REFERENCES

Cornelius, S. and Hurlbut, Jr. R. 1991. Gemology 2nd edition. USA; John Wiley & Sons, 336 pp.

Emmett, J.L. and Douthit, T.R. 1993. Heat treating the sapphires of rock creek, Montana. Gem & Gemology. 29(4): 250-272.

Fritsch, E. and Rossman, G.R. 1987. An Update on Color in Gems. Part 1: Introduction and colors caused by dispersed metal ions. Gem & Gemology. 23(3): 126-139.

Fritsch, E. and Rossman, G.R. 1988. An Update on Color in Gems. Part 2: Colors involving multiple atoms and color centers. Gem & Gemology. 24(1): 3-15.

Gemmological Association of great Britain (GAGTL). 2001. Manual of Diploma, Section 23. UK, 36 pp.

Häger, T. 2001. High temperature treatment of natural corundum. Proceedings of the International Workshop on Material Characterization by Solid State Spectroscopy: Gems and Minerals of Vietnam, 4-10th April 2001, Hanoi, 24-37.

Hughes, R. W. 1997. Ruby&Sapphire. Colorado USA; RWH Publishing. 511 pp.

Hansawek, R. 2001. Gem potential and investment opportunity of Madagascar. Proceedings of Seminar on Madagascar's Gems : New perspectives for Thai Entreperneurs. 15 February 2001. Department of Mineral Resources. Bangkok, Thailand. Second published, 107-114 (in Thai).

Intasopa, S. 2001. Ruby and sapphire occurrences. Proceedings of Seminar on Madagascar's Gems : New perspectives for Thai Entreperneurs. 15 February 2001. Department of Mineral Resources. Bangkok, Thailand. Second published, 23-32 (in Thai).

Kyi, U. H., Buchholz, P. and Wolf, D. 1998. Heat treatment of milky sapphires from the Mogok stone tract, Myanmar. Journal of Gemmology, 26(5): 313-315.

Milisenda, C. C., Henn, U., and Hem, J. 2001. New gemstone occurrences in the south-west of Madagascar. Journal of Gemmology, 27(7): 385-394.

Nassau, K. 1978. The origins of color in minerals. American Mineralogist, 63: 219-229.

Nassau, K. 1994. Gemstone Enhancement, Science and State of the Art, London; Butterworth-Heinemann, 252 pp.

Pattamalai, K. 2002. Heat Treatment of some Corundum from Madagascar. M.Sc. Thesis. Department of Geology. Faculty of Science. Chulalongkorn University: 178 pp.

Pemadasa, T.G. and Danapala, M.V. 1994. Heat treated corundums of Sri Lanka: their heat treatment. The Australian Gemmologist: 18(11): 346-347.

Perera, S.I., Gunasekera, H.P.N.T and Ediriweera R.N. 1991. Anomalous behaviour of certain geuda corundums during heat treatment. Journal of Gemmology, 22(7): 405 - 407.

Pezzotta, F. 1999. Madagascar, a Mineral and Gemstone Paradise. extraLapis English No.1. Lapis International LLC: 97pp.

Read, P. G. 1999. Gemology 2nd. Oxford; Butterworth-Heinemann, 326 pp.

Schmetzer, K. and Kiefert, L. 1990. Spectroscopic evidence for heat treatment of blue sapphires from Sri Lanka – additional data. Journal of Gemmology, 22(2): 80 – 82.

Smith, C.P. 1995. A Contribution to understanding the infrared spectra of rubies from Mong Hsu, Myanmar. Journal of Gemmology, 24(5): 321-335.

Somboon, C. 2000. Internal characteristics of corundum resulting from thermal enhancement. Senior project report. Department of Geology. Faculty of Science. Chulalongkorn University: 86 pp.

Themelis, T. 1992. The Heat Treatment of Ruby and Sapphire, USA; Word Graphics Inc, 236 pp.

U.S.Dept. of State and the CIA World Fact Book. 2004. Madagascar [online]. Available from: http://www.geographyiq.com/countries/ma/Madagascar_map_flag_geography.htm [2004, September 1].

Volynets, F. K., Vorob'ev, V. G., and Sidorova, E.A. 1972. Infrared absorption bands in corundum crystals, Journal of Applied Spectroscopy, 665-667 pp.

Yan, G., Jingzhi, L., and Beili, Z. 1995. The infrared microscope and rapid identification of gemstones. Journal of Gemmology, 24(6): 411-414.

APPENDICES

APPENDIX I

Table I.1 Showing the gemmological properties of some Ilakaka-Sakaraha sapphires.

Table I.2 Color codes of dark blue, medium blue, very light blue, milky very light blue, dark violet, medium violet and light violet sapphires before heating based on GIA GemSet color specimens (Retail Set).

Table I.1 Showing the gemmological properties of some Ilakaka-Sakaraha sapphires.

Sample no.	SG	RI		Birefringence	Fluorescence	
		n_o	n_e		SWUV	LWUV
Dark blue						
IDB 1	4.000	1.760	1.769	0.009	inert	inert
IDB 2	3.971	1.761	1.770	0.009	inert	inert
IDB 3	3.937	1.761	1.770	0.009	inert	inert
IDB 4	3.980	1.761	1.769	0.008	inert	inert
IDB 5	3.967	1.761	1.769	0.008	inert	inert
IDB 6	3.962	1.760	1.769	0.009	inert	inert
DB 1	3.947	1.761	1.770	0.009	inert	weak: red
DB 2	3.920	1.760	1.769	0.009	inert	weak: red
DB 3	4.048	1.761	1.770	0.009	inert	inert
DB 4	4.039	1.761	1.770	0.009	inert	mod: red
DB 5	3.919	1.761	1.770	0.009	inert	weak: red
Medium blue						
IMB 1	3.975	1.760	1.769	0.009	inert	inert
IMB 2	3.992	1.760	1.769	0.009	inert	inert
IMB 3	3.984	1.761	1.770	0.009	inert	inert
IMB 4	3.989	1.760	1.769	0.009	inert	inert
IMB 5	3.993	1.761	1.770	0.009	inert	inert
MB 1	3.962	1.761	1.770	0.009	inert	inert
MB 2	3.927	1.760	1.769	0.009	inert	inert
MB 3	3.953	1.760	1.769	0.009	inert	weak: red
MB 4	4.043	1.760	1.769	0.009	inert	weak: red
MB 5	3.958	1.760	1.769	0.009	inert	inert
MB 6	3.989	1.760	1.769	0.009	inert	weak: red
MB 7	3.973	1.760	1.769	0.009	inert	inert
MB 8	3.959	1.760	1.770	0.010	inert	mod: red
MB 9	3.977	1.760	1.768	0.008	inert	mod: red

Table I.1 Showing the gemmological properties of some Ilakaka-Sakaraha sapphires (continued).

Sample no.	SG	RI		Birefringence	Fluorescence	
		n_o	n_e		SWUV	LWUV
Medium blue						
MB 10	3.967	1.760	1.770	0.010	inert	mod: oR
Very light blue						
IVLB 1	3.996	1.760	1.768	0.008	inert	weak: oR
IVLB 2	3.974	1.760	1.768	0.008	inert	inert
IVLB 4	4.026	1.760	1.768	0.008	inert	inert
IVLB 5	4.000	1.760	1.768	0.008	inert	inert
VLB 1	3.963	1.760	1.769	0.009	inert	weak: oY
VLB 2	3.996	1.760	1.769	0.009	inert	weak: oY
VLB 3	3.986	1.760	1.769	0.009	inert	mod: oY
VLB 4	3.915	1.760	1.769	0.009	inert	weak: oY
VLB 5	3.972	1.760	1.769	0.009	inert	weak: oY
VLB 6	4.006	1.760	1.769	0.009	inert	mod: oY
VLB 7	3.969	1.760	1.769	0.009	inert	mod: oY
Milky, very light blue						
MVLB 1	3.942	1.760	1.768	0.008	inert	inert
MVLB 2	3.958	1.760	1.769	0.009	inert	inert
MVLB 3	3.955	1.760	1.768	0.008	inert	inert
MVLB 5	3.958	1.760	1.768	0.008	inert	inert
MVLB 6	3.963	1.760	1.768	0.008	inert	mod: oR
MVLB 7	3.953	1.760	1.768	0.008	inert	inert
MVLB 8	3.857	1.760	1.768	0.008	inert	inert
Dark violet						
DV 1	3.983	1.761	1.769	0.008	inert	mod: oR
DV 2	3.953	1.761	1.770	0.009	inert	mod: oR
DV 3	3.993	1.760	1.770	0.010	inert	mod: oR

Table I.1 Showing the gemmological properties of some Ilakaka-Sakaraha sapphires (continued).

Sample no.	SG	RI		Birefringence	Fluorescence	
		n_o	n_e		SWUV	LWUV
Medium violet						
MV 1	3.948	1.760	1.770	0.010	inert	inert
MV 3	3.956	1.760	1.769	0.009	inert	mod: oR
Light violet						
LV 1	3.949	1.761	1.771	0.010	inert	mod: oR
LV 2	3.913	1.760	1.769	0.009	inert	mod: oR
LV 3	3.959	1.761	1.770	0.009	inert	weak: oR

Table I.2 Colour codes of some blue sapphires before heating based on GIA GemSet colour specimens (Retail Set).

Sample no.	Code	Tone, Saturation Hue
Dark blue		
IDB 1	bV 6/5 + rP 5/3	medium dark, strong bluish violet + very
(colour-change)	(daylight)	slightly grayish reddish purple
	* V 6/5 + P 4/3	medium dark, strong bluish violet + medium
		light, very slightly grayish purple
IDB 2	V 6/4 + rP 5/3	medium dark, moderately strong violet +
(colour-change)	(daylight)	medium, very slightly grayish reddish purple
	* V 6/5 + rP 8/3	medium dark, strong violet + very slightly
		grayish reddish purple
IDB 3	bV 5/4 + rP 5/3	medium, moderately strong bluish violet +
(colour-change)	(daylight)	medium, very slightly grayish reddish purple
	* V 6/5 + rP 8/3	medium dark, strong violet + very dark, very
		slightly grayish reddish purple
IDB 4	bV 6/5	medium dark, strong bluish violet
IDB 5	bV 6/5	medium dark, strong bluish violet
IDB 6	bV 6/5	medium dark, strong bluish violet
DB 1	bV 6/5	medium dark, strong bluish violet
DB 2	bV 6/4	medium dark, moderately strong bluish
(colour-change)	(daylight)	violet
	* V 7/4	dark, moderately strong violet
DB 3	bV 6/5	medium dark, strong bluish violet
DB 4	bP 7/4 + V 7/4	dark, moderately strong bluish purple
(colour-change)	(daylight)	dark, moderately strong violet
	* V 7/4	dark, moderately strong violet
DB 5	V 6/4	
(colour-change	(daylight)	medium dark, moderately strong violet
sapphire)	* V 6/5	medium dark, strong violet

Table I.2 Colour codes of some blue sapphires before heating based on GIA GemSet colour specimens (Retail Set). (continued)

Sample no.	Code	Tone, Saturation Hue
Medium blue		
IMB 1	bV 5/4	medium, moderately strong bluish violet
IMB 2	bV 5/4 + bV 4/5	medium, moderately strong bluish violetปน
	(banding)	medium light, strong bluish violet (banding)
IMB 3	bV 8/3	very dark, very slightly grayish bluish violet
IMB 4	bV 5/5 + B 2/2	medium, strong bluish violetปน very light, slightly grayish blue
IMB 5	bV 4/5	medium light, strong bluish violet
MB1	bV 2/3	very light, very slightly grayish bluish violet
MB 2	bV 3/4	light, moderately strong bluish violet
MB 3	bV 4/3	medium light, very slightly grayish bluish violet
MB 4	bV 3/4	light, moderately strong bluish violet
MB 5	bV 3/4	light, moderately strong bluish violet
MB 6	bV 5/4	medium, moderately strong bluish violet
MB 7	bV 4/3	medium light, very slightly grayish bluish violet
MB 8	bV 5/4	medium, moderately strong bluish violet
(colour-change)	(daylight)	
	* V 5/5	medium, strong violet
MB 9	bV 5/4	medium, moderately strong bluish violet
(colour-change)	(daylight)	
	* V 5/5	medium, strong violet
MB 10	bV 3/4 + V 4/4	light, moderately strong bluish violet +
(colour-change)	(daylight)	medium light, moderately strong violet
	* V 5/2	medium, slightly grayish violet

Table I.2 Colour codes of some blue sapphires before heating based on GIA GemSet colour specimens (Retail Set). (continued)

Sample no.	Code	Tone, Saturation Hue
Very light blue		
IVLB 1	B 2/2	very light, slightly grayish blue
IVLB 2	B 3/3	light, very slightly grayish blue
IVLB 4	vB 4/3	medium light, very slightly grayish violetish blue
IVLB 5	B 3/3	light, very slightly grayish blue
VLB 1	B 3/1	light, grayish blue
VLB 2	bV 2/3	very light, very slightly grayish bluish violet
VLB 3	bV 2/3	very light, very slightly grayish bluish violet
VLB 4	bV 3/4	light, moderately strong bluish violet
VLB 5	bV 2/3	Very light, very slightly grayish bluish violet
VLB 6	bV 3/4	light, moderately strong bluish violet
VLB 7	B 3/1	light, grayish blue
Milky very light blue		
MVLB 1	B 3/1	light, grayish blue
MVLB 2	B 3/1	light, grayish blue
MVLB 3	B 2/2	very light, slightly grayish blue
MVLB 5	B 3/1	light, grayish blue
MVLB 6	B 3/1 + V 2/2	light, grayish blue น very light, slightly grayish blue
MVLB 7	B 3/1	light, grayish blue
MVLB 8	B 3/1	light, grayish blue
Dark violet		
DV 1 (colour-change)	V 6/4 + rP 4/4 (daylight)	medium dark, moderately strong violet + medium light, moderately strong reddish purple
	* V 6/4 + P 6/4	medium dark, moderately strong violet + medium dark, moderately strong purple

Table I.2 Colour codes of some blue sapphires before heating based on GIA GemSet colour specimens (Retail Set). (continued)

Sample no.	Code	Tone, Saturation Hue
Dark violet		
DV 2	bP 5/5 + P 6/4	medium, strong bluish purple + medium
(colour-change)	(daylight)	dark, moderately strong purple
	* bP 6/5	medium dark, strong bluish purple
DV 3	bP 5/5 + P 6/4	medium, strong bluish purple + medium
(colour-change)	(daylight)	dark, moderately strong purple
	* bP 6/5	medium dark, strong bluish purple
Medium violet		
MV 1	V 4/3	medium light, very slightly grayish violet
(colour-change)	(daylight)	
	* bP 4/4	medium light, moderately strong bluish purple
MV 3	V 4/4	medium light, moderately strong violet
(colour-change)	(daylight)	
	* bP 6/3	medium dark, very slightly grayish bluish purple
Light violet		
LV 1	V 2/2	very light, slightly grayish violet
LV 2	V 2/2	very light, slightly grayish violet
LV 3	V 2/2	very light, slightly grayish violet

* under incandescent light

List of hue, tone and saturation terms for describing gem colours with their abbreviations.

HUE			
Purple	P	slightly yellowish Green	slyG
reddish Purple	rP	Green	G
Red-Purple or Purple-Red	RP/PR	very slightly bluish Green	VslbG
strongly purplish Red	stpR	bluish Green	BG
slightly purplish Red	slpR	very strongly bluish Green	VstbG
Red	R	Green-Blue or Blue-Green	GB/BG
orangy Red	oR	very strongly greenish Blue	VstgB
Red-Orange or Orange-Red	RO/OR	greenish Blue	gB
reddish Orange	rO	very slightly greenish Blue	vslgB
Orange	O	Blue	B
yellowish Orange	yO	violetish Blue	vB
orangy Yellow	oY	bluish Violet	bV
yellow	Y	Violet	V
greenish Yellow	gY	bluish Purple	bP
Yellow-Green or Green Yellow	YG/GY	Pink	Pk
strongly yellowish Green	styG	Brown	Br
yellowish Green	yG		

TONE		SATURATION	
0	colorless or white	1	grayish (brownish)
1	extremely light	2	slightly grayish (brownish)
2	very light	3	very slightly grayish (brownish)
3	light	4	moderately strong
4	medium light	5	strong
5	medium	6	vivid
6	medium dark		
7	dark		
8	very dark		
9	extremely dark		
10	black		

From GIA GEMSET MANUAL

Table I.2 Color codes of dark blue, medium blue, very light blue, milky very light blue, dark violet, medium violet and light violet sapphires before heating based on GIA GemSet color specimens (Retail Set)

Sample no.	324 GIA GemSet Colour Specimens (Retail Set)	Natural Bureau of Standard's Colour Name
Dark blue		
IDB 1	bV 6/5 + rP 5/3	medium dark, strong bluish violet + very
(colour-change)	(daylight)	slightly grayish reddish purple
	V 6/5 + P 4/3	medium dark, strong bluish violet + medium
	(incandescent light)	light, very slightly grayish purple
IDB 2	V 6/4 + rP 5/3	medium dark, moderately strong violet +
(colour-change)	(daylight)	medium, very slightly grayish reddish purple
	V 6/5 + rP 8/3	medium dark, strong violet + very slightly
	(incandescent light)	grayish reddish purple
IDB 3	bV 5/4 + rP 5/3	medium, moderately strong bluish violet +
(colour-change)	(daylight)	medium, very slightly grayish reddish purple
	V 6/5 + rP 8/3	medium dark, strong violet + very dark,
	(incandescent light)	very slightly grayish reddish purple
IDB 4	bV 6/5	medium dark, strong bluish violet
IDB 5	bV 6/5	medium dark, strong bluish violet
IDB 6	bV 6/5	medium dark, strong bluish violet
DB 1	bV 6/5	medium dark, strong bluish violet
DB 2	bV 6/4	medium dark, moderately strong bluish
(colour-change)	(daylight)	violet
	V 7/4	dark, moderately strong violet
	(incandescent light)	
DB 3	bV 6/5	medium dark, strong bluish violet

Table I.2 Color codes of dark blue, medium blue, very light blue, milky very light blue, dark violet, medium violet and light violet sapphires before heating based on GIA GemSet color specimens (Retail Set) (continued)

Sample no.	324 GIA GemSet Colour Specimens (Retail Set)	Natural Bureau of Standard's Colour Name
Dark blue (continued)		
DB 4 (colour-change)	bP 7/4 + V 7/4 (daylight)	dark, moderately strong bluish purple with dark, moderately strong violet
	V 7/4 (incandescent light)	dark, moderately strong violet
DB 5 (colour-change sapphire)	V 6/4 (daylight)	medium dark, moderately strong violet
	V 6/5 (incandescent light)	medium dark, strong violet
Medium blue		
IMB 1	bV 5/4	medium, moderately strong bluish violet
IMB 2	bV 5/4 + bV 4/5 (banding)	medium, moderately strong bluish violet with medium light, strong bluish violet (banding)
IMB 3	bV 8/3	very dark, very slightly grayish bluish violet
IMB 4	bV 5/5 + B 2/2	medium, strong bluish violet with very light, slightly grayish blue
IMB 5	bV 4/5	medium light, strong bluish violet
MB1	bV 2/3	very light, very slightly grayish bluish violet
MB 2	bV 3/4	light, moderately strong bluish violet
MB 3	bV 4/3	medium light, very slightly grayish bluish violet

Table I.2 Color codes of dark blue, medium blue, very light blue, milky very light blue, dark violet, medium violet and light violet sapphires before heating based on GIA GemSet color specimens (Retail Set) (continued)

Sample no.	324 GIA GemSet Colour Specimens (Retail Set)	Natural Bureau of Standard's Colour Name
Medium blue (continued)		
MB 4	bV 3/4	light, moderately strong bluish violet
MB 5	bV 3/4	light, moderately strong bluish violet
MB 6	bV 5/4	medium, moderately strong bluish violet
MB 7	bV 4/3	medium light, very slightly grayish bluish violet
MB 8 (colour-change)	bV 5/4 (daylight)	medium, moderately strong bluish violet
	V 5/5 (incandescent light)	medium, strong violet
MB 9 (colour-change)	bV 5/4 (daylight)	medium, moderately strong bluish violet
	V 5/5 (incandescent light)	medium, strong violet
MB 10 (colour-change)	bV 3/4 + V 4/4 (daylight)	light, moderately strong bluish violet + medium light, moderately strong violet
	V 5/2 (incandescent light)	medium, slightly grayish violet
Very light blue		
IVLB 1	B 2/2	very light, slightly grayish blue
IVLB 2	B 3/3	light, very slightly grayish blue
IVLB 4	vB 4/3	medium light, very slightly grayish violetish blue
IVLB 5	B 3/3	light, very slightly grayish blue

Table I.2 Color codes of dark blue, medium blue, very light blue, milky very light blue, dark violet, medium violet and light violet sapphires before heating based on GIA GemSet color specimens (Retail Set) (continued)

Sample no.	324 GIA GemSet Colour Specimens (Retail Set)	Natural Bureau of Standard's Colour Name
Very light blue (continued)		
VLB 1	B 3/1	light, grayish blue
VLB 2	bV 2/3	very light, very slightly grayish bluish violet
VLB 3	bV 2/3	very light, very slightly grayish bluish violet
VLB 4	bV 3/4	light, moderately strong bluish violet
VLB 5	bV 2/3	Very light, very slightly grayish bluish violet
VLB 6	bV 3/4	light, moderately strong bluish violet
VLB 7	B 3/1	light, grayish blue
Milky, very light blue		
MVLB 1	B 3/1	light, grayish blue
MVLB 2	B 3/1	light, grayish blue
MVLB 3	B 2/2	very light, slightly grayish blue
MVLB 5	B 3/1	light, grayish blue
MVLB 6	B 3/1 + V 2/2	light, grayish blue with very light, slightly grayish blue
MVLB 7	B 3/1	light, grayish blue
MVLB 8	B 3/1	light, grayish blue
Dark violet		
DV 1 (colour-change)	V 6/4 + rP 4/4 (daylight)	medium dark, moderately strong violet + medium light, moderately strong reddish purple
	V 6/4 + P 6/4 (incandescent light)	medium dark, moderately strong violet + medium dark, moderately strong purple

Table I.2 Color codes of dark blue, medium blue, very light blue, milky very light blue, dark violet, medium violet and light violet sapphires before heating based on GIA GemSet color specimens (Retail Set) (continued)

Sample no.	324 GIA GemSet Colour Specimens (Retail Set)	Natural Bureau of Standard's Colour Name
Dark violet (continued)		
DV 2 (colour-change)	bP 5/5 + P 6/4 (daylight)	medium, strong bluish purple + medium dark, moderately strong purple
	bP 6/5 (incandescent light)	medium dark, strong bluish purple
DV 3 (colour-change)	bP 5/5 + P 6/4 (daylight)	medium, strong bluish purple + medium dark, moderately strong purple
	bP 6/5 (incandescent light)	medium dark, strong bluish purple
Medium violet		
MV 1 (colour-change)	V 4/3 (daylight)	medium light, very slightly grayish violet
	bP 4/4 (incandescent light)	medium light, moderately strong bluish purple
MV 3 (colour-change)	V 4/4 (daylight)	medium light, moderately strong violet
	bP 6/3 (incandescent light)	medium dark, very slightly grayish bluish purple
Light violet		
LV 1	V 2/2	very light, slightly grayish violet
LV 2	V 2/2	very light, slightly grayish violet
LV 3	V 2/2	very light, slightly grayish violet

List of hue, tone and saturation terms for describing gem colors, with their abbreviations.

