

TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS	iii
ABSTRACT (ENGLISH)	v
ABSTRACT (THAI)	vii
TABLE OF CONTENTS	ix
LIST OF TABLES	xii
LIST OF FIGURES	xiii
CHAPTER 1 INTRODUCTION AND RESEARCH OBJECTIVE	1
1.1 Introduction	1
1.2 Research objective	3
CHAPTER 2 THEORETICAL BACKGROUND	4
2.1 Titanium dioxide (TiO ₂)	4
2.2 Properties of TiO ₂	7
2.2.1 Photocatalysis	8
2.2.2 Hydrophilicity and super-hydrophilicity	13
2.3 Practical applications	20
2.3.1 Self cleaning surface	20
2.3.2 Anti fogging surface	23
2.3.3 Antibacterial	26

	page
2.3.4 Air purification	27
2.3.5 Water treatment	27
2.4 Iron oxide	28
2.5 Properties of iron oxide	28
2.5.1 Iron (II) oxide (FeO)	29
2.5.2 Iron (III) oxide (Fe ₂ O ₃)	30
2.5.3 Iron (II, III) oxide (Fe ₃ O ₄)	32
2.6 Practical applications of iron oxide	34
2.7 Synthesis of colloidal NPs	36
2.7.1 Synthesis of colloidal TiO ₂ NPs by sparking process	36
2.7.2 Synthesis of Fe ₂ O ₃ NPs by pyrosol method	37
CHAPTER 3 EXPERIMENTAL PROCEDURE AND SAMPLE CHARACTERIZATIONS	40
3.1 Synthesis of colloidal TiO ₂ NPs by sparking process	40
3.1.1 Experimental setup and experimental procedure	40
3.1.2 Sample characterization	42
3.2 Synthesis of Fe ₂ O ₃ NPs by pyrosol method	47
3.2.1 Experimental setup and experimental procedure	47
3.2.2 Sample characterization	48
3.3 Measurement instruments	48
3.3.1 Scanning electron microscopy (SEM)	48
3.3.2 Transmission electron microscopy (TEM)	49

	page
3.3.3 X-ray diffraction (XRD)	50
3.3.4 Raman spectroscopy	52
3.3.5 UV-vis spectroscopy	54
CHAPTER 4 RESULTS AND DISCUSSION	58
4.1 Synthesis of colloidal TiO ₂ NPs by sparking process	58
4.1.1 Relationship between NP concentration and sparking time	58
4.1.2 Morphology	61
4.1.3 Structural properties	65
4.1.4 Optical properties	70
4.1.5 Anti-bacterial activity	73
4.2 Synthesis of Fe ₂ O ₃ NPs by pyrosol method	80
4.2.1 Morphology	80
4.2.2 Structural property	83
CHAPTER 5 CONCLUSIONS AND SUGGESTIONS	85
REFERENCES	88
APPENDICES	103
APPENDIX A	104
APPENDIX B	107
CURRICULUM VITAE	139

LIST OF TABLES

Table	page
2.1 Refractive index of rutile and anatase TiO ₂	6
4.1 Comparison of anatase-rutile phase transformation temperature at various particle sizes of TiO ₂ NPs	68
4.2 The calculated diameter of the misted droplets and mean particle size of α -Fe ₂ O ₃ particles using Eqs. (2.6)* and (2.7)**	82

LIST OF FIGURES

Figure	page
2.1 Crystal structures of (a) anatase and (b) rutile TiO ₂	5
2.2 Percent reflectance of anatase and rutile at various wavelength regions	6
2.3 Mobile charge carriers by (a) thermal generation (b) photo-excitation and (c) doping	8
2.4 Operation of a photochemical excited semiconductor particle	9
2.5 Band-edge energies of typical semiconductors	11
2.6 Oxidation-reduction reaction on the surface of TiO ₂	12
2.7 Droplet on the solid surface	14
2.8 Mechanism of photo-induced hydrophilicity	15
2.9 Shape of water drops on the surface of glass, resin and hydrophobic resin	16
2.10 Change of the contact angle of water with TiO ₂ -silicone thin film by UV irradiation	17
2.11 Chemisorbed water on the TiO ₂ surface	18
2.12 Irradiation of light on the TiO ₂ surface	18
2.13 Exposed chemisorbed water physisorbs and bonds with another water on the TiO ₂ surface	19
2.14 Physisorbed water on the TiO ₂ surface	19
2.15 Major areas of activity in TiO ₂ photocatalysis	20
2.16 (a) Ordinary surface and (b) hydrophobic surface (Lotus effect)	22

