Duran, C., & Soylak, M. (2009). Removal of phenol from aqueous solutions by adsorption onto organomodified Tirebolu bentonite: Equilibrium, kinetic and thermodynamic study. *Journal of Hazardous Materials*, **172** (1), 353-362.

Simujide, H., Aorigele, C., Wang, C.-J., Lina, M., & Manda, B. (2013). Microbial activities during mesophilic composting of manure and effect of calcium cyanamide addition. *International Biodeterioration & Biodegradation*, **83**, 139-144.

Sinhamahapatra, A., Sutradhar, N., Pahari, S., Bajaj, H. C., & Panda, A. B. (2011). Mesoporous zirconium phosphate: An efficient catalyst for the synthesis of coumarin derivatives through Pechmann condensation reaction. *Applied Catalysis A: General*, **394** (1-2), 93-100.

Song, L., & Zhang, S. (2009). Formation of α-Fe_2O_3/FeOOH nanostructures with various morphologies by a hydrothermal route and their photocatalytic properties. *Colloids and Surfaces A: Physicochemical and Engineering Aspects,* **348** (1–3), 217-220.

Srivastava, V. C., Swamy, M. M., Mall, I. D., Prasad, B., & Mishra, I. M. (2006). Adsorptive removal of phenol by bagasse fly ash and activated carbon: Equilibrium, kinetics and thermodynamics. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, **272** (1-2), 89-104.

Stehlickova, L., Svab, M., Wimmerova, L., & Kozler, J. (2009). Intensification of phenol biodegradation by humic substances. *International Biodeterioration & Biodegradation,* **63** (7), 923-927.

Swarts, H. J., Verhagen, F. J. M., Field, J. A., & Wijnberg, J. B. P. A. (1998). Trichlorinated phenols from hypholoma elongatum. *Phytochemistry*, **49** (1), 203-206.

Talukdar, A. K., Bhattacharyya, K. G., & Sivasanker, S. (1993). Hydrogenation of phenol over supported platinum and palladium catalysts. *Applied Catalysis A: General*, **96** (2), 229-239.

Tao, C. Z., Liu, W. W., & Sun, J. Y. (2009). Copper-catalyzed synthesis of phenols from aryl halides and 4-methoxylbenzyl alcohol. *Chinese Chemical Letters,* **20** (10), 1170-1174.

Teter D. M. & Hemley R. J. (1996). Low-compressibility carbon nitride. *Science*, **271**, 53–55.

Thomas, A., Fischer, A., Goettmann, F., Antonietti, M., Muller, J.-O., Schlogl, R., & Carlsson, J. M. (2008). Graphitic carbon nitride materials: variation of structure and morphology and their use as metal-free catalysts. *Journal of Materials Chemistry,* **18** (41), 4893-4908.

Tomita, B., & Hse, C. Y. (1998). Phenol–urea–formaldehyde (PUF) co-condensed wood adhesives. *International Journal of Adhesion and Adhesives,* **18** (2), 69-79.

Townsend, T. K., Sabio, E. M., Browning, N. D., & Osterloh, F. E. (2011). Photocatalytic water oxidation with suspended alpha-Fe_2O_3 particles-effects of nanoscaling. *Energy & Environmental Science*, **4** (10), 4270-4275.

Tsanaktsidis, C. G., Favvas, E. P., Scaltsoyiannes, A. A., Christidis, S. G., Katsidi, E. X., & Scaltsoyiannes, A. V. (2013). Natural resins and their application in antifouling fuel technology: Part I: Improving the physicochemical properties of diesel fuel using natural resin polymer as a removable additive. *Fuel Processing Technology,* **114**, 135-143.

Tyagi, B., Mishra, M. K., & Jasra, R. V. (2007). Synthesis of 7-substituted 4-methyl coumarins by Pechmann reaction using nano-crystalline sulfated-zirconia. *Journal of Molecular Catalysis A: Chemical,* **276** (1-2), 47-56.

United States Department of Labor (1996). Occupational Safety and Health Guideline for Phenol.

Urtiaga, A., Gutiérrez, R., & Ortiz, I. (2009). Phenol recovery from phenolic resin manufacturing: Viability of the emulsion pertraction technology. *Desalination,* **245** (1–3), 444-450.

Vavilov, G. A., & Khmelevskii, V. I. (1973). Use of cyanamide for production of carbomethoxysulfanilylthiourea. *Pharmaceutical Chemistry Journal,* **7** (12), 768-769.

Wang, X., Maeda, K., Chen, X., Takanabe, K., Domen, K., Hou, Y., Fu, X., & Antonietti, M. (2009a). Polymer semiconductors for artificial photosynthesis: Hydrogen evolution by mesoporous graphitic carbon nitride with visible light. *Journal of the American Chemical Society,* **131** (5), 1680-1681.