HUE			
Purple	P	slightly yellowish Green	slyG
reddish Purple	rP	Green	G
Red-Purple or Purple-Red	RP/PR	very slightly bluish Green	VslbG
strongly purplish Red	stpR	bluish Green	BG
slightly purplish Red	slpR	very strongly bluish Green	VstbG
Red	R	Green-Blue or Blue-Green	GB/BG
orangy Red	oR	very strongly greenish Blue	VstgB
Red-Orange or Orange-Red	RO/OR	greenish Blue	gB
reddish Orange	rO	very slightly greenish Blue	vslgB
Orange	O	Blue	B
yellowish Orange	yO	violetish Blue	vB
orangy Yellow	oY	bluish Violet	bV
yellow	Y	Violet	V
greenish Yellow	gY	bluish Purple	bP
Yellow-Green or Green Yellow	YG/GY	Pink	Pk
strongly yellowish Green	styG	Brown	Br
yellowish Green	yG		

TONE		SATURATION	
0	colorless or white	1	grayish (brownish)
1	extremely light	2	slightly grayish (brownish)
2	very light	3	very slightly grayish (brownish)
3	light	4	moderately strong
4	medium light	5	strong
5	medium	6	vivid
6	medium dark		
7	dark		
8	very dark		
9	extremely dark		
10	black		

From GIA GEMSET MANUAL

APPENDIX II

FTIR Spectra of sapphires before and after heating

Dark blue: IDB1, IDB 2, IDB 3, IDB 4, IDB 5, IDB 6,
DB 1, DB 2, DB 3, DB 4 and DB5

Medium blue: IMB 1, Imb 2, IMB 3, IMB 4, IMB 5,
MB 1, MB 3, MB 4, MB 6 and MB 9

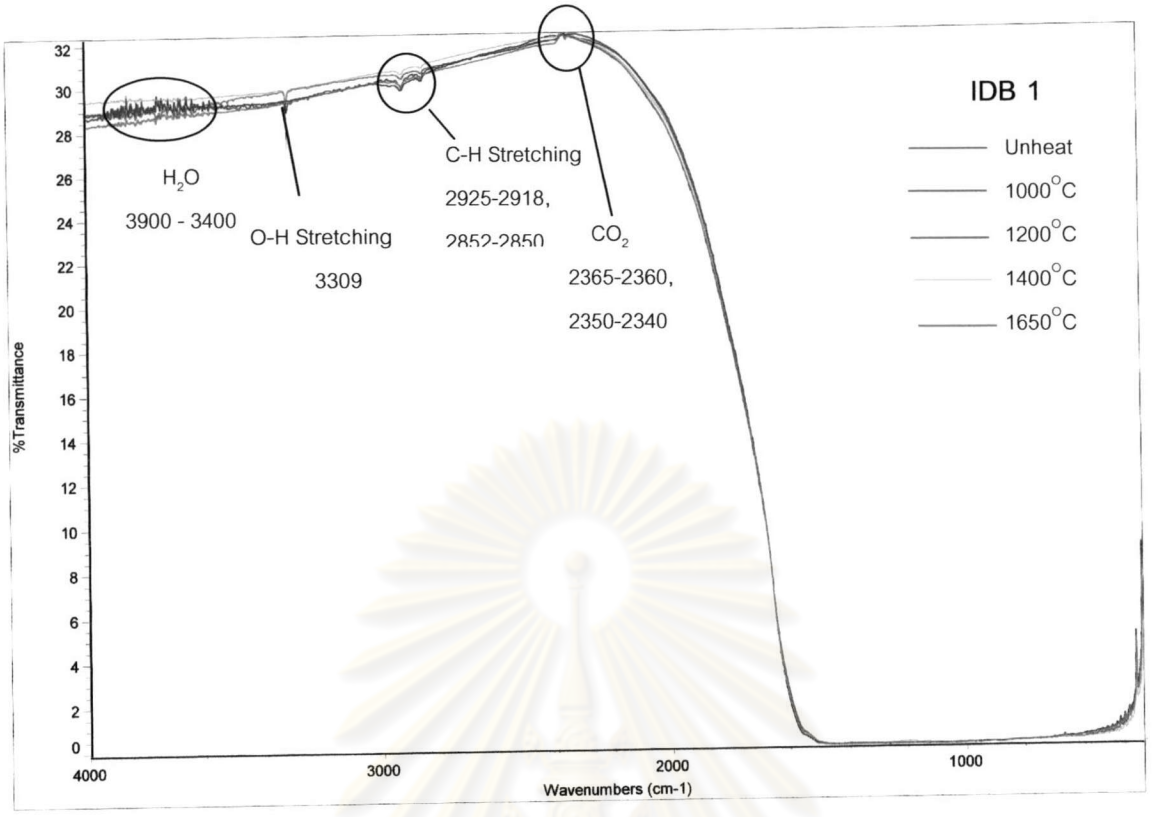
Very light blue: IVLB 1, IVLB 2, IVLB 4, IVLB 5,
VLB 1, VLB 2, VLB 3, VLB 4, VLB 5, VLB 6 and VLB 7

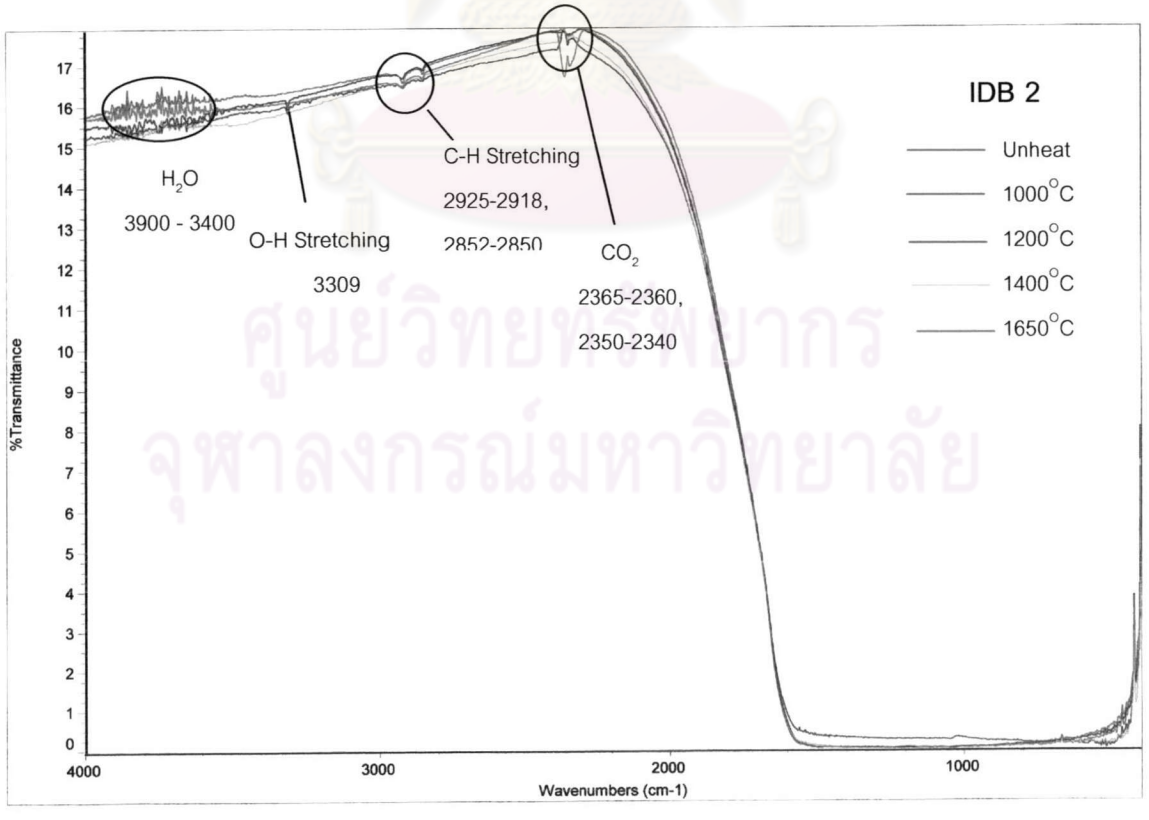
Milky, very light blue: MVLB 3, MVLB 5, MVLB 6, MVLB 7 and MVLB 8