Figure

2.17	Dependence of the anti-fogging ability on the contact angle of water	23
2.18	The difference of the fogging with steam between normal glass and the photocatalyst coated glass	24
2.19	Time dependence of the water contact angle in ambient atmosphere: (a) Upon UV illumination and (b) in the dark	25
2.20	Chemical structure of iron (II) oxide	29
2.21	Chemical structure of Fe_2O_3	30
2.22	Chemical structure of Fe_3O_4	33
2.23	Schematic diagram of the nucleation mechanism of colloidal NPs deposited by the sparking off two metallic sharp tips	37
2.24	Schematic diagrams of the pyrosol apparatus	38
3.1	Schematic diagrams of the sparking apparatus	41
3.2	(a) High DC voltage power supply and (b) An experiment	41
3.3	Flow chart of the experimental procedures for study of antibacterial activity of TiO_2 NPs	43
3.4	Standard preparation for TEM analysis	44
3.5	The experimental setup	47
3.6	Scanning electron microscopy (SEM)	49
3.7	Transmission electron microscopes (TEM)	50
3.8	X-ray diffraction (XRD)	51
3.9	Raman spectroscopy	52
3.10	Raman scattering	53

Figure

3.11	UV-vis spectroscope	54
3.12	Schematic diagram of the absorption transitions between direct Parabolic bands	56
4.1	Photograph of TiO ₂ NPs deposited into 10 ml of distilled water at various sparking time	58
4.2	Weight loss of Ti wires vs. sparking time	59
4.3	Total mass of the NPs and weight loss vs. sparking time	60
4.4	TEM images and their corresponding SAED patterns of the as-deposited NPs at sparking times of (a) 1 h, and (b) 5 h	62
4.5	Size distributions of the as-prepared TiO ₂ NPs	63
4.6	SEM images of (a) the as-deposited NPs on quartz substrate by two drops of the NP-dispersed water (b) the annealed sample at 250 and (d) 500°C	64
4.7	(a) Raman spectra, (b) the main anatase peak and (c) plot of main anatase peak and its FWHM against the as-prepared NPs, the annealed samples at 250 and 500 °C	66
4.8	Plot of the phase transformation temperature against the mean particle size of TiO ₂ NPs	68
4.9	Plots of optical transmittance against the wavelength of the as-deposited NPs and the annealed samples at 250 and 500 °C for 1 h. Inset: the variation of $(\alpha h\nu)^2$ versus $h\nu$ of the thin films for estimation of the E_g	70

Figure

- 4.10 Temporal spectral changes of MB solution, (a) concentration of 10 μM 72
containing the as-prepared TiO_2 NPs at the various sparking times under
sunbath for 1 h, (b) at dilute concentrations from 10 μM to 2.5 μM
without TiO_2 NPs, and (c) decomposition rate of MB vs. concentration
of TiO_2 NPs
- 4.11 Petri dishes of *E.coli* (a) in UV light without TiO_2 NPs and 75
supplemented with TiO_2 NPs (b) in the dark and (c) under UV
light, incubated at reaction times of 0, 1, 2 and 4 h
- 4.12 Plot of the survival rates of *E.coli* against the reaction time 76
in UV light without NPs, supplement with NPs in the dark
- 4.13 SEM images of (a) controlled and (b) treated *E.coli* cells 77
with TiO_2 NPs under UV light for 4 h
- 4.14 Cross section TEM image of treated *E.coli* cell with TiO_2 NPs 78
under UV light for 4 h
- 4.15 SEM images (a) and their size distribution of Fe_2O_3 NPs 81
at the precursor concentrations of 0.01, 0.1 and 1 M
- 4.16 Plot of theoretical and Experimental mean diameter against various 82
concentration of precursor solution
- 4.17 XRD patterns for α - Fe_2O_3 NPs with various concentration 83
of precursor solution
- 4.18 Raman spectrum of α - Fe_2O_3 NPs 84