Wang, X., Maeda, K., Thomas, A., Takanabe, K., Xin, G., Carlsson, J. M., Domen, K., & Antonietti, M. (2009b). A metal-free polymeric photocatalyst for hydrogen production from water under visible light. *Natural Matter,* **8** (1), 76-80.

Wang, Y., Shi, R., Lin, J., & Zhu, Y. (2011). Enhancement of photocurrent and photocatalytic activity of ZnO hybridized with graphite-like C_3N_4. *Energy & Environmental Science,* **4** (8), 2922-2929.

White, G. V., Mackenzie, K. J. D., & Johnston, J. H. (1992). Carbothermal synthesis of titanium nitride. *Journal of Materials Science,* **27** (16), 4287-4293.

Whitehouse, A. A. K., Pritchett, E. G. K., & Barnett, G. (1967). *Phenolic resins*. Russell Square, London: Iliffe Books Limited.

Williams, W. (1997). Transition metal carbides, nitrides, and borides for electronic applications. *The Journals of Minerals,* **49** (3), 38-42.

Wong, M.-S., Wang, S.-H., Chen, T.-K., Weng, C.-W., & Rao, K. K. (2007). Co-sputtered carbon-incorporated titanium oxide films as visible light-induced photocatalysts. *Surface and Coatings Technology,* **202** (4–7), 890-894.

Wu, C.-G., Chao, C.-C., & Kuo, F.-T. (2004). Enhancement of the photo catalytic performance of TiO_2 catalysts via transition metal modification. *Catalysis Today,* **97** (2–3), 103-112.

Xia, C., Yanjun, X., & Ning, W. (2012). Hollow Fe_2O_3 polyhedrons: One-pot synthesis and their use as electrochemical material for nitrite sensing. *Electrochimica Acta*, **59**, 81-85.

Xu, A., Yang, M., Qiao, R., Du, H., & Sun, C. (2007). Activity and leaching features of zinc-aluminum ferrites in catalytic wet oxidation of phenol. *Journal of Hazardous Materials*, **147** (1-2), 449-45.

Yamanaka, I., Katagiri, M., Takenaka, S., & Otsuka, K. (2000). Direct synthesis of phenol from benzene with O_2 over VMo-oxide/SiO_2 catalyst. *Studies in Surface Science and Catalysis*, **130**, 809-814.

Yan, H., Chen, Y., & Xu, S. (2012). Synthesis of graphitic carbon nitride by directly heating sulfuric acid treated melamine for enhanced photocatalytic H_2 production from water under visible light. *International Journal of Hydrogen Energy*, **37** (1), 125-133.

Yan, S. C., Li, Z. S., & Zou, Z. G. (2009). Photodegradation performance of g-C_3N_4 fabricated by directly heating melamine. *Langmuir*, **25** (17), 10397-10401.

Yang, J., Li, D., Zhang, Z., Li, Q., & Wang, H. (2000). A study of the photocatalytic oxidation of formaldehyde on Pt/Fe_2O_3/TiO_2. *Journal of Photochemistry and Photobiology A: Chemistry*, **137** (2-3), 197-202.

Yuliati, L., Mazalan, M., & Lintang, H. O. (2011). Synthesis of tungsten oxide as visible light-driven photocatalyst for removal of salicylic acid (2011). *Journal of Fundamental Sciences*, **7** (1), 62-66.

Yun, H. J., Lee, H., Joo, J. B., Kim, N. D., & Yi, J. (2010). Tuning the band-gap energy of TiO_2-xCx nanoparticle for high performance photo-catalyst. *Electrochemistry Communications*, **12** (6), 769-772.

Zhang, W., Nowlan, D. T., Thomson, L. M., Lackowski, W. M., & Simanek, E. E. (2001). Orthogonal, convergent syntheses of dendrimers based on melamine with one or two unique surface sites for manipulation. *Journal of the American Chemical Society,* **123** (37), 8914-8922.

Zhang, Y., & Antonietti, M. (2010). Photocurrent generation by polymeric carbon nitride solids: An initial step towards a novel photovoltaic system. *Chemistry – An Asian Journal,* **5** (6), 1307-1311.

Zhang, Z., Hossain, M. F., & Takahashi, T. (2010). Fabrication of shape-controlled [alpha]-Fe_2O_3 nanostructures by sonoelectrochemical anodization for visible light photocatalytic application. *Materials Letters,* **64** (3), 435-438.

Zhao, W., Liu, Y., Liu, J., Chen, P., Chen, I. W., Huang, F., & Lin, J. (2013). Controllable synthesis of silver cyanamide as a new semiconductor photocatalyst under visible-light irradiation. *Journal of Materials Chemistry A,* **1** (27), 7942-7948.