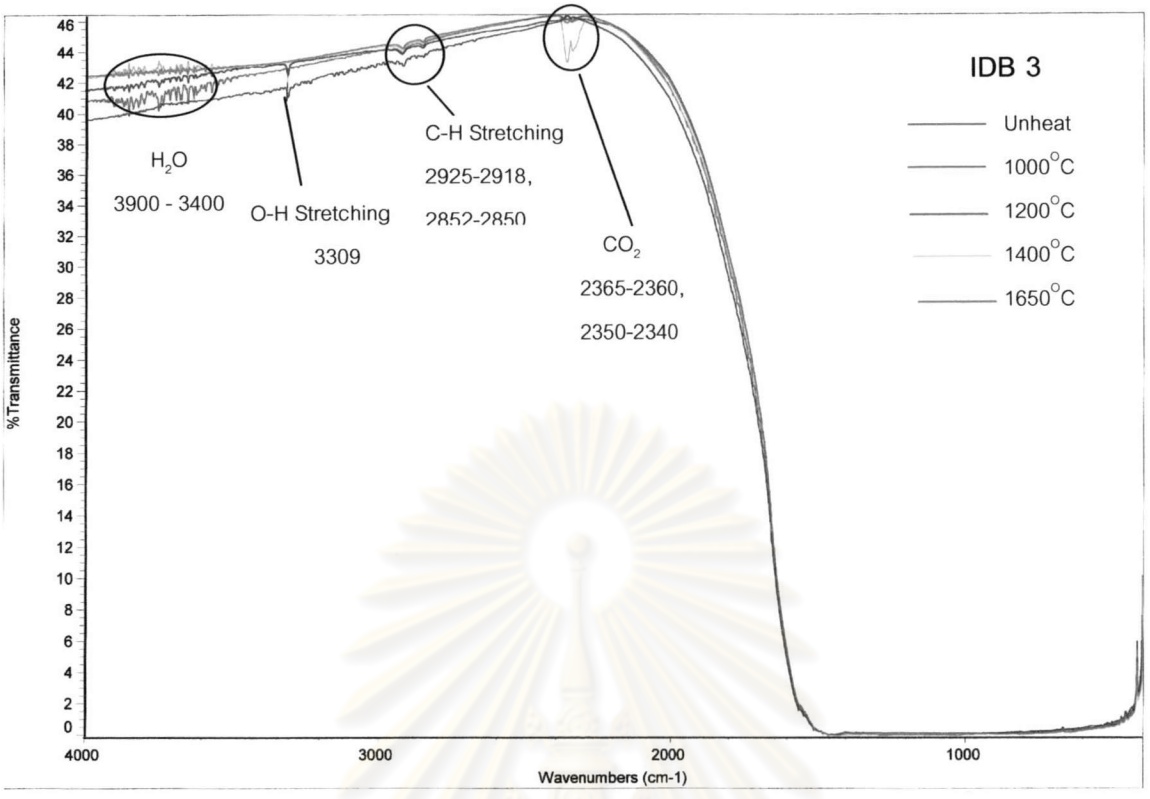
Dark violet: DV 1, DV 2 and DV 3

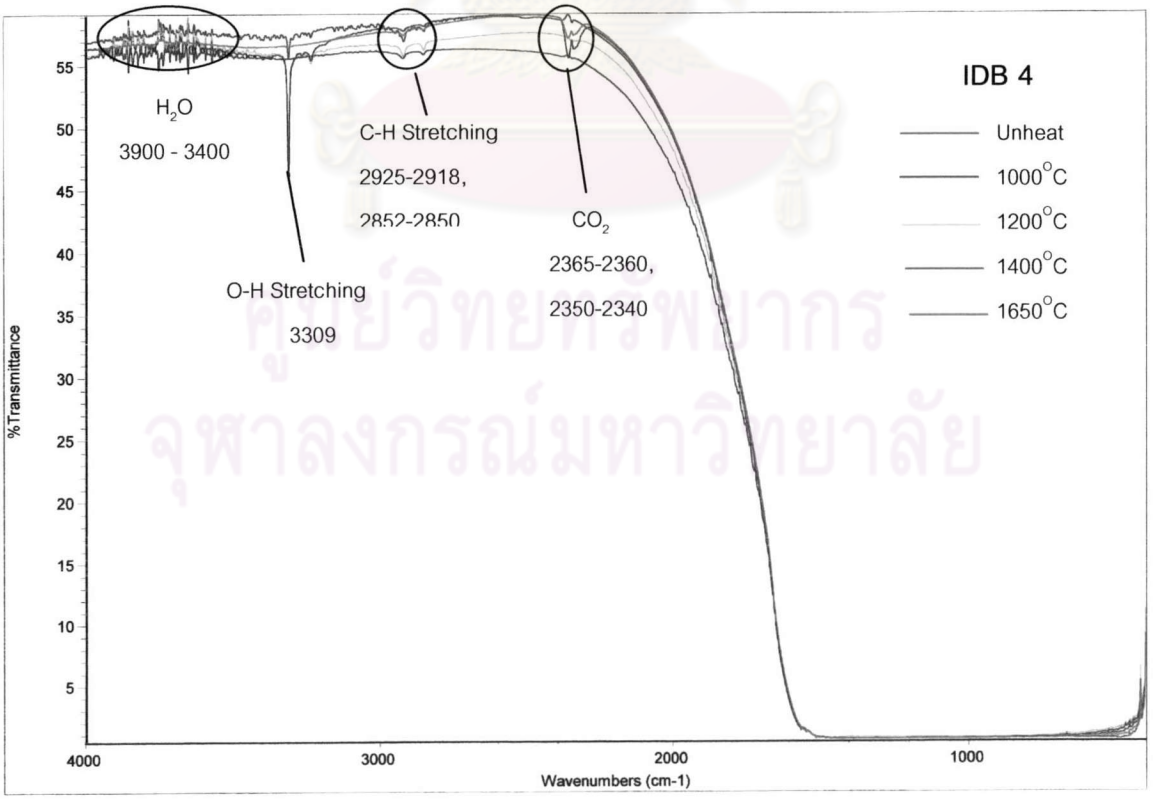
Medium violet: MV1 and MV 3

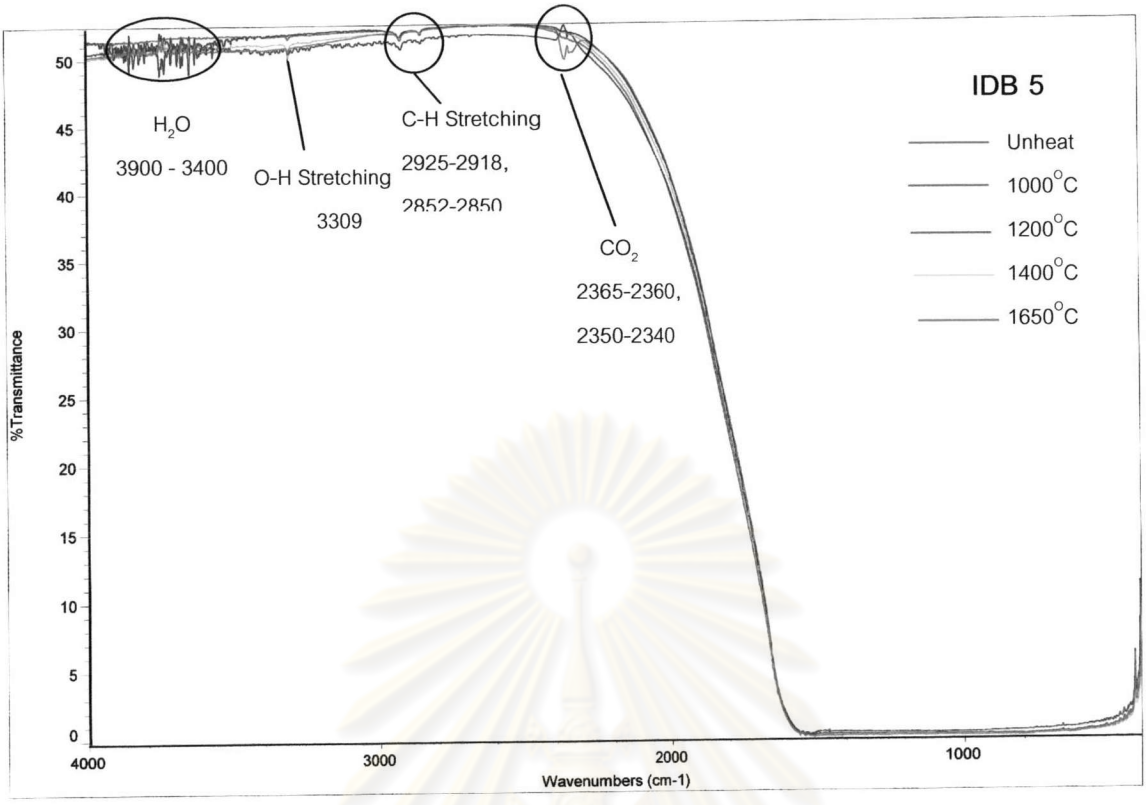
Light violet: LV1, LV 2 and LV 3

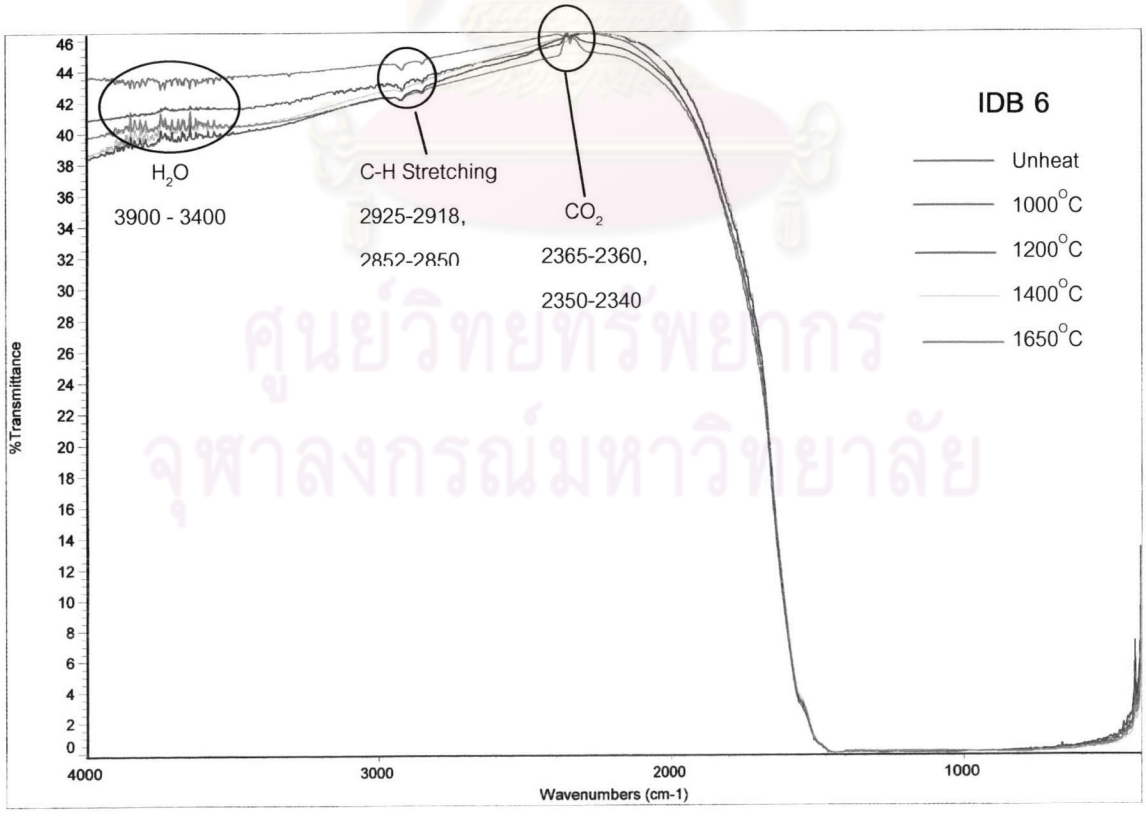


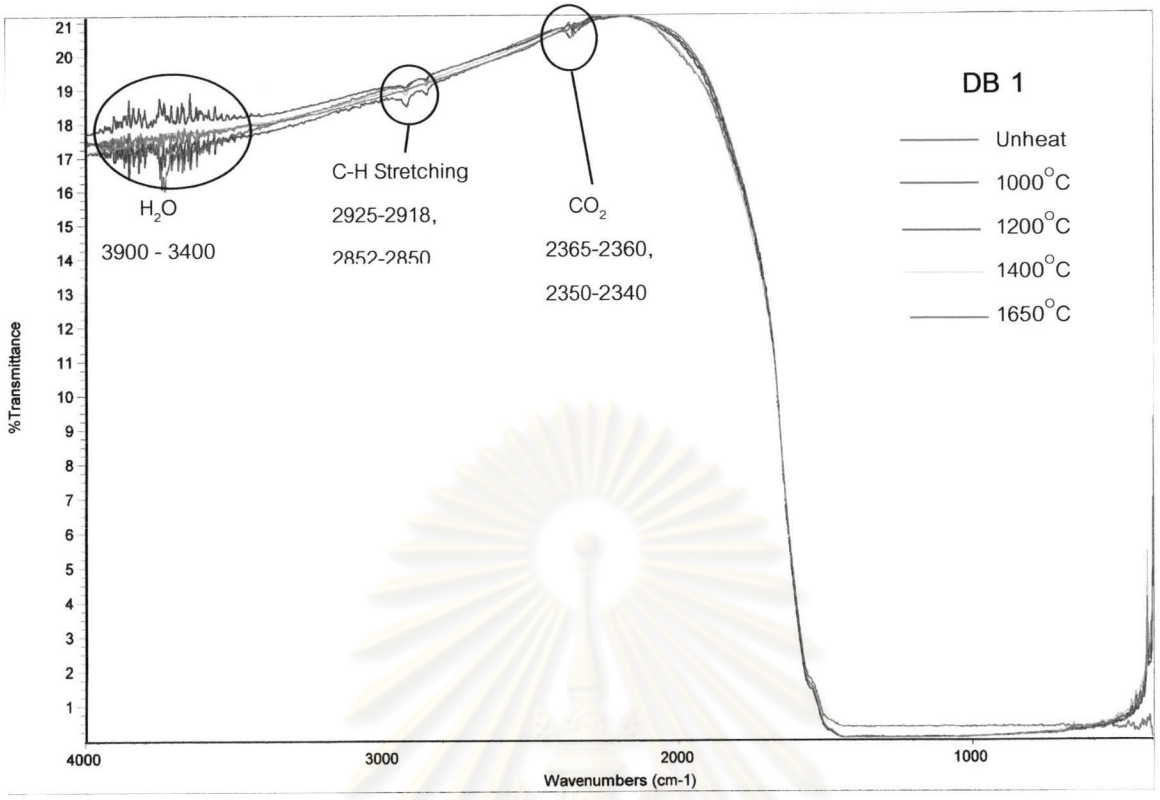


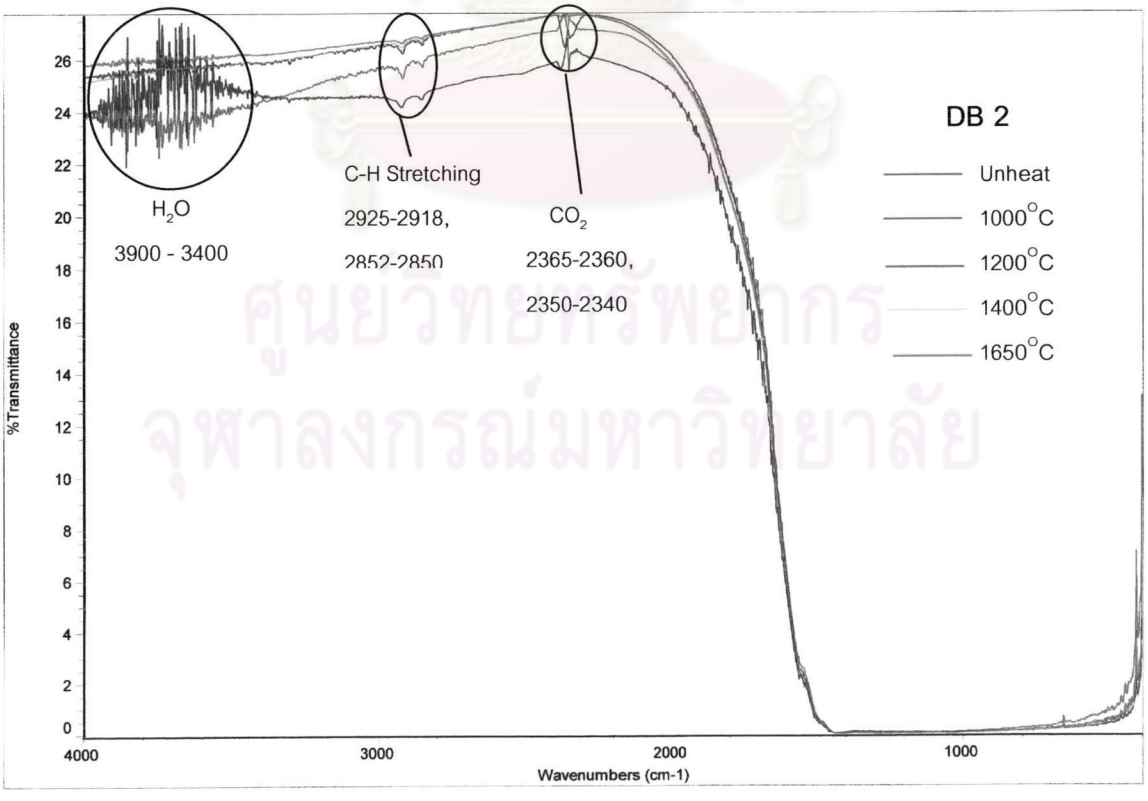


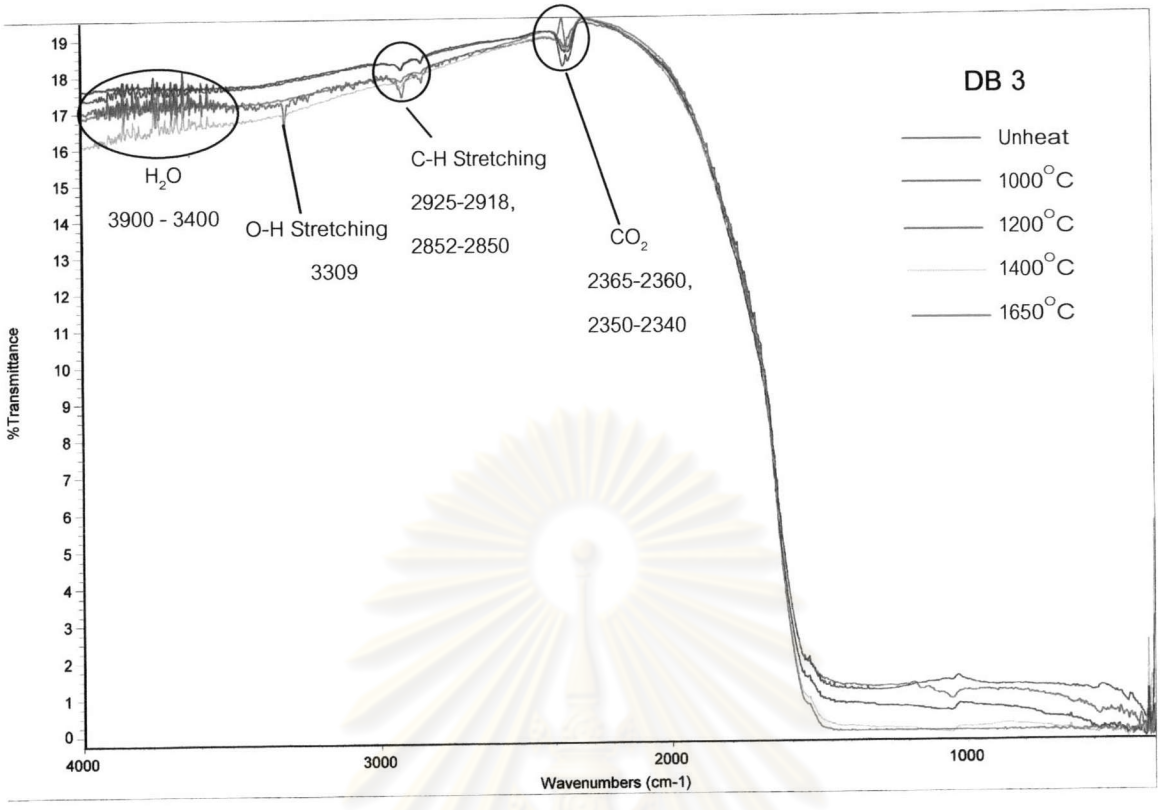


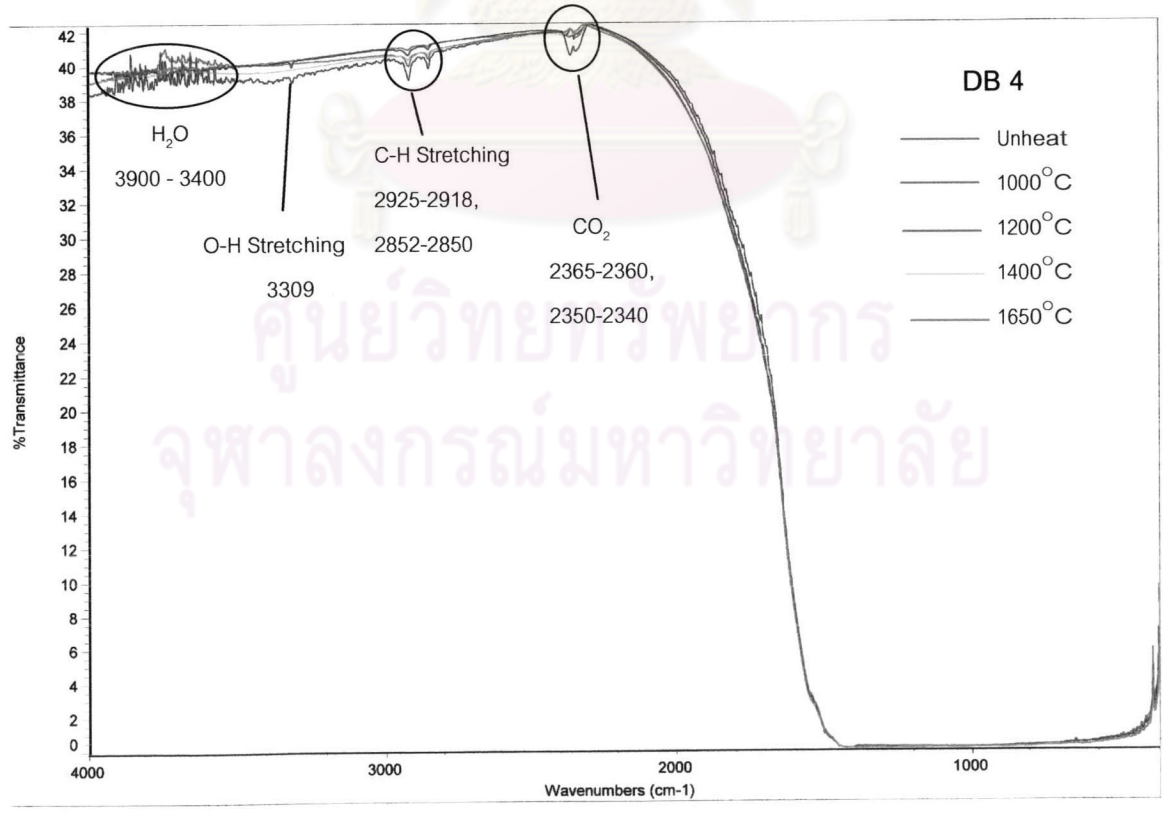


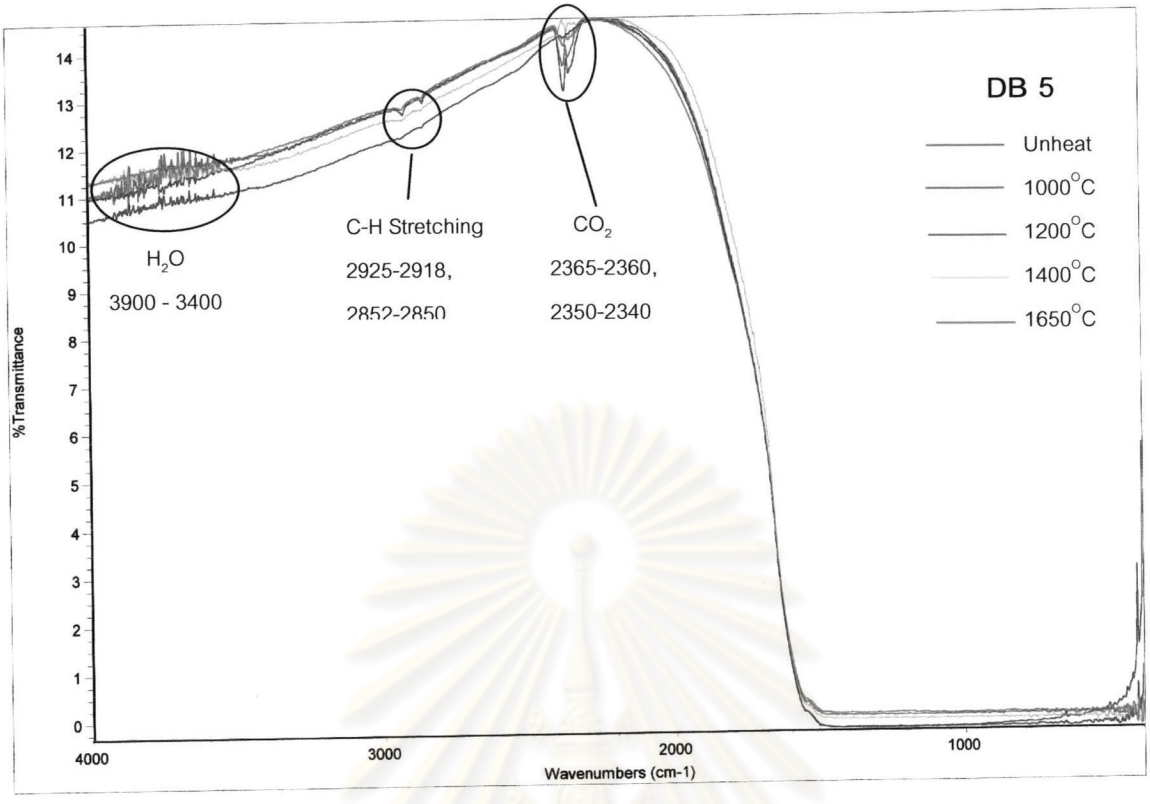


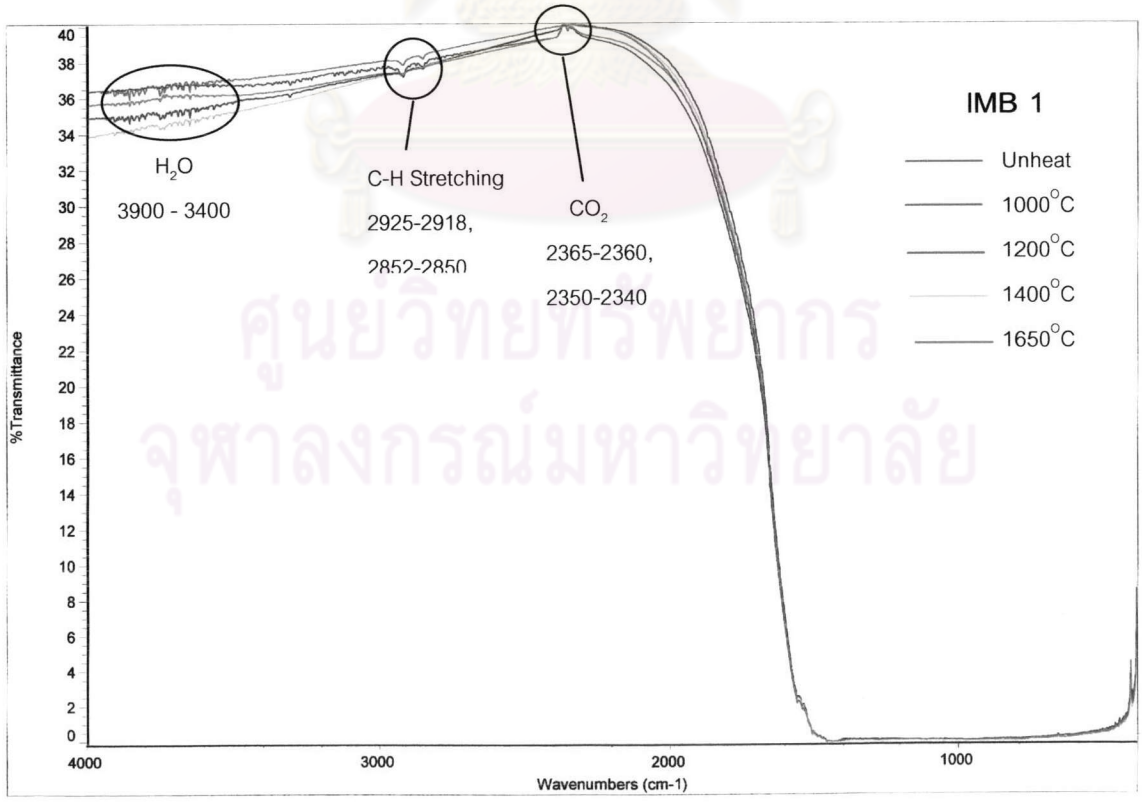


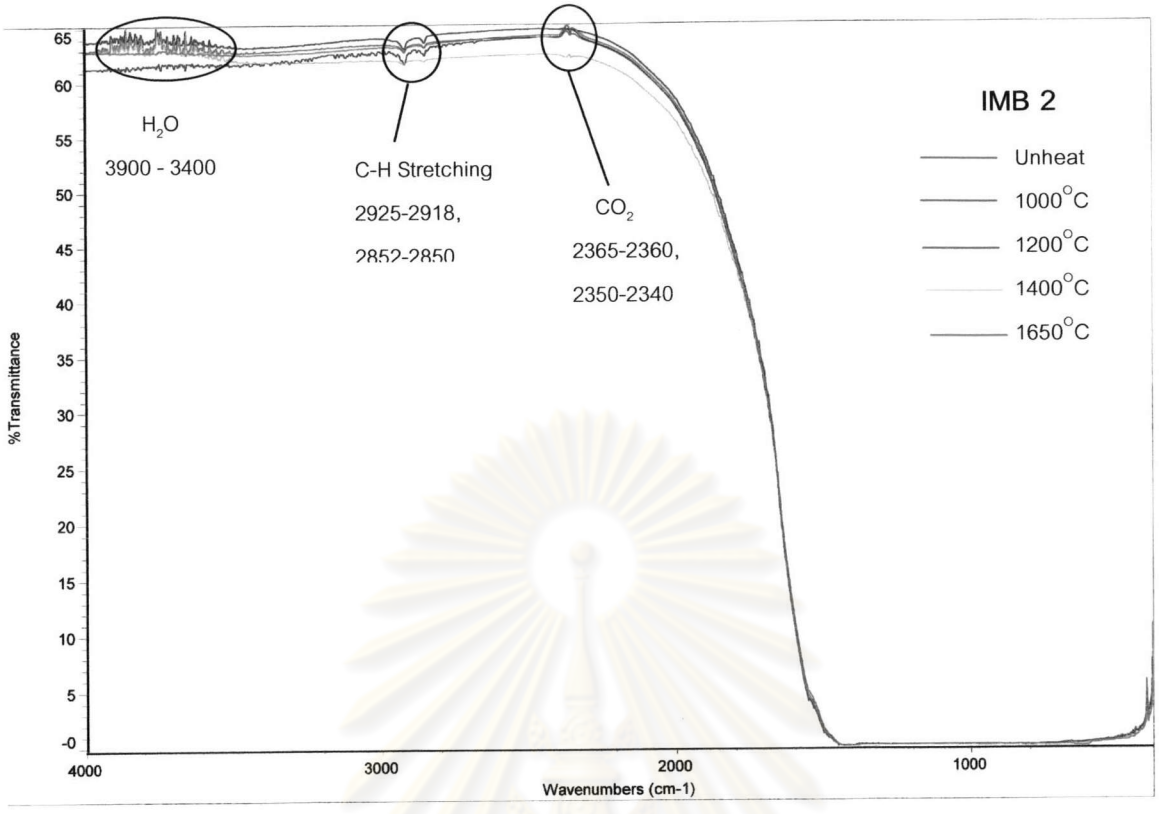


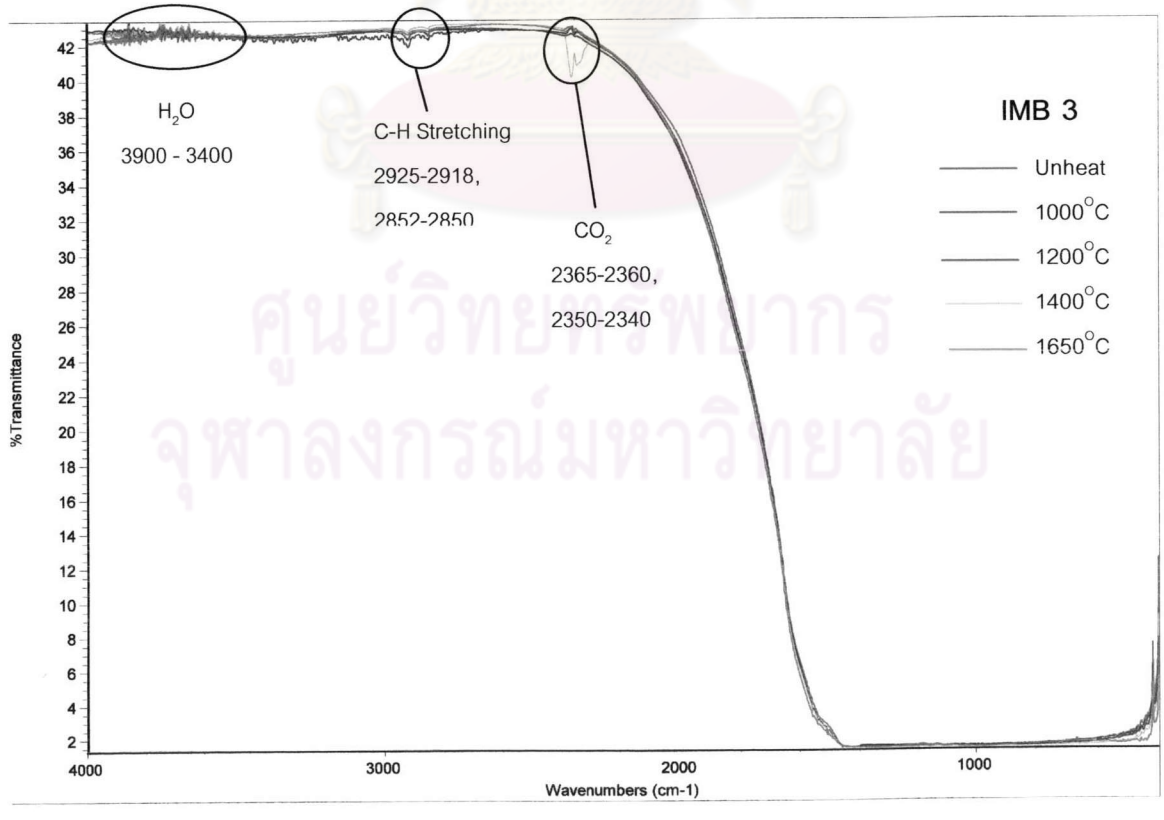


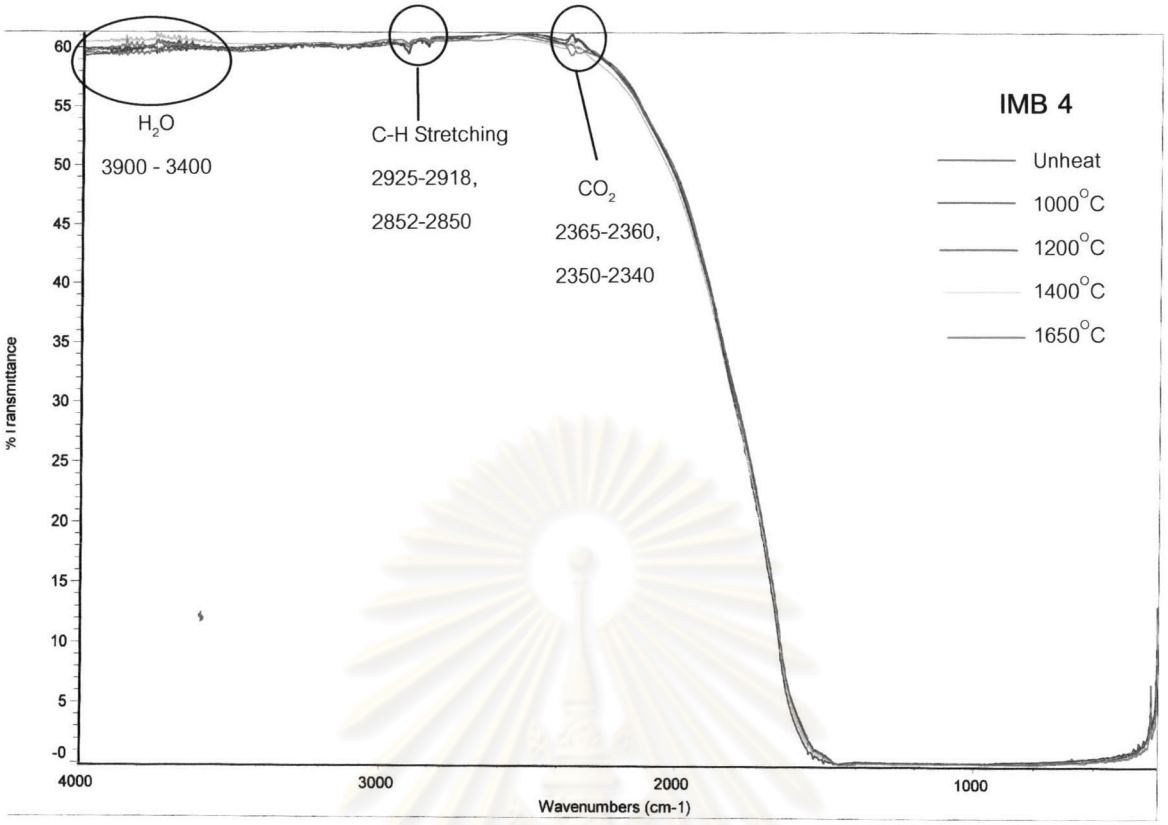


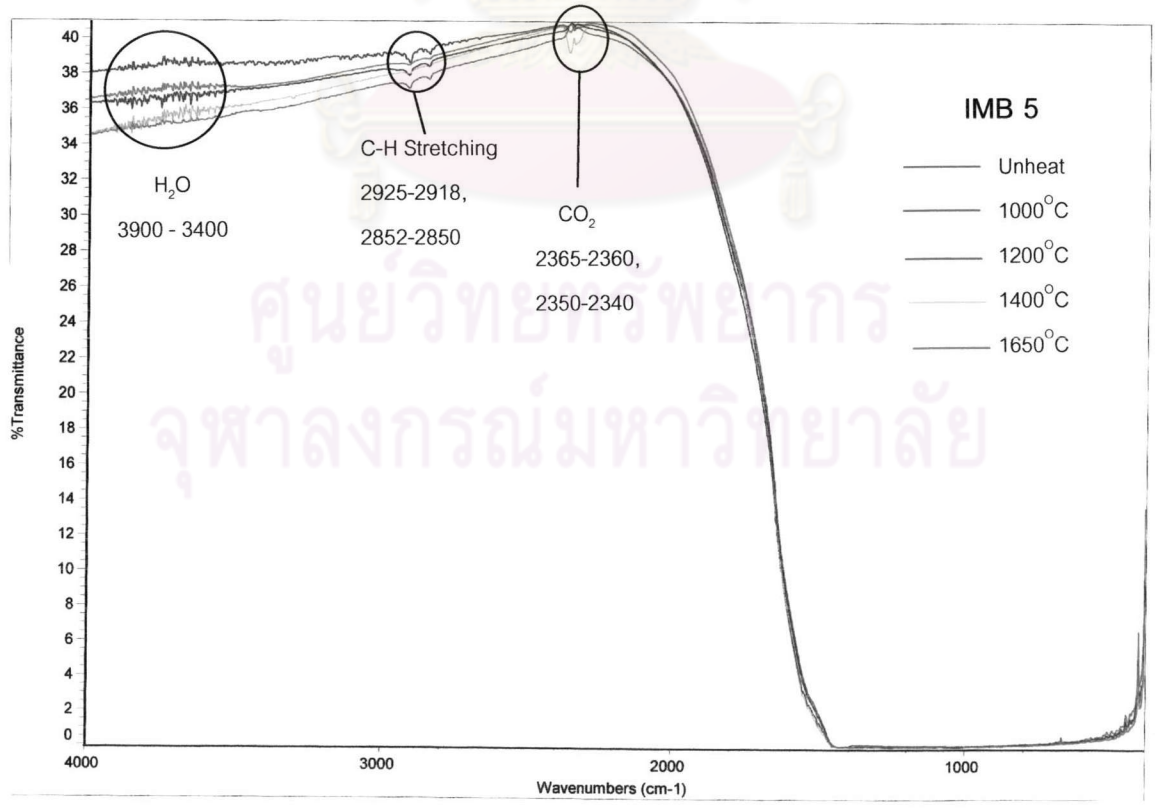


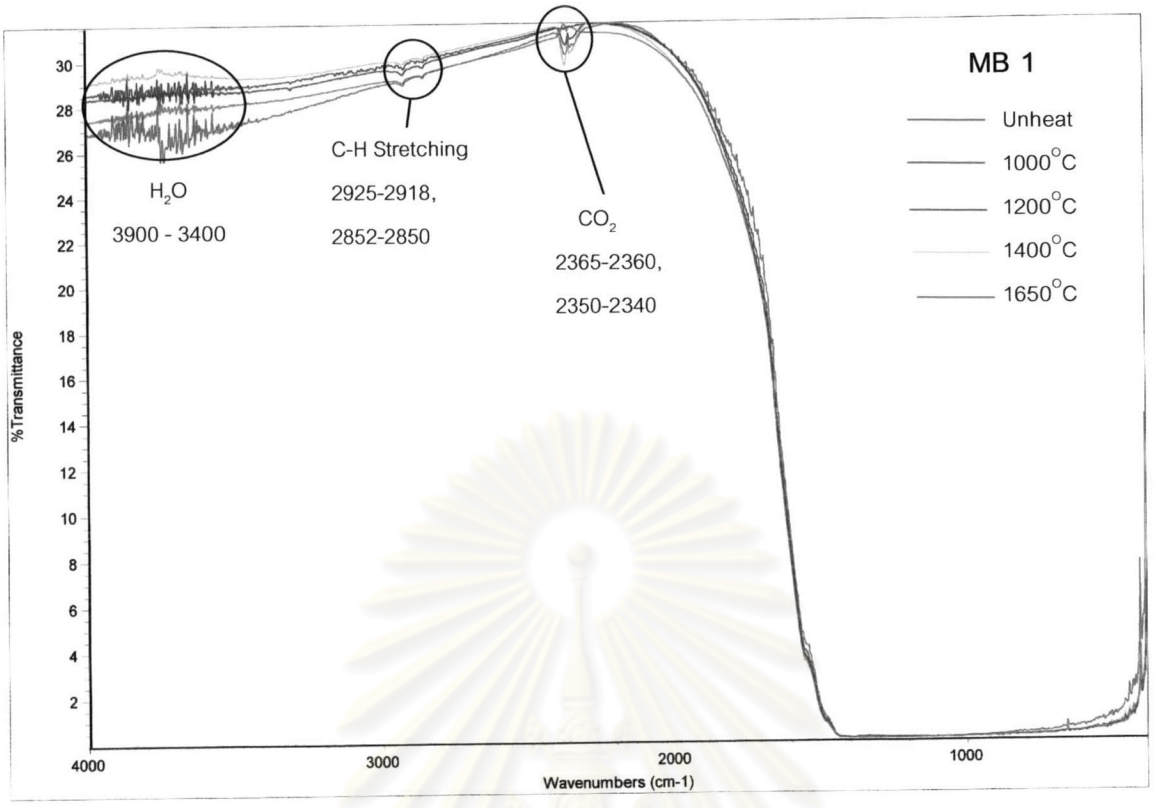


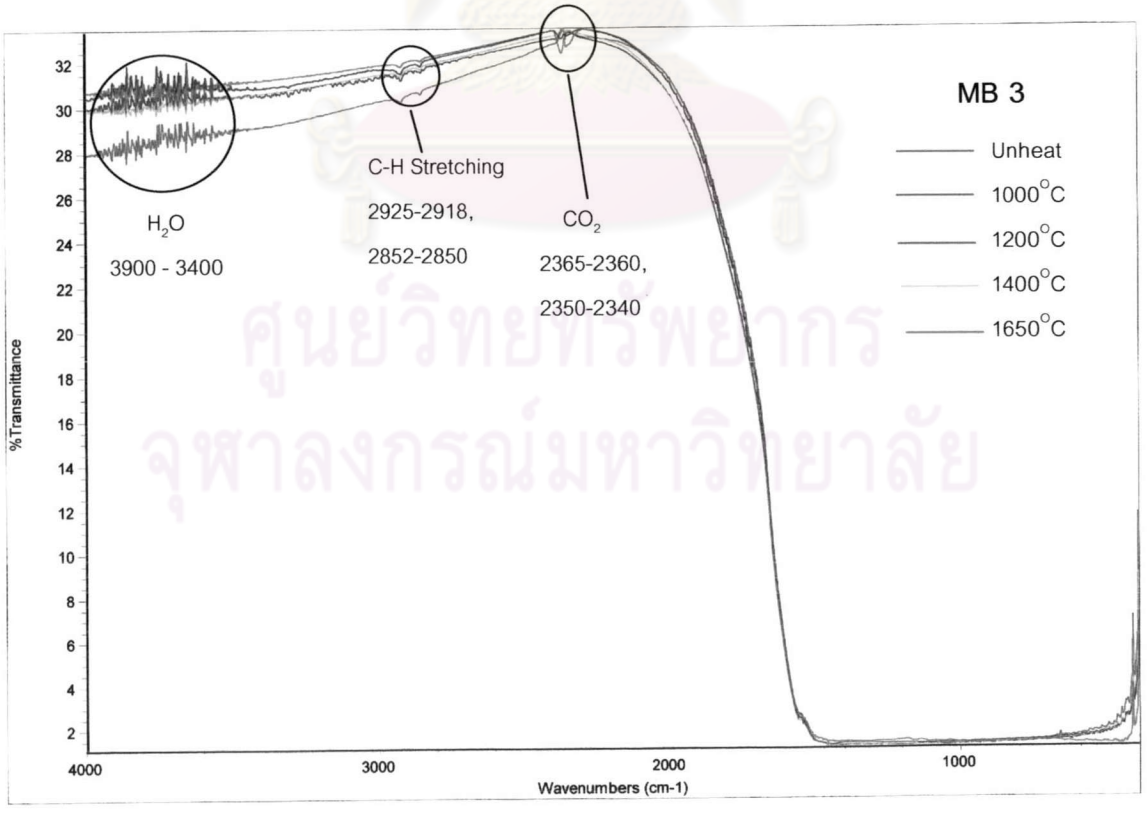


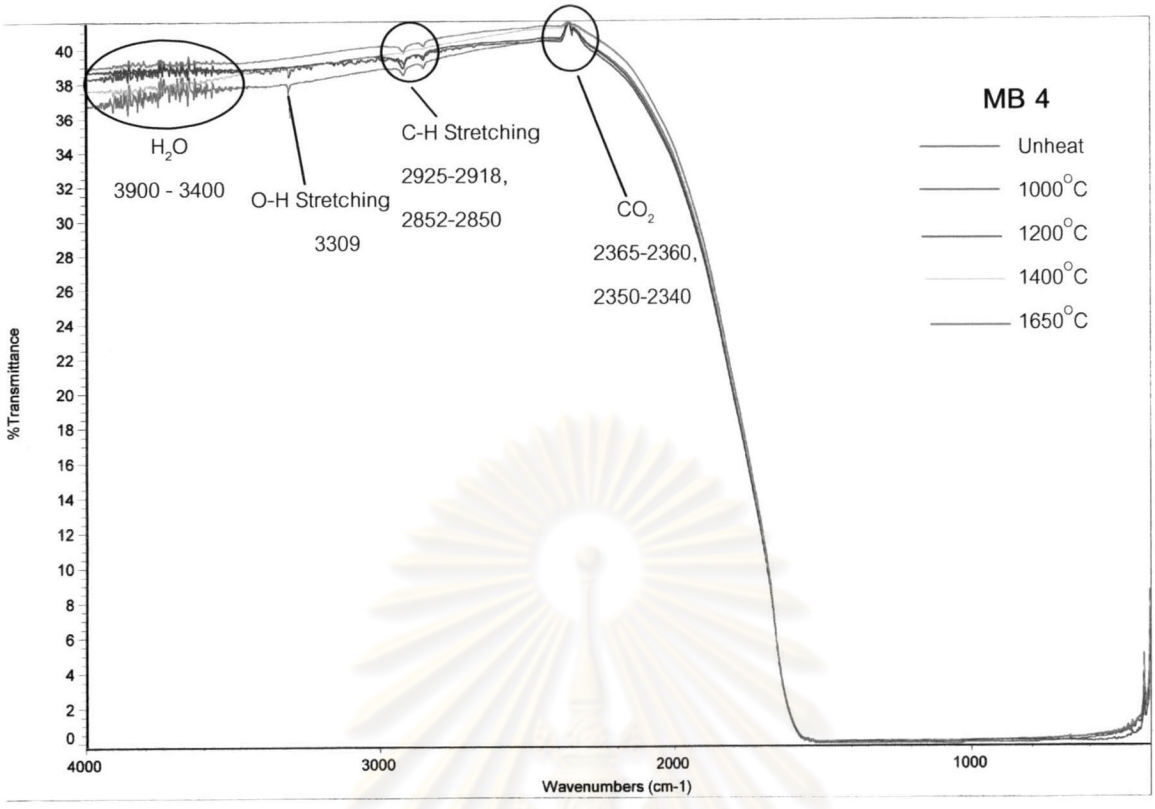


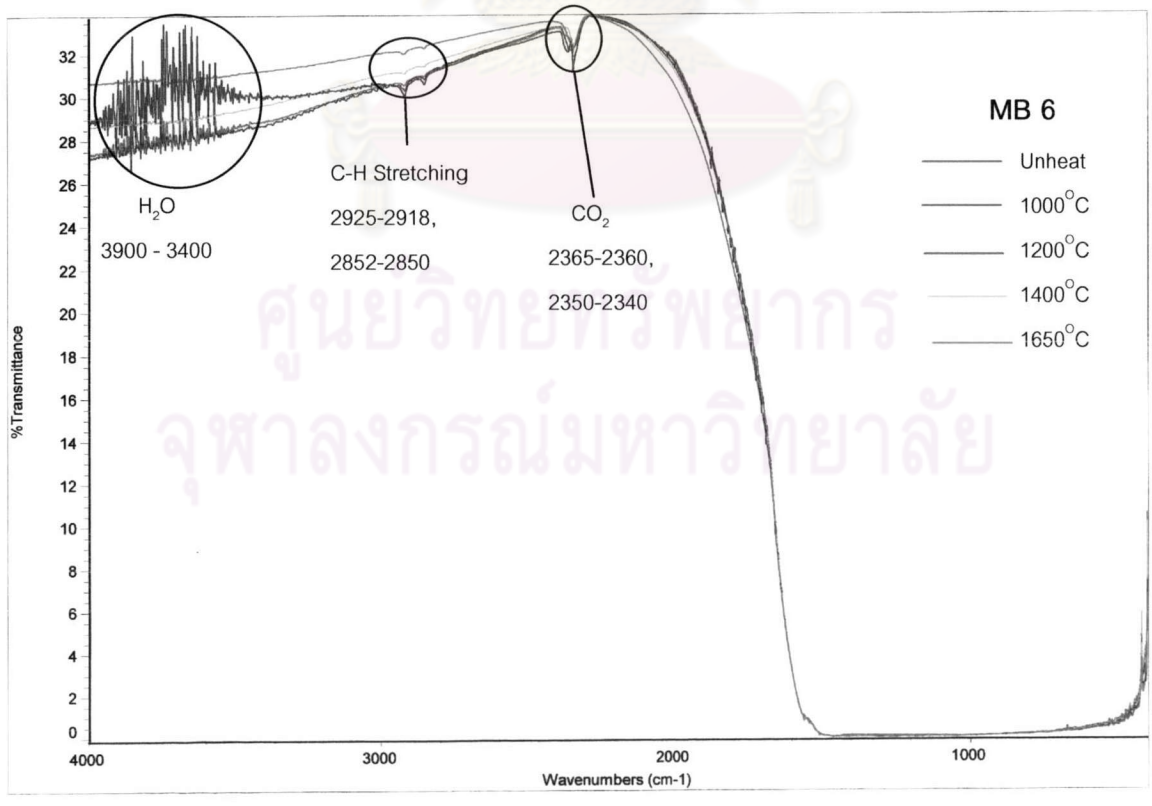


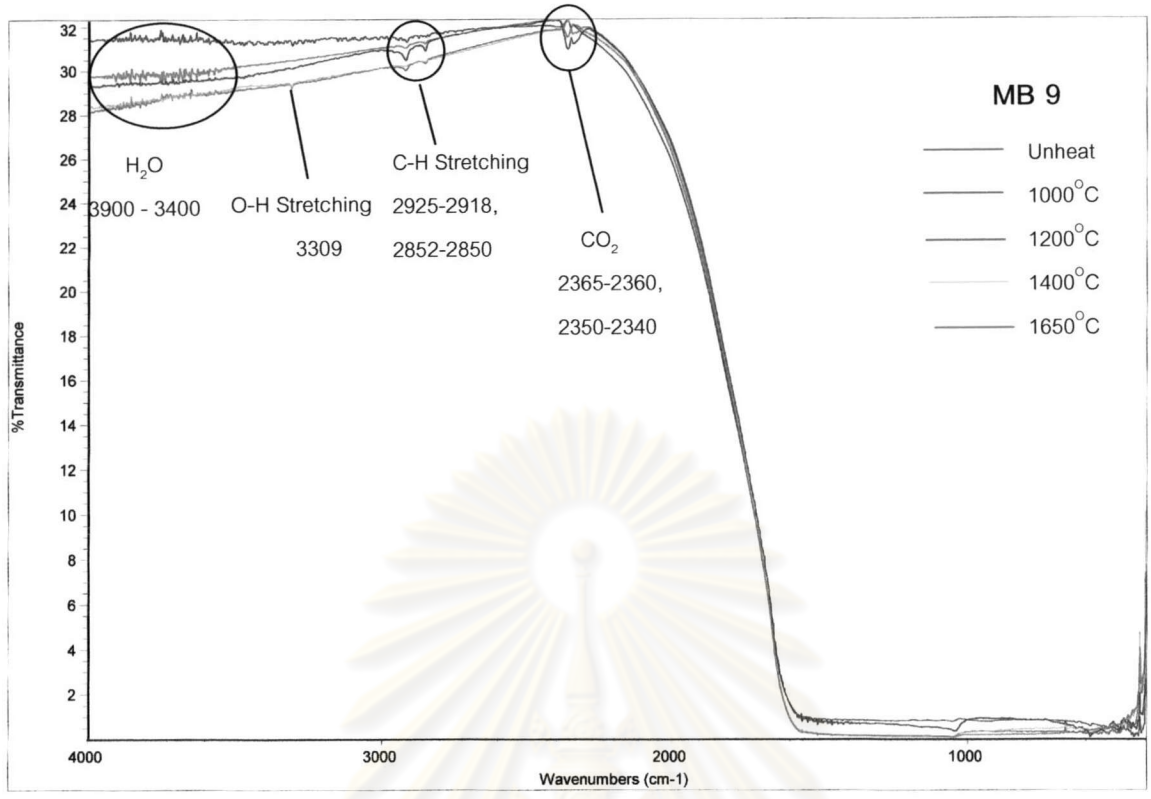


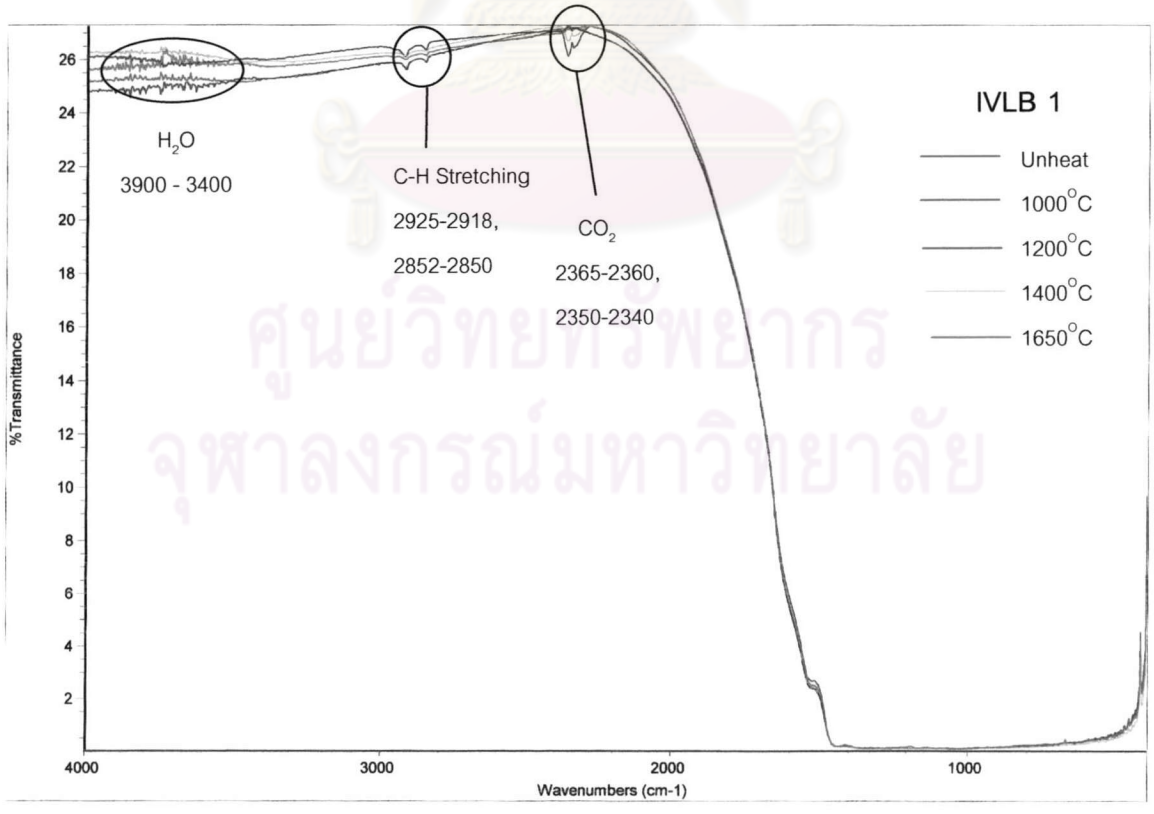


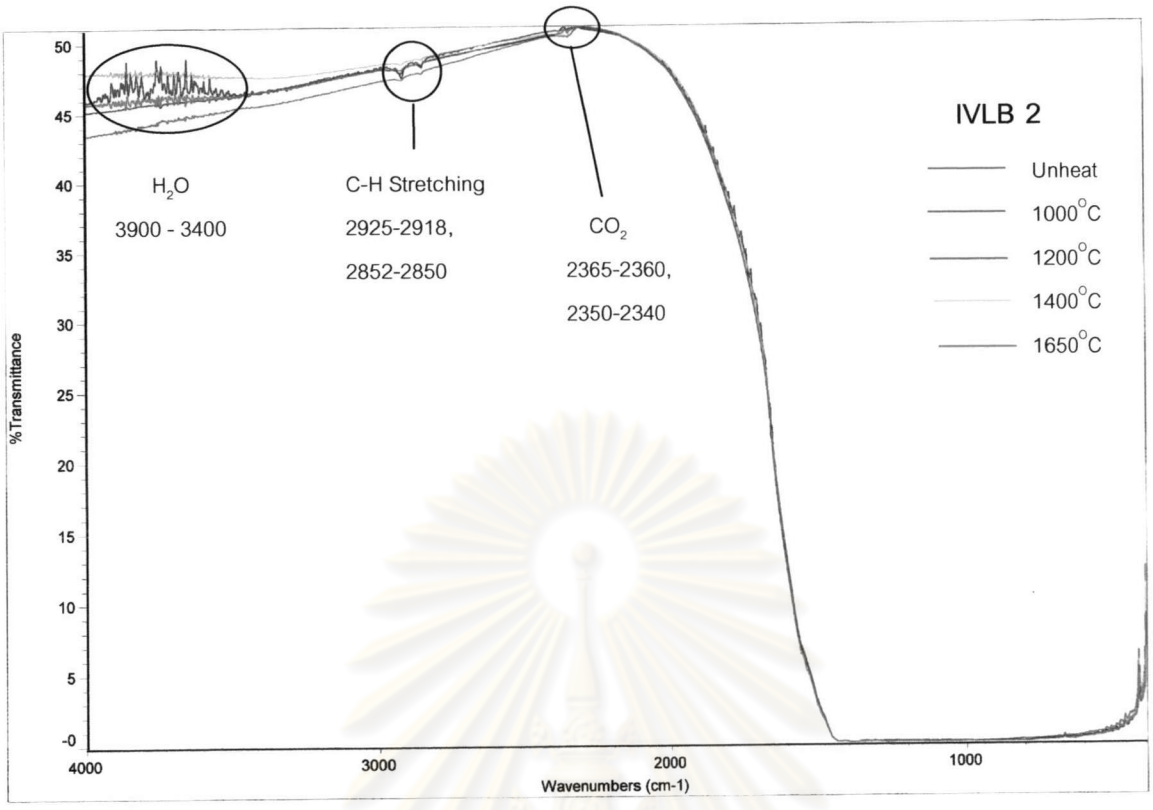


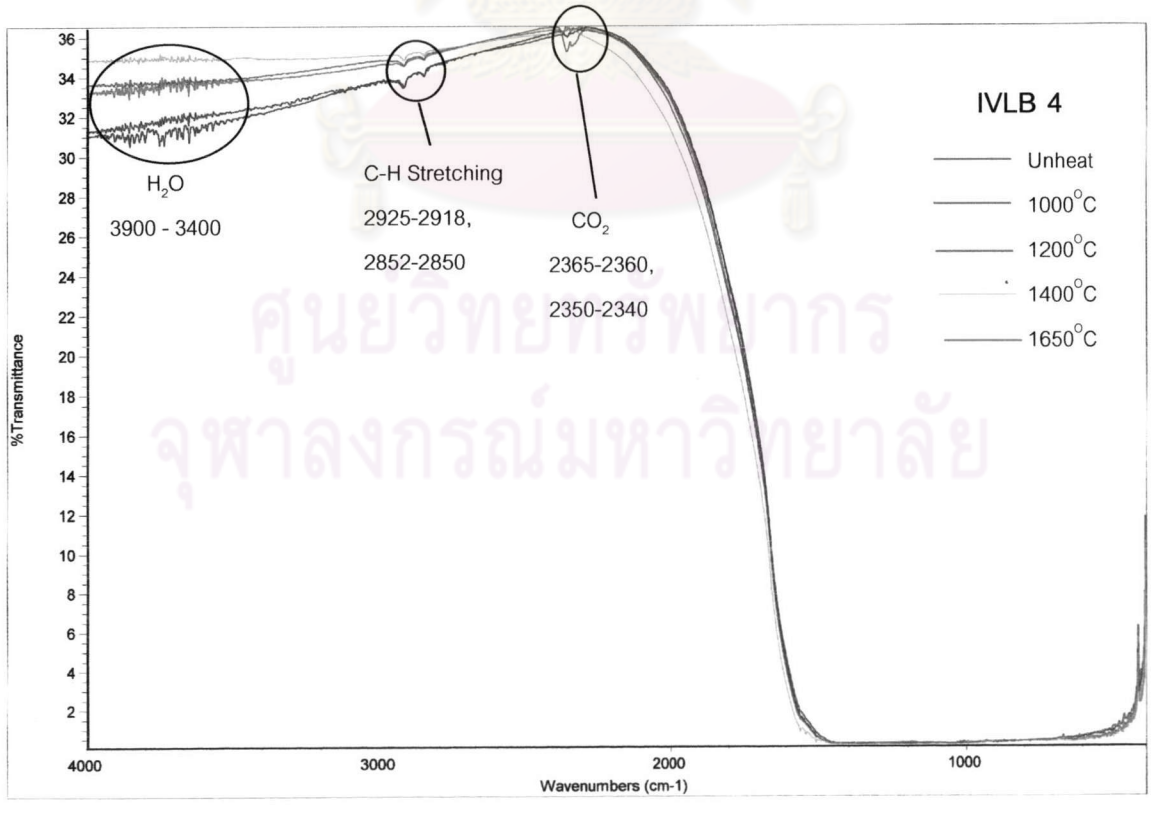


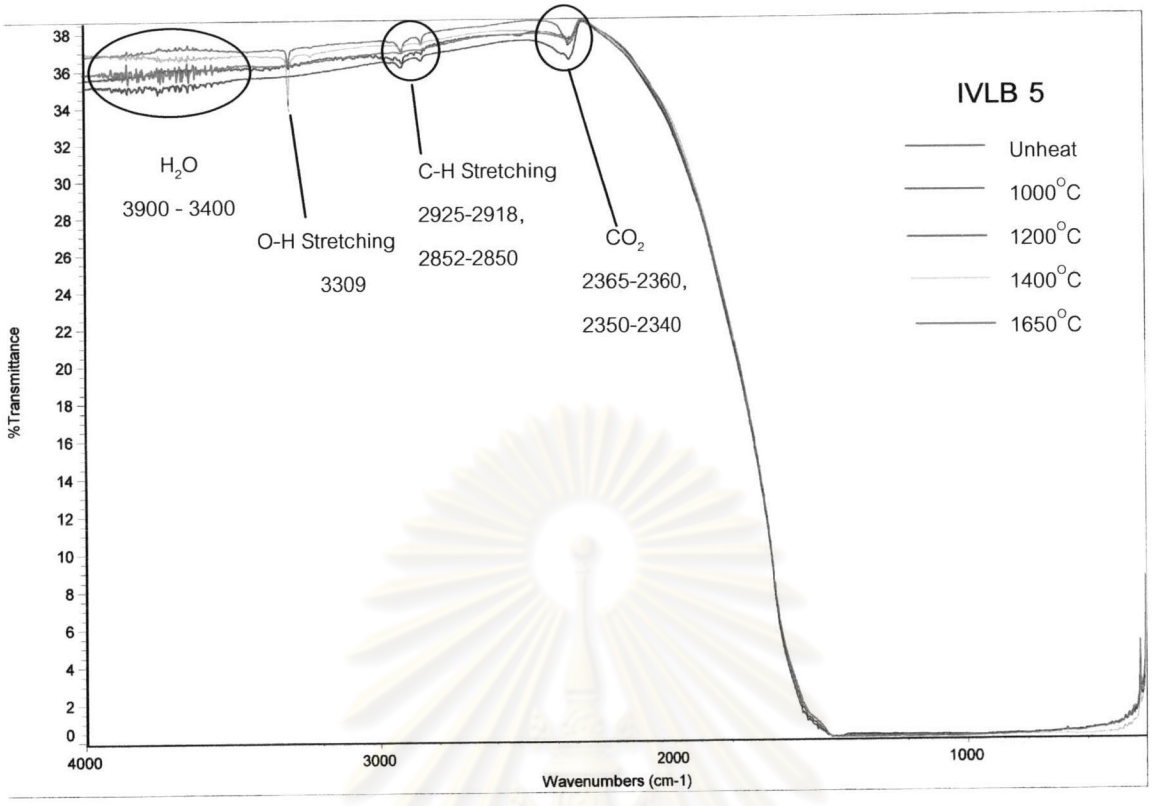


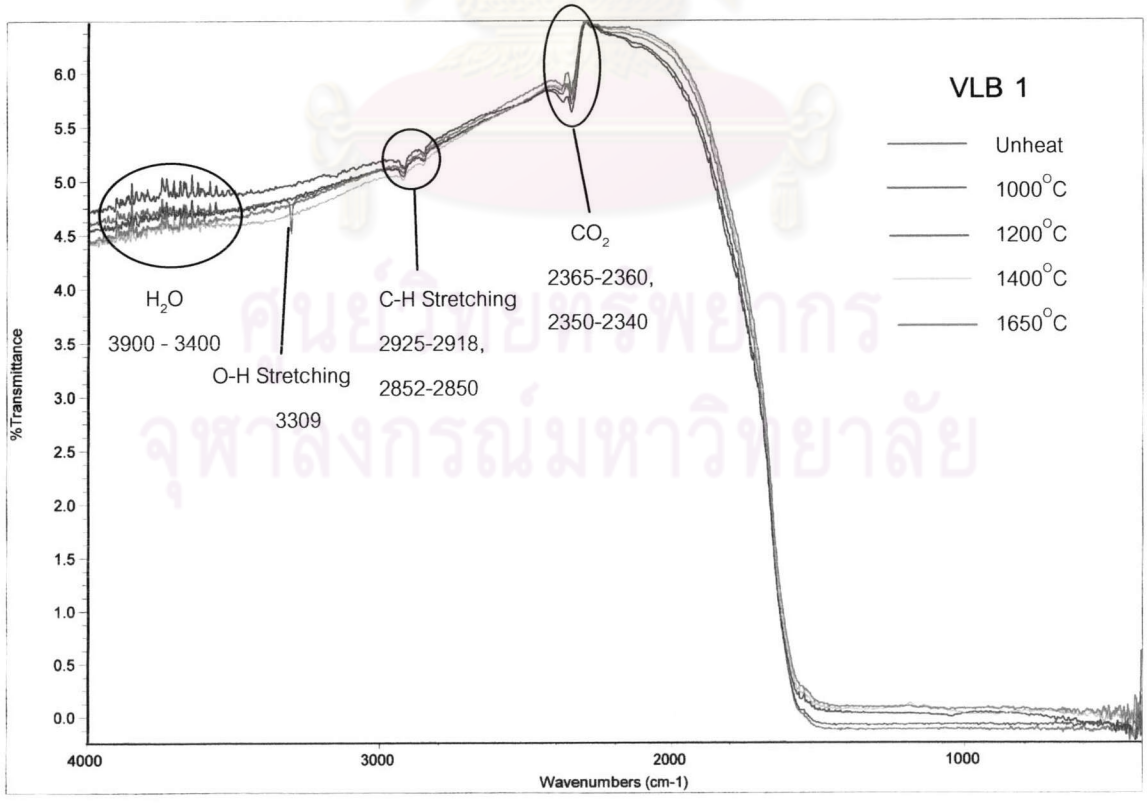


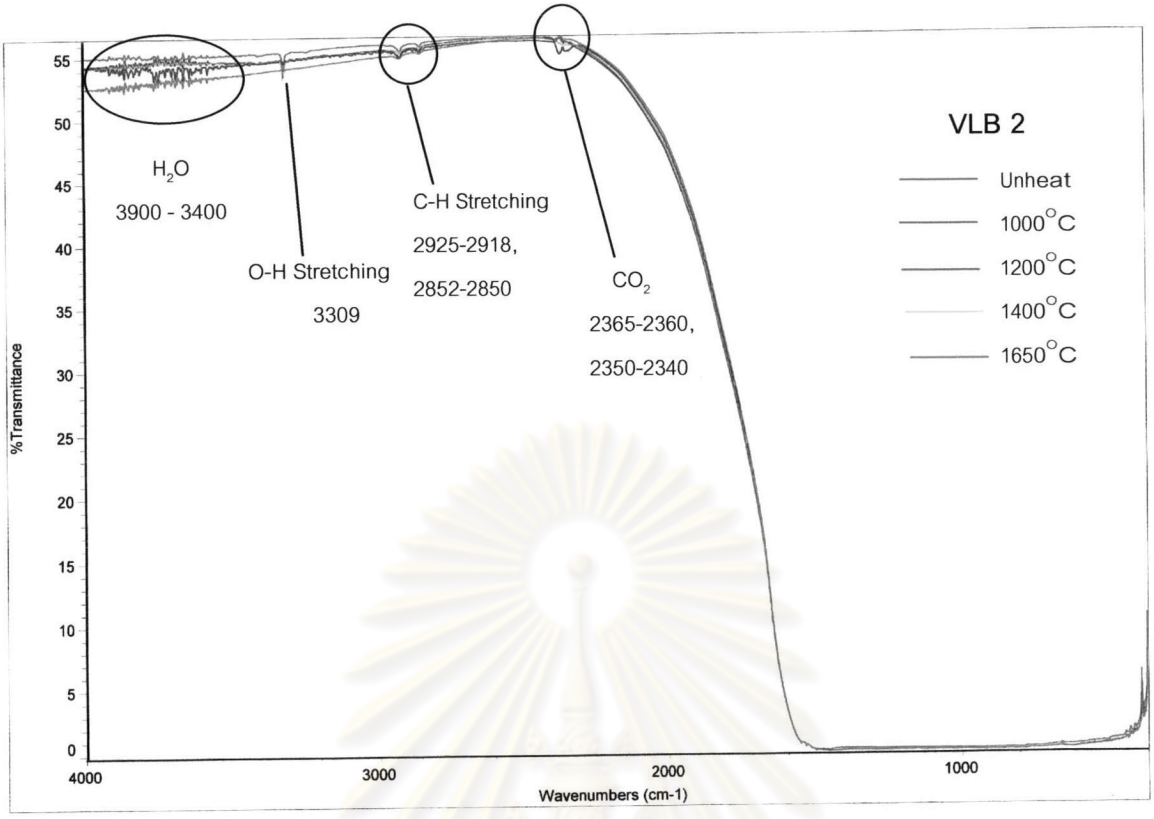


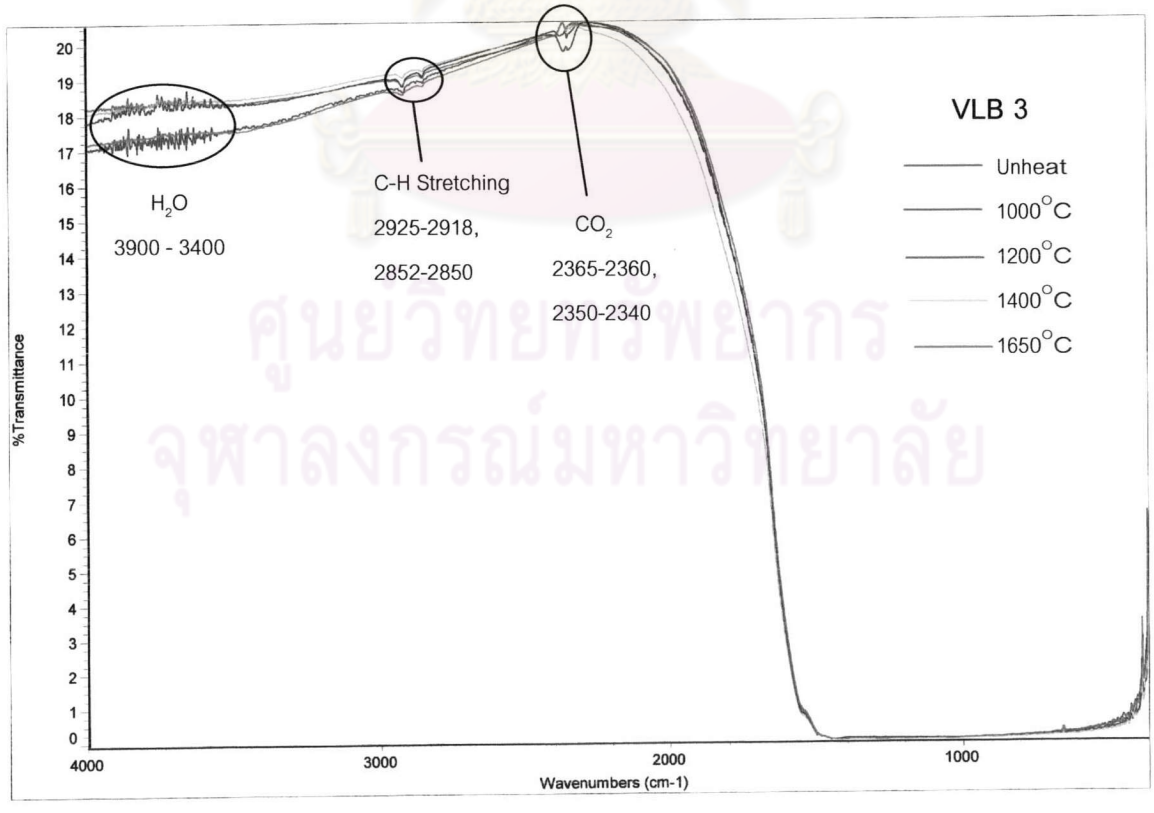


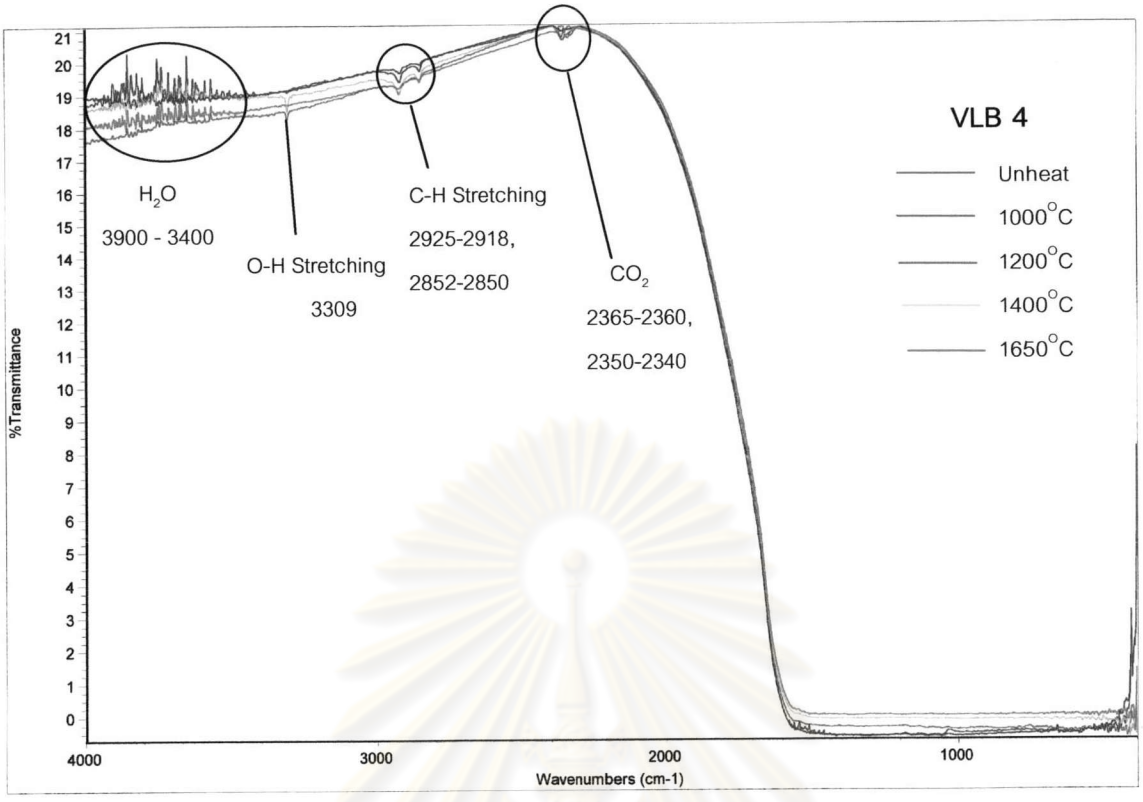


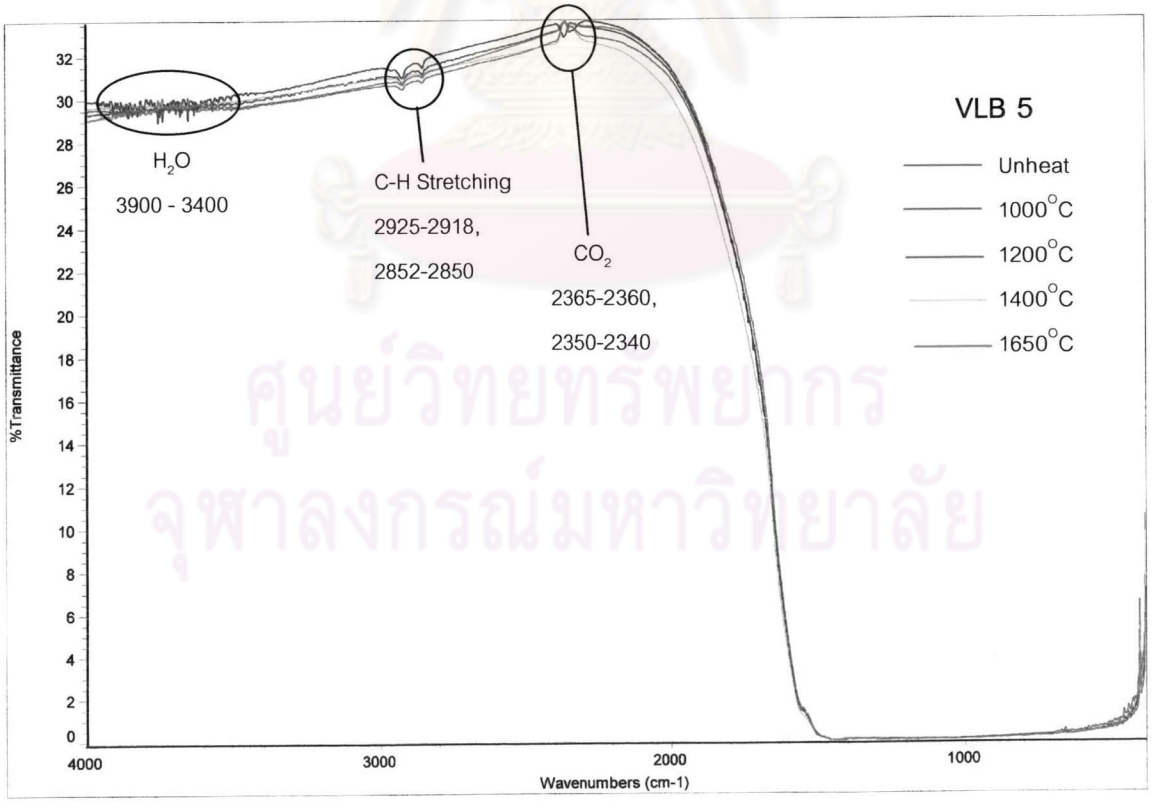


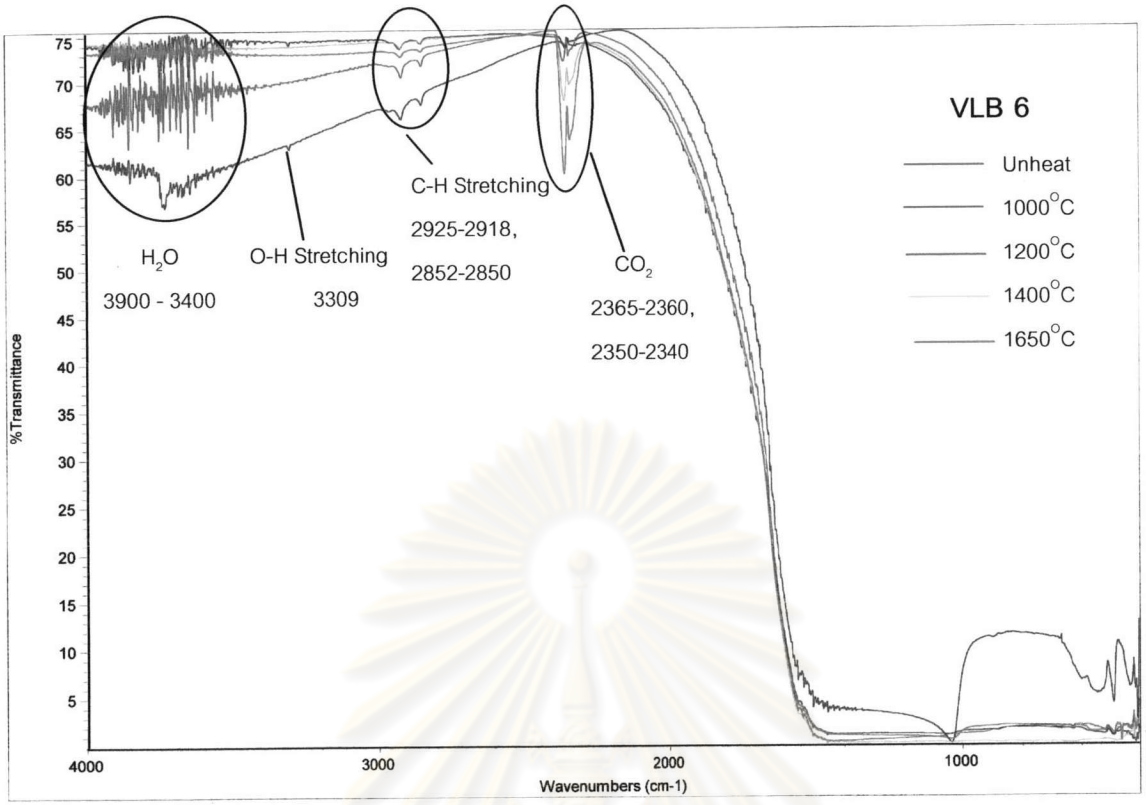


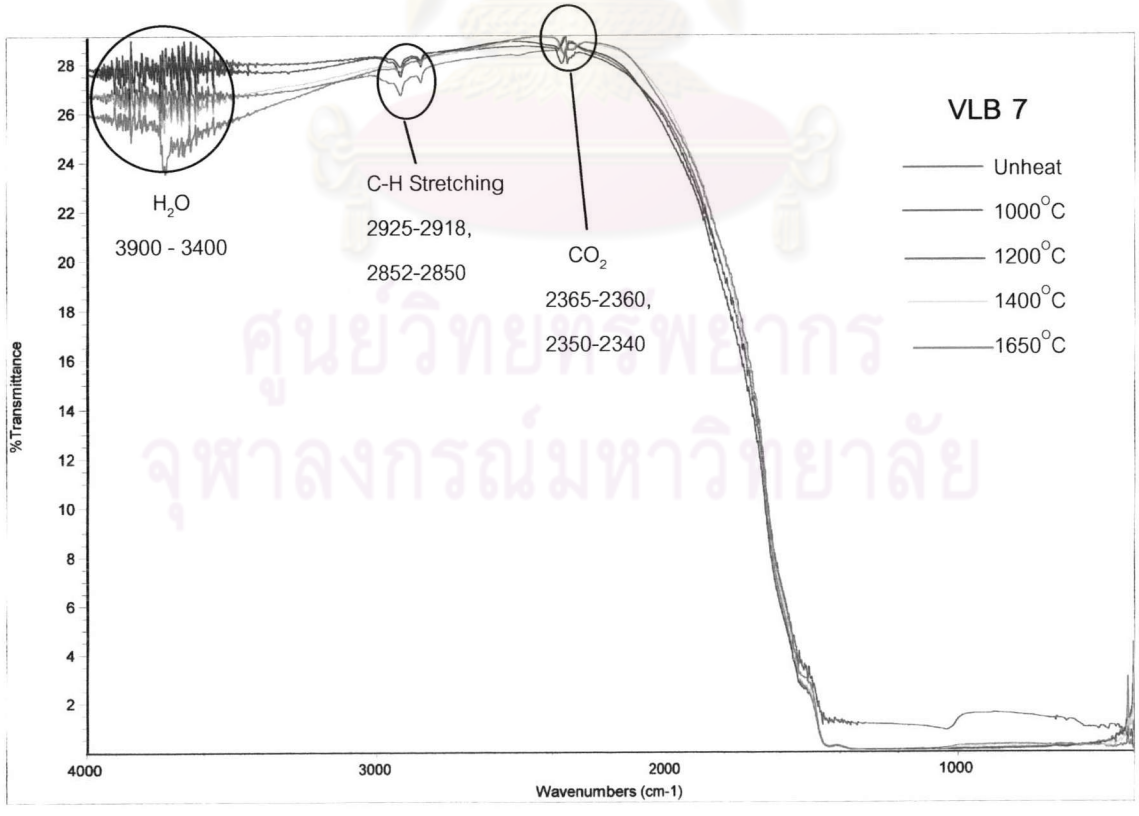


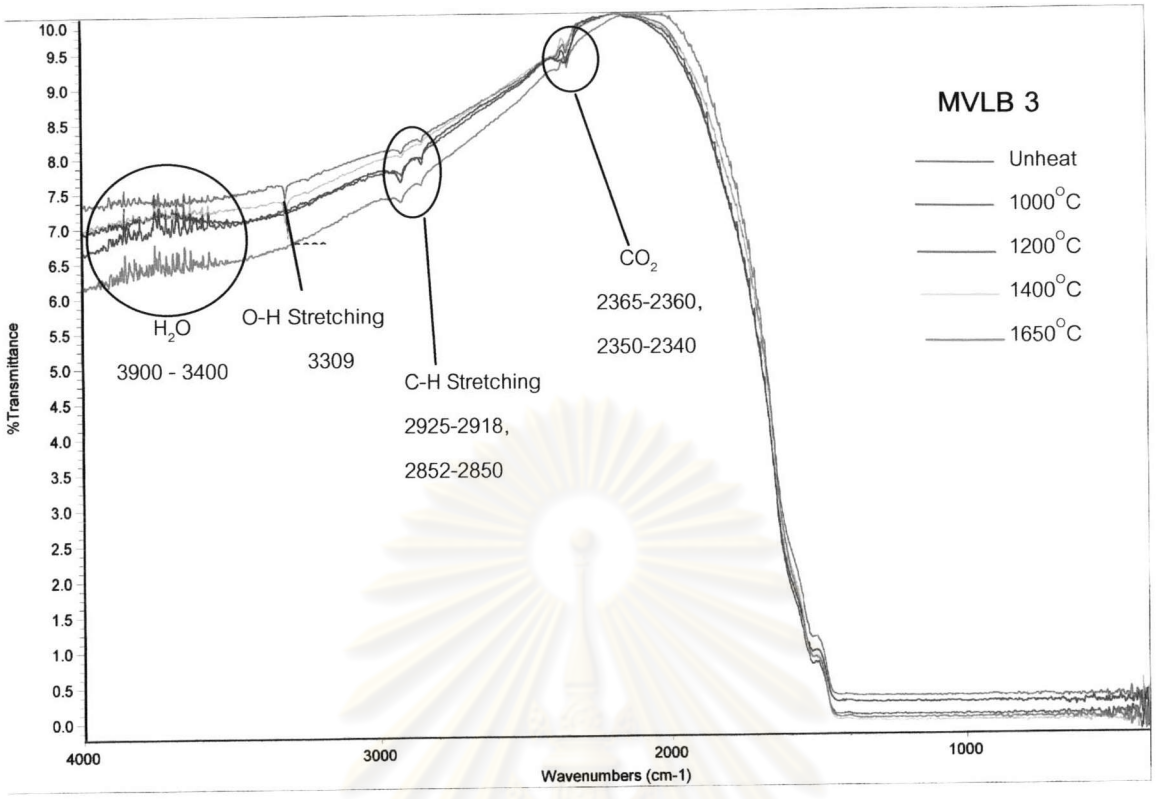


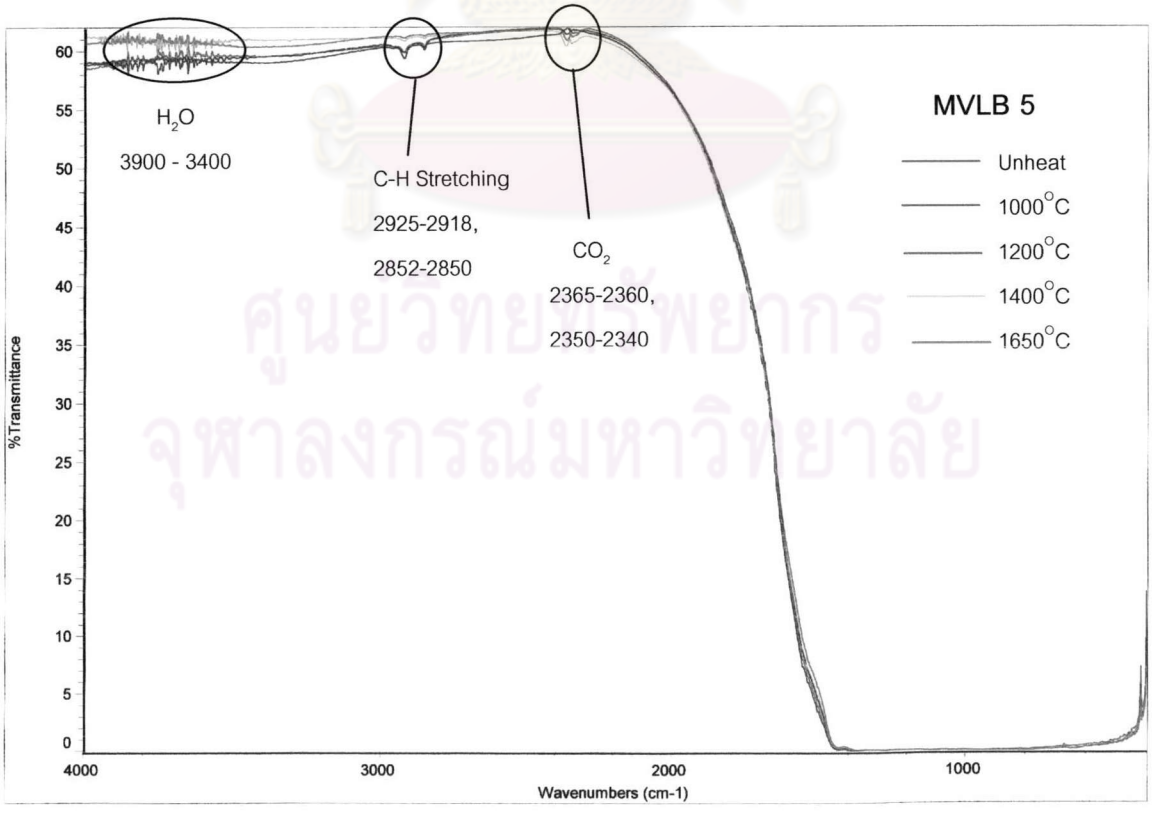


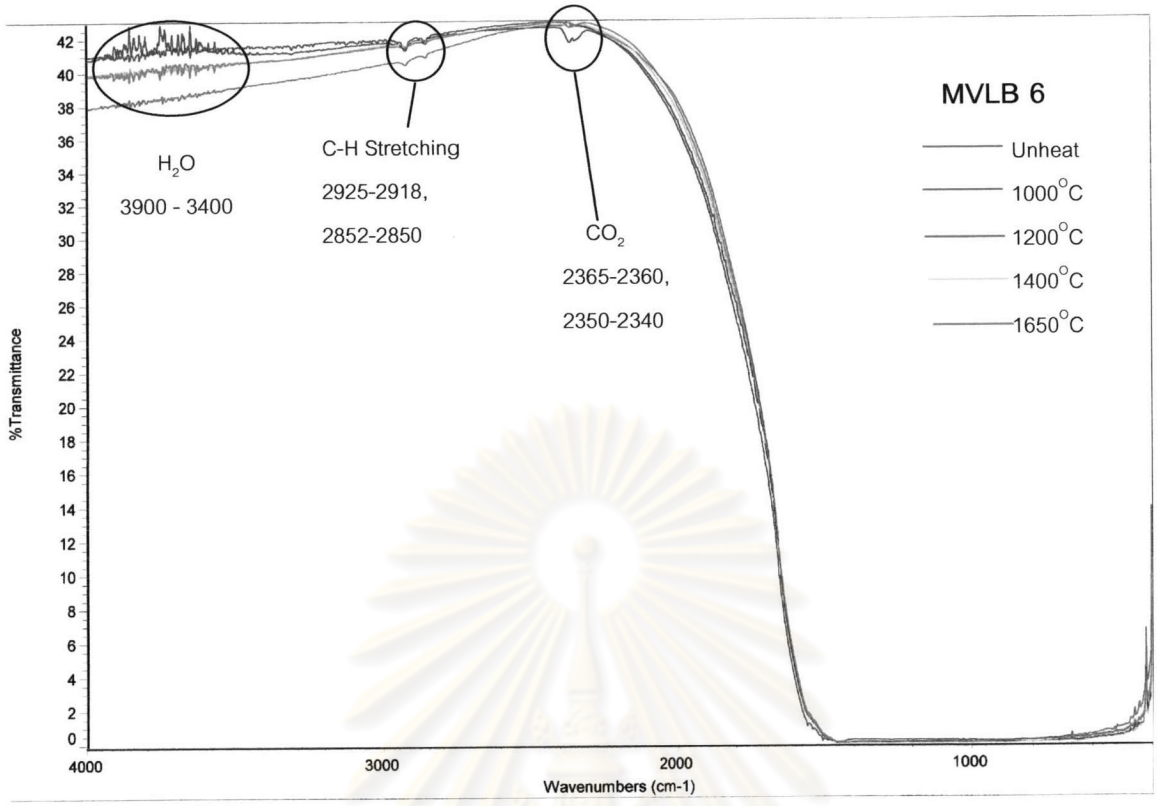


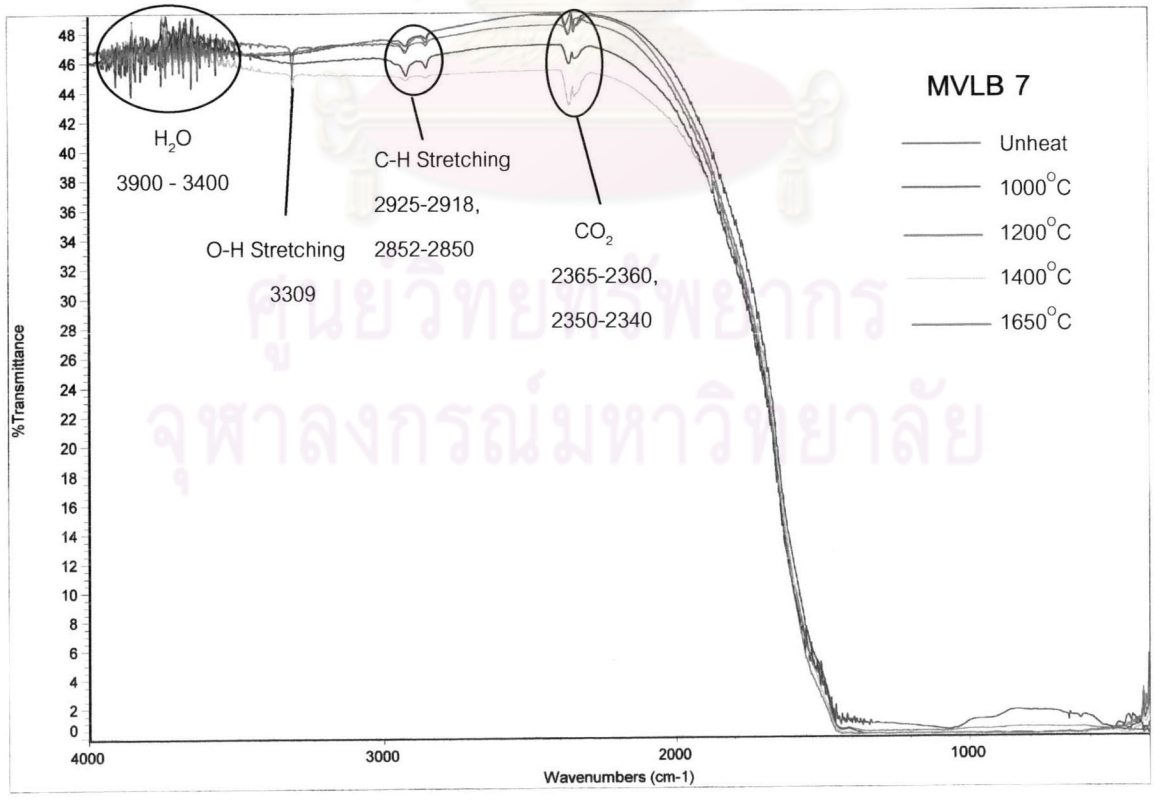


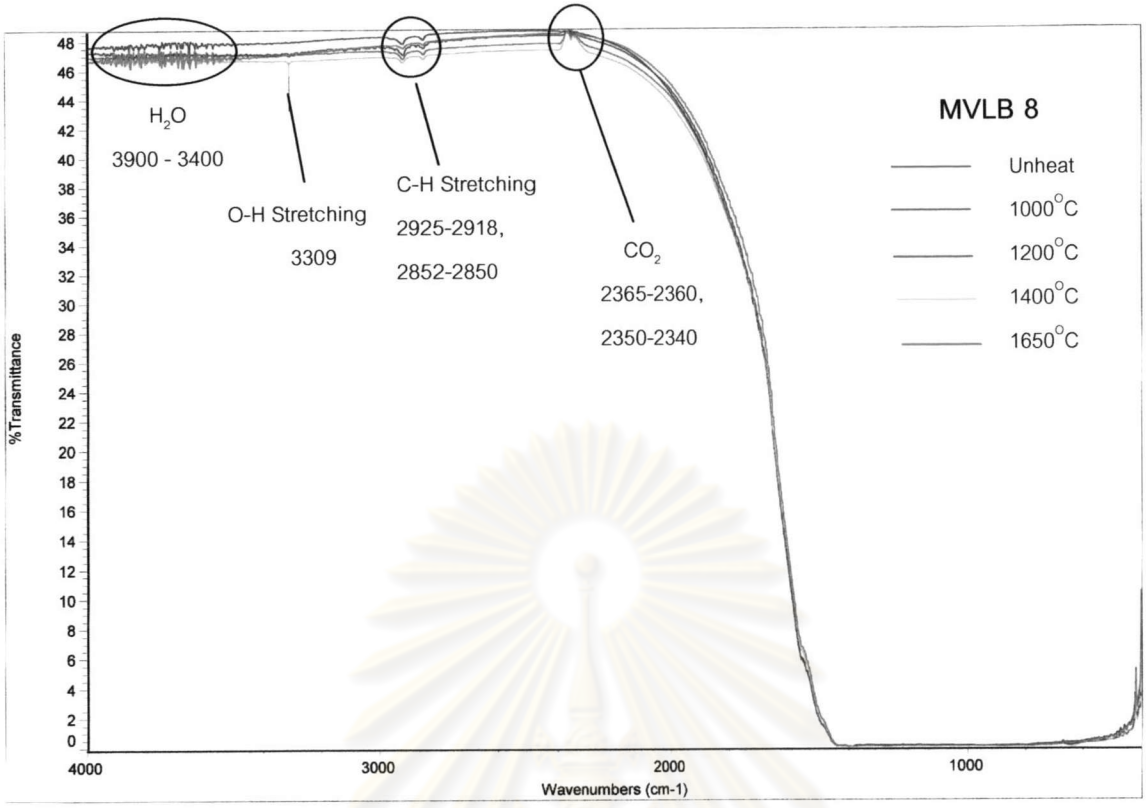


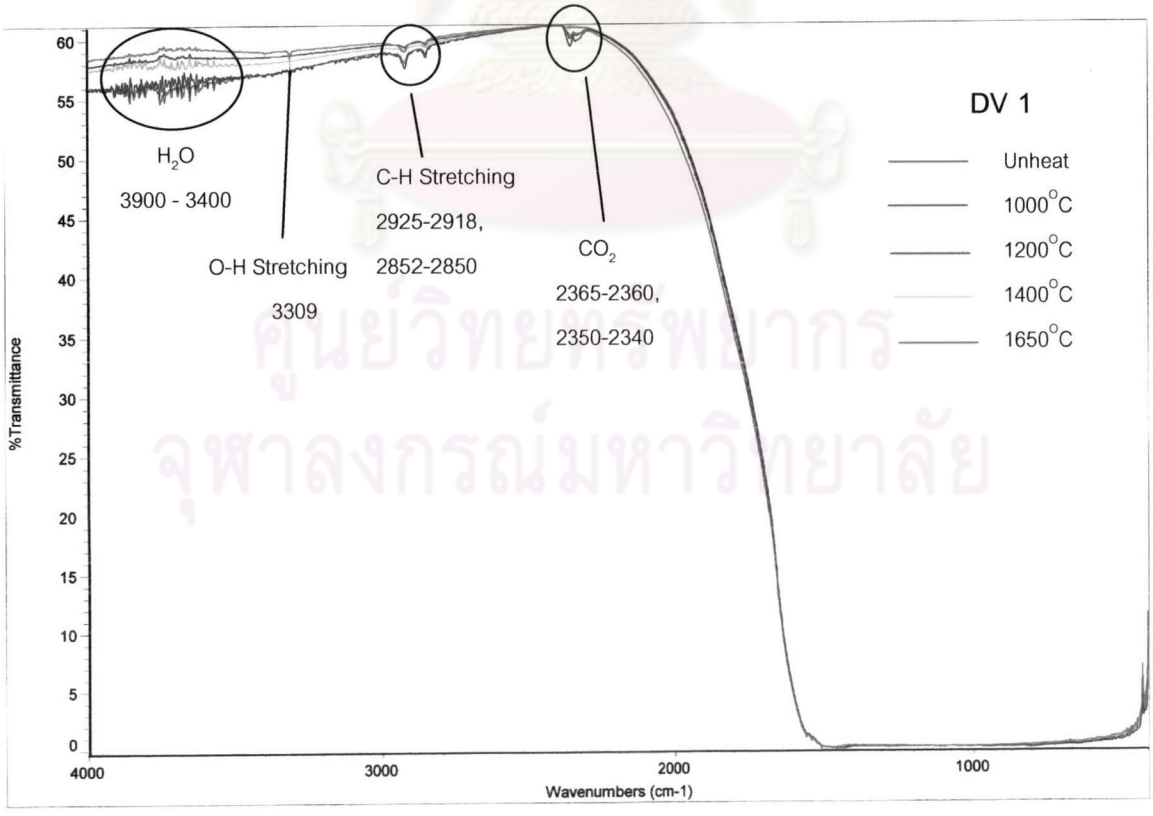


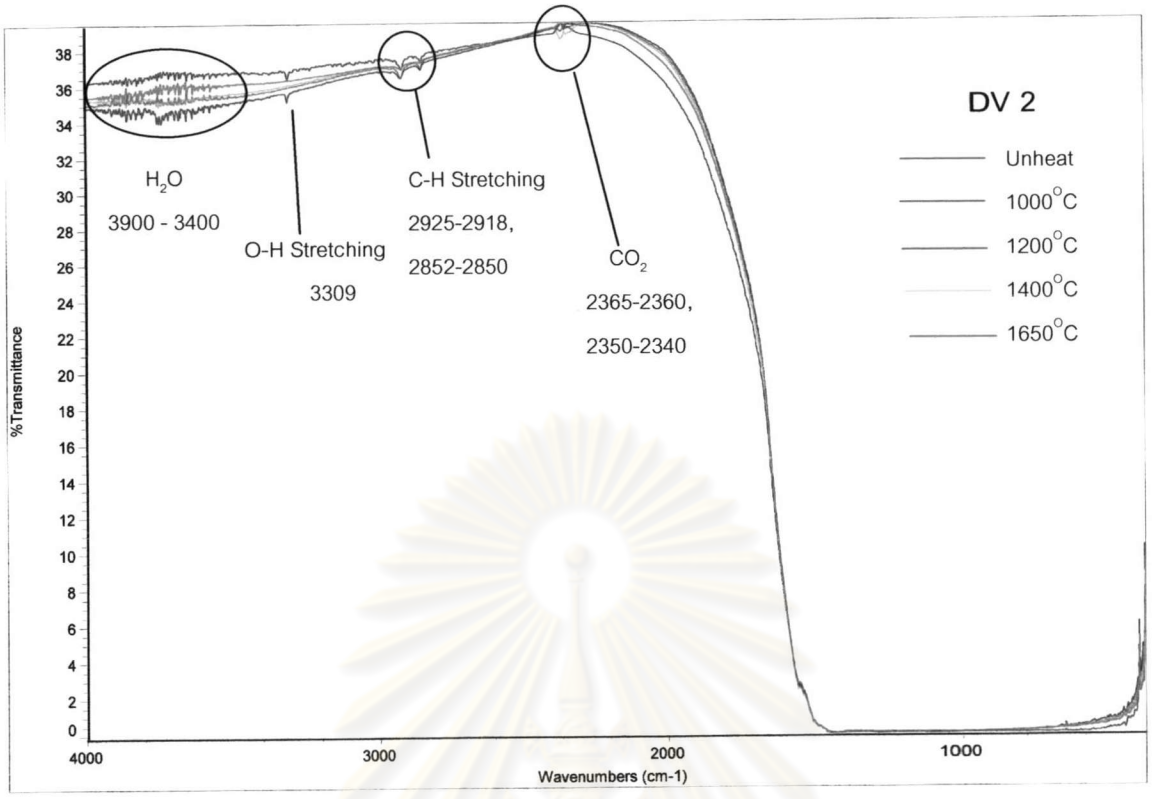


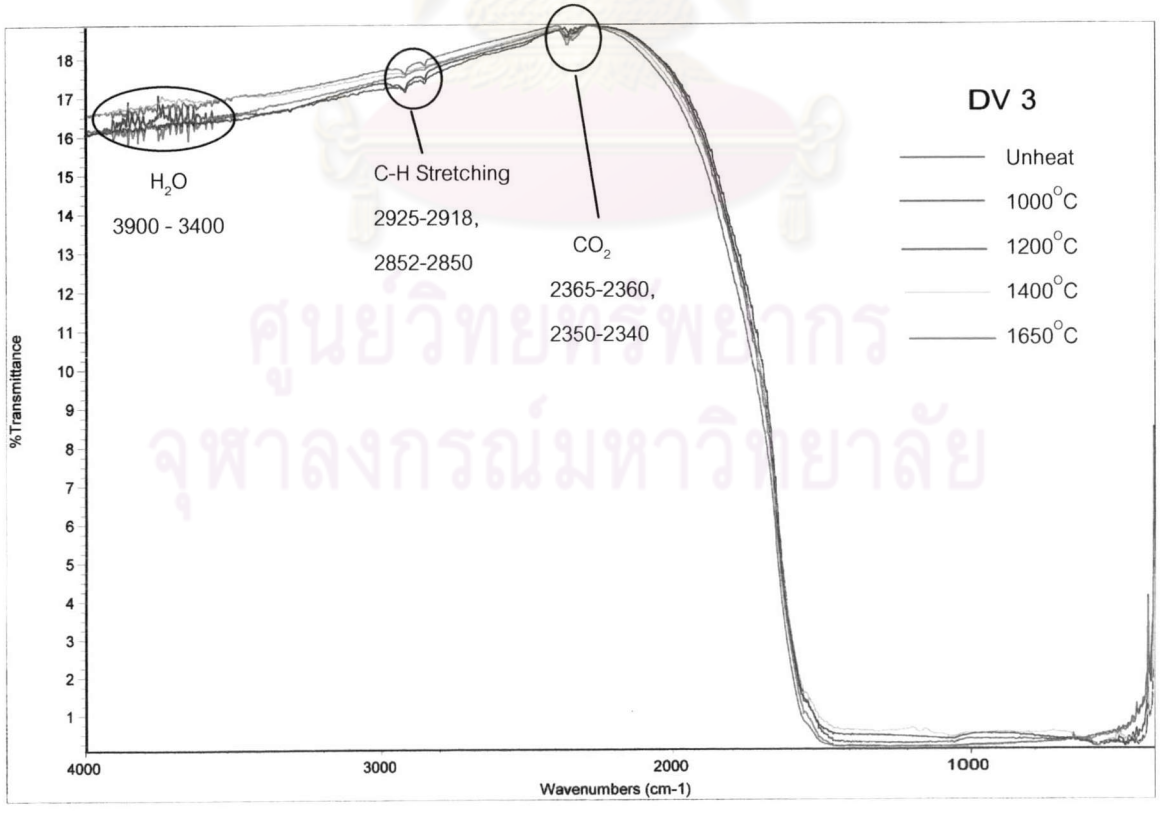


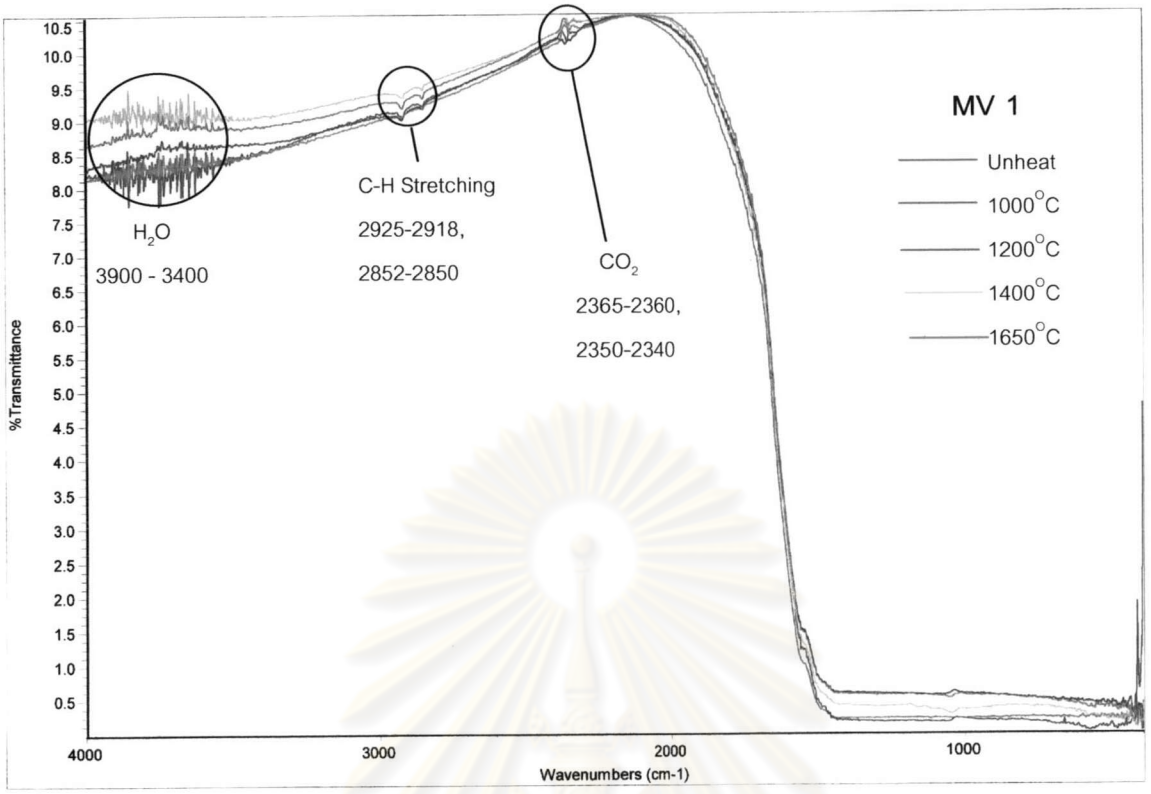


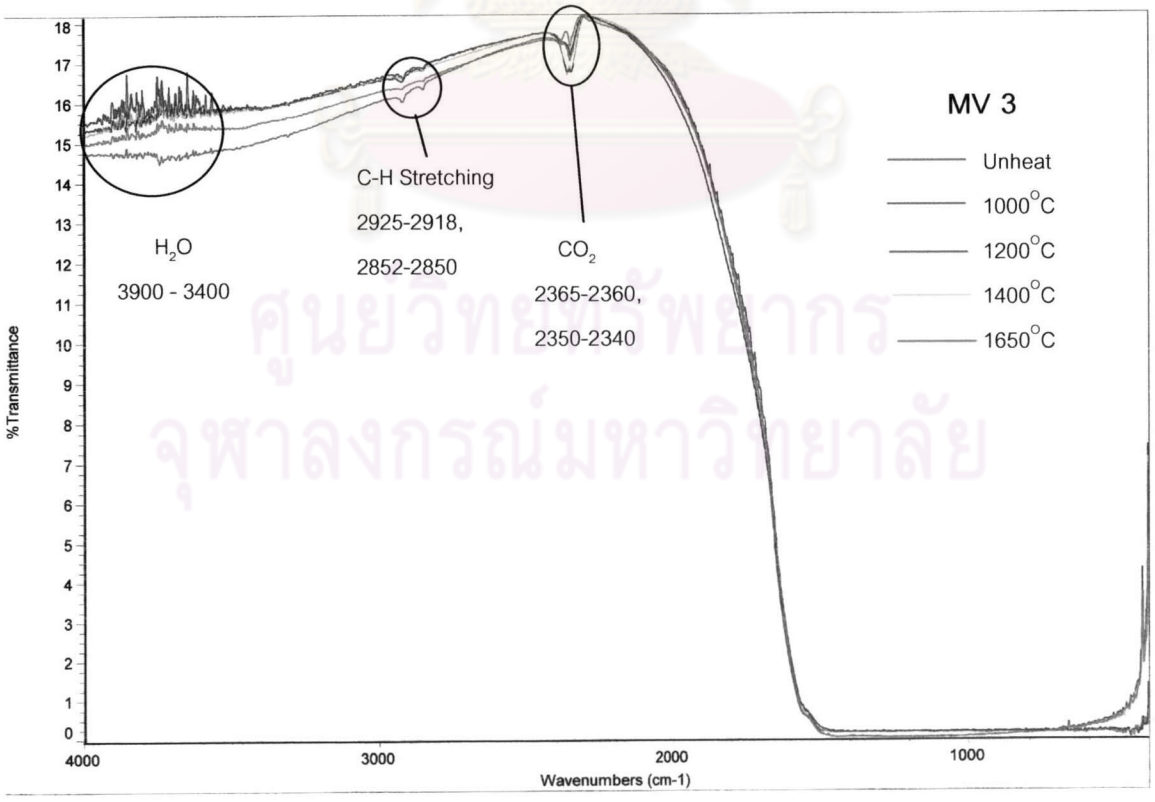


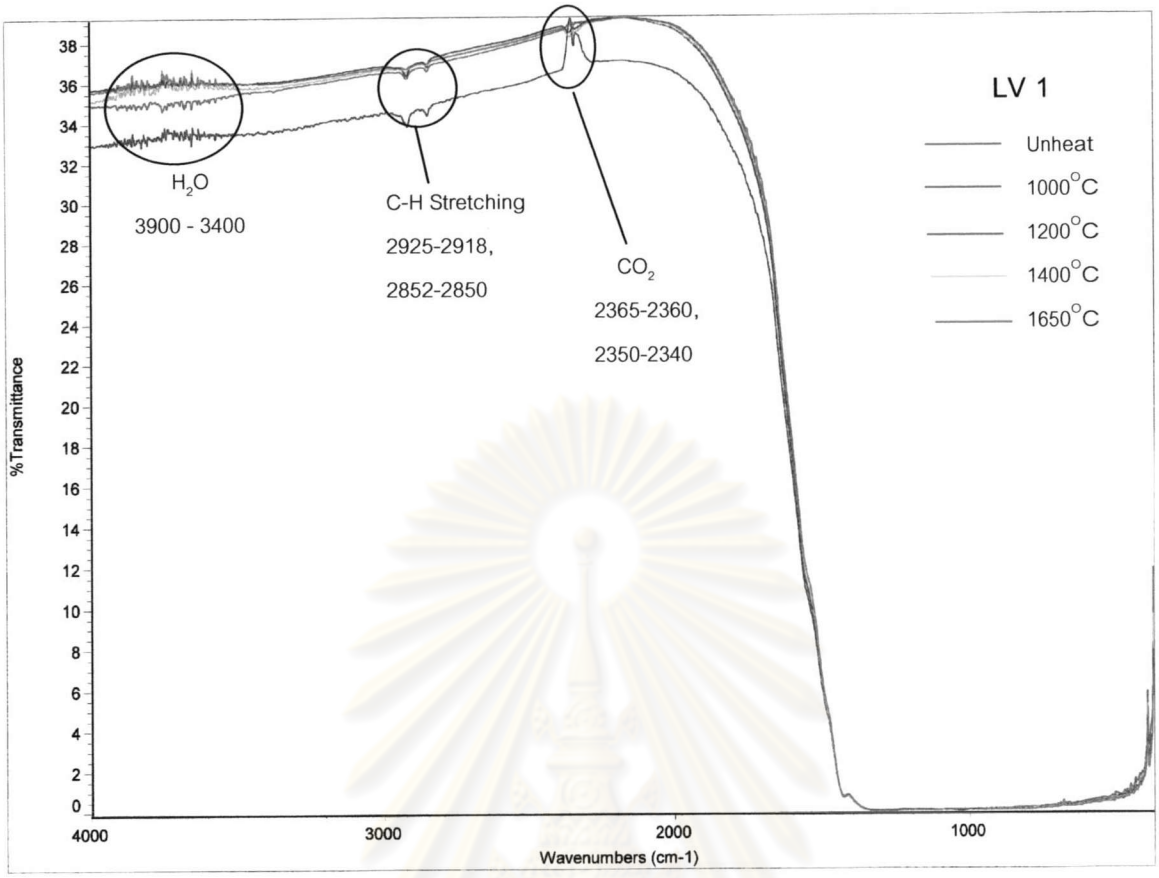


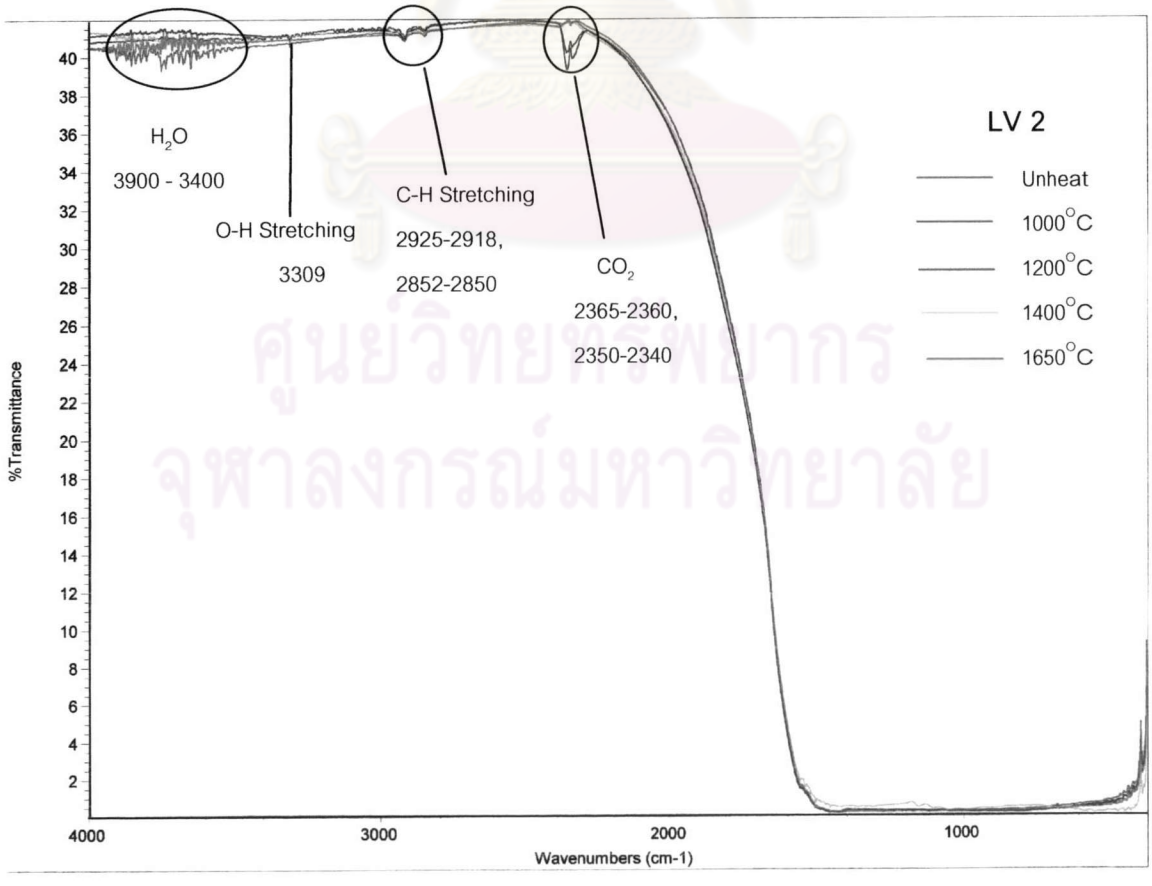


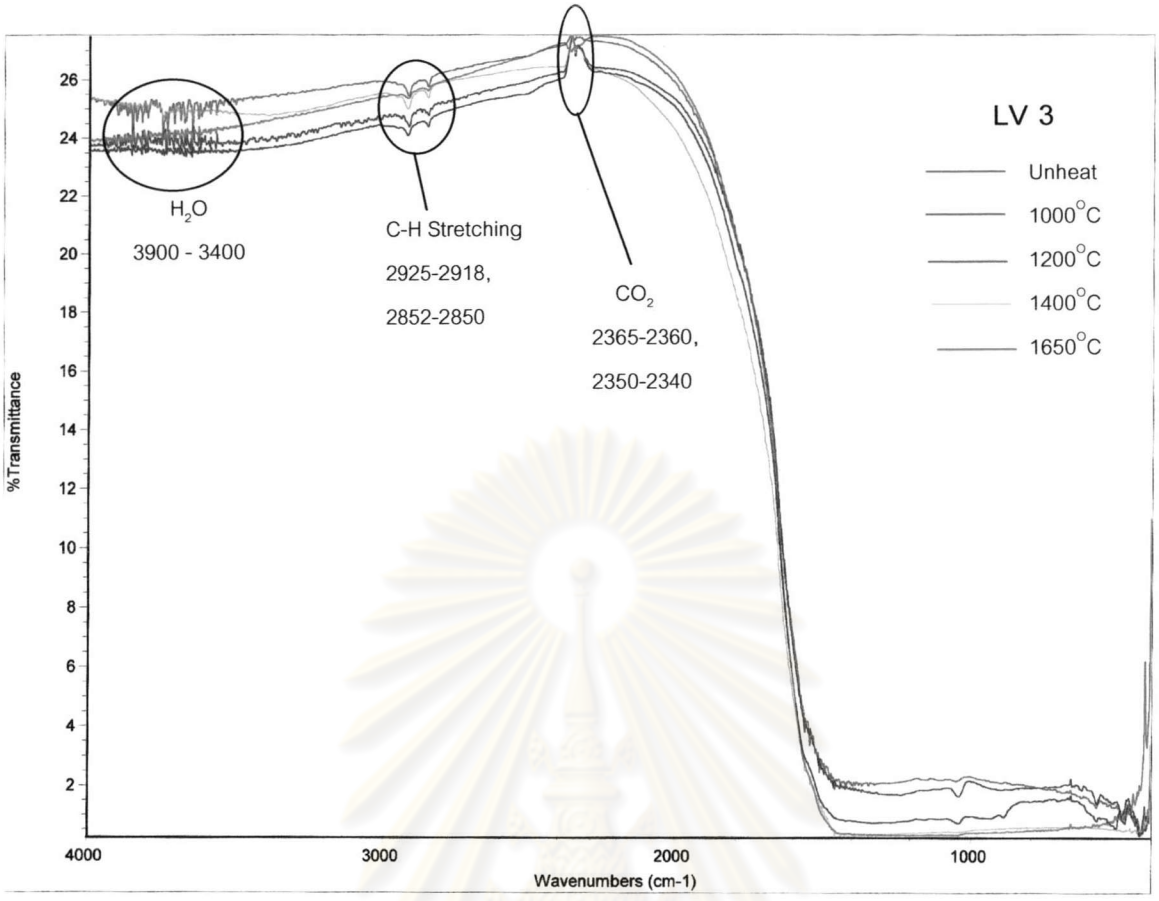












APPENDIX III

UV-VIS-NIR Spectra of sapphires before and after heating

Dark blue: IDB1, IDB 2, IDB 3, IDB 4, IDB 5, IDB 6,
DB 1, DB 2, DB 3, DB 4 and DB5

Medium blue: IMB 1, Imb 2, IMB 3, IMB 4, IMB 5,
MB 1, MB 3, MB 4, MB 6 and MB 9

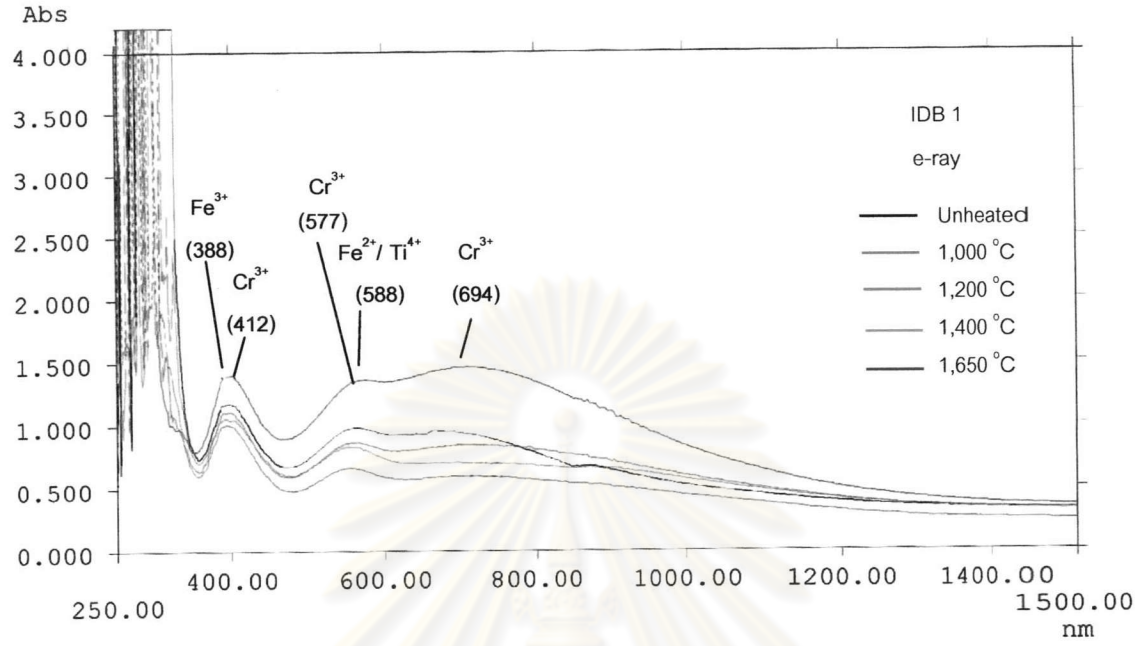
Very light blue: IVLB 1, IVLB 2, IVLB 4, IVLB 5,
VLB 1, VLB 2, VLB 3, VLB 4, VLB 5, VLB 6 and VLB 7

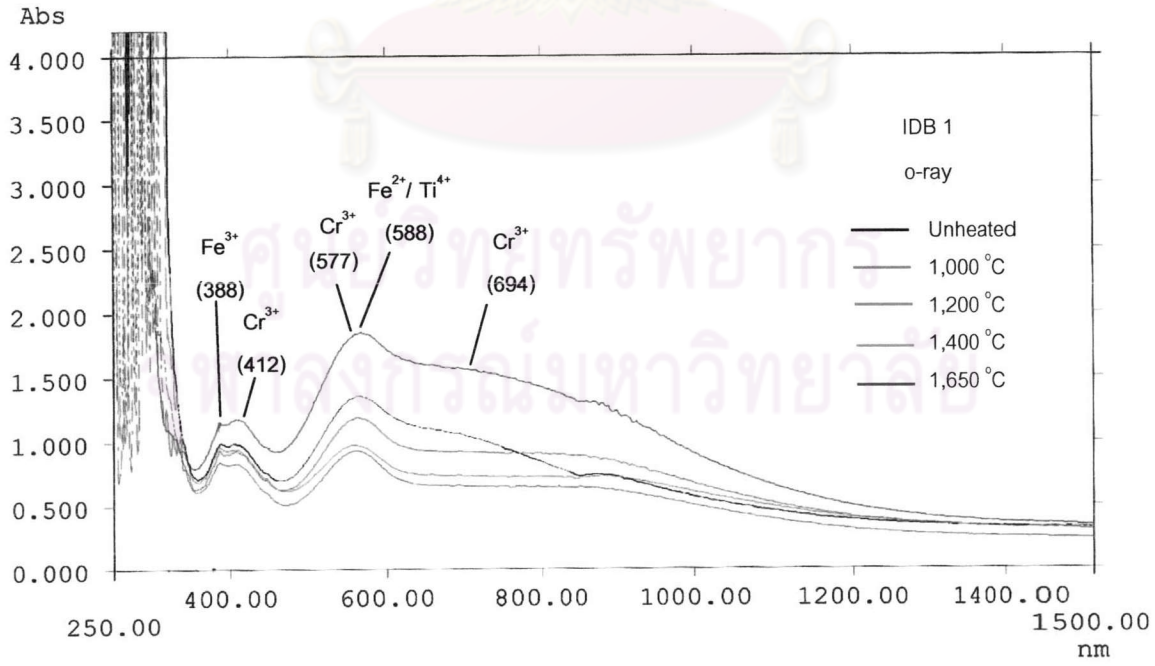
Milky, very light blue: MVLB 3, MVLB 5, MVLB 6, MVLB 7 and MVLB 8

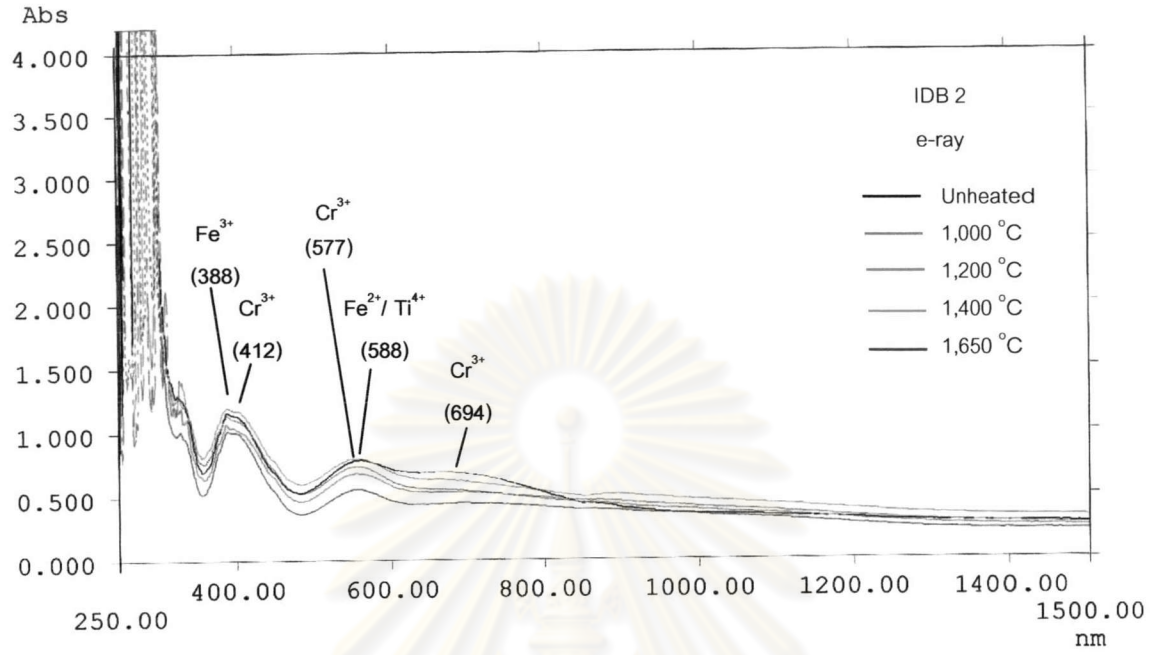
Dark violet: DV 1, DV 2 and DV 3

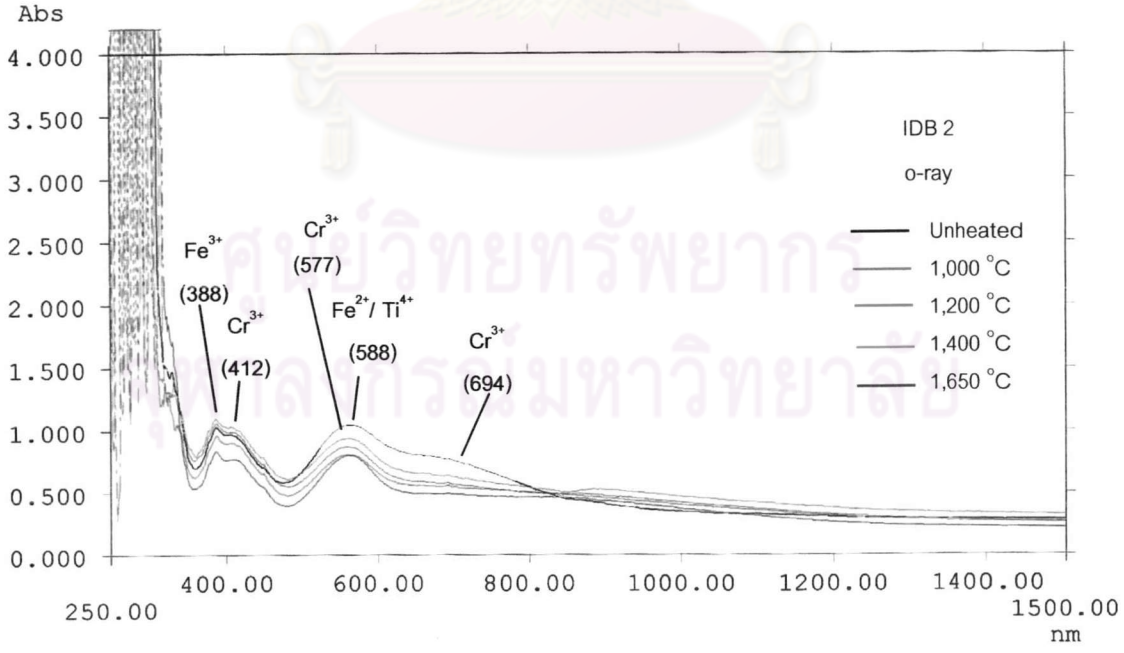
Medium violet: MV1 and MV 3

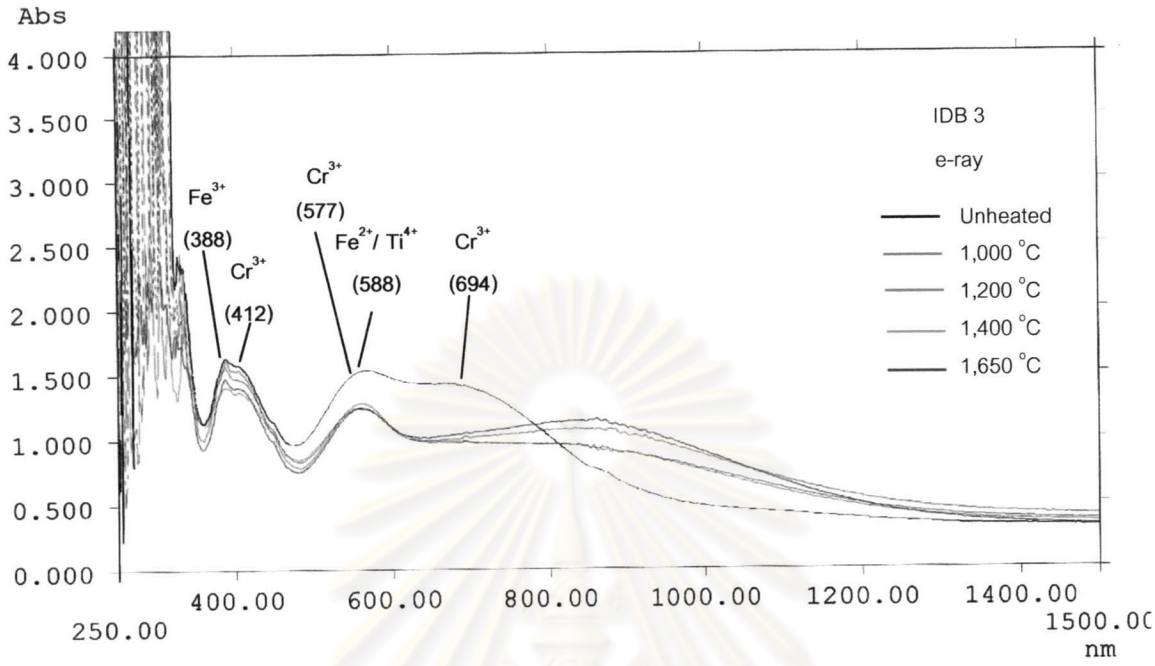
Light violet: LV1 and LV 3

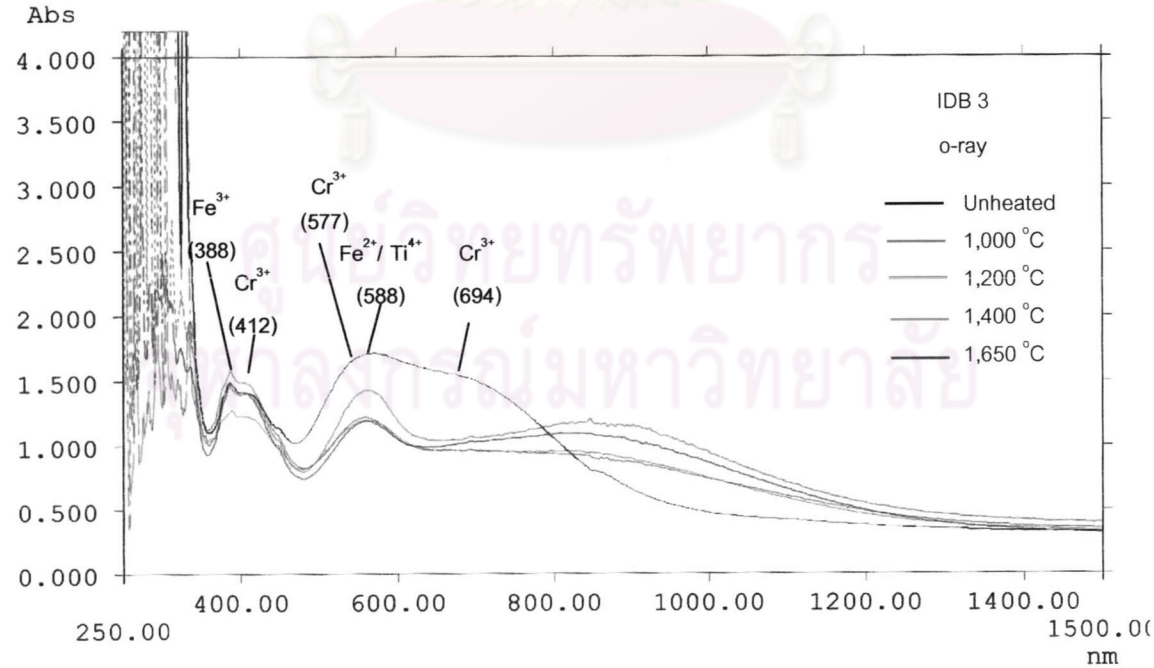

Abs
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
250.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
1500.00
nm
IDB 1
e-ray
Unheated
1,000 °C
1,200 °C
1,400 °C
1,650 °C
Fe3+
(388)
Cr3+
(412)
Cr3+
(577)
Fe2+/ Ti4+
(588)
Cr3+
(694)

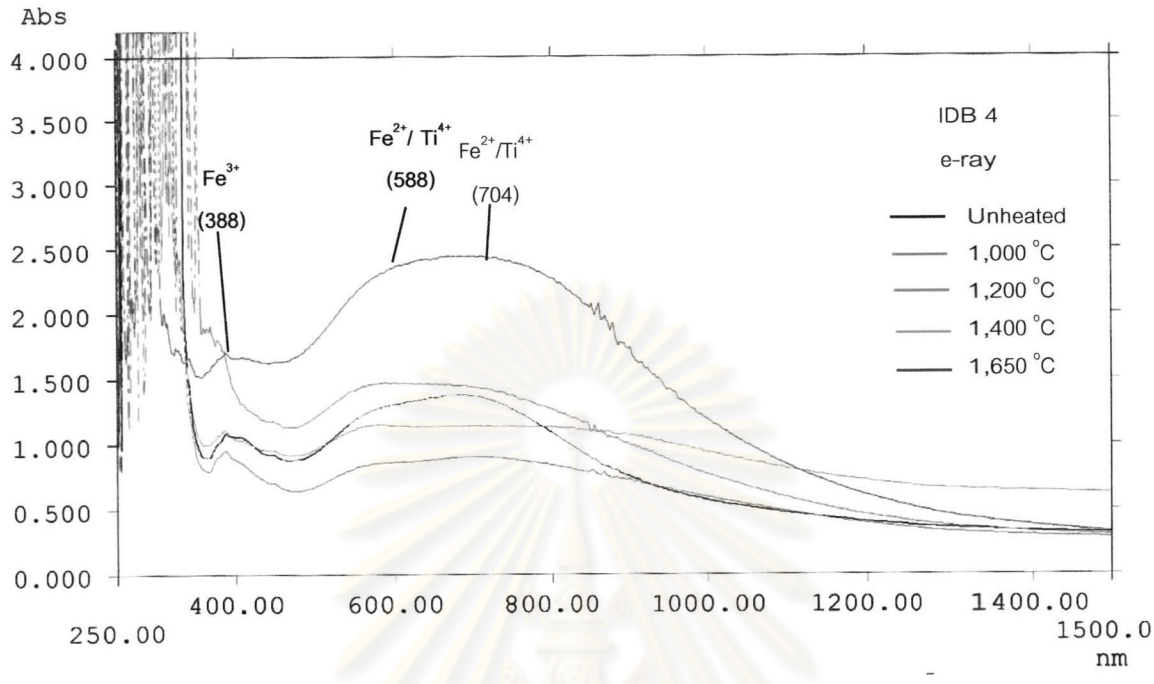

Abs
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
250.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
1500.00
nm
IDB 1
o-ray
Unheated
1,000 °C
1,200 °C
1,400 °C
1,650 °C
Fe3+
(388)
Cr3+
(412)
Cr3+
(577)
Fe2+/ Ti4+
(588)
Cr3+
(694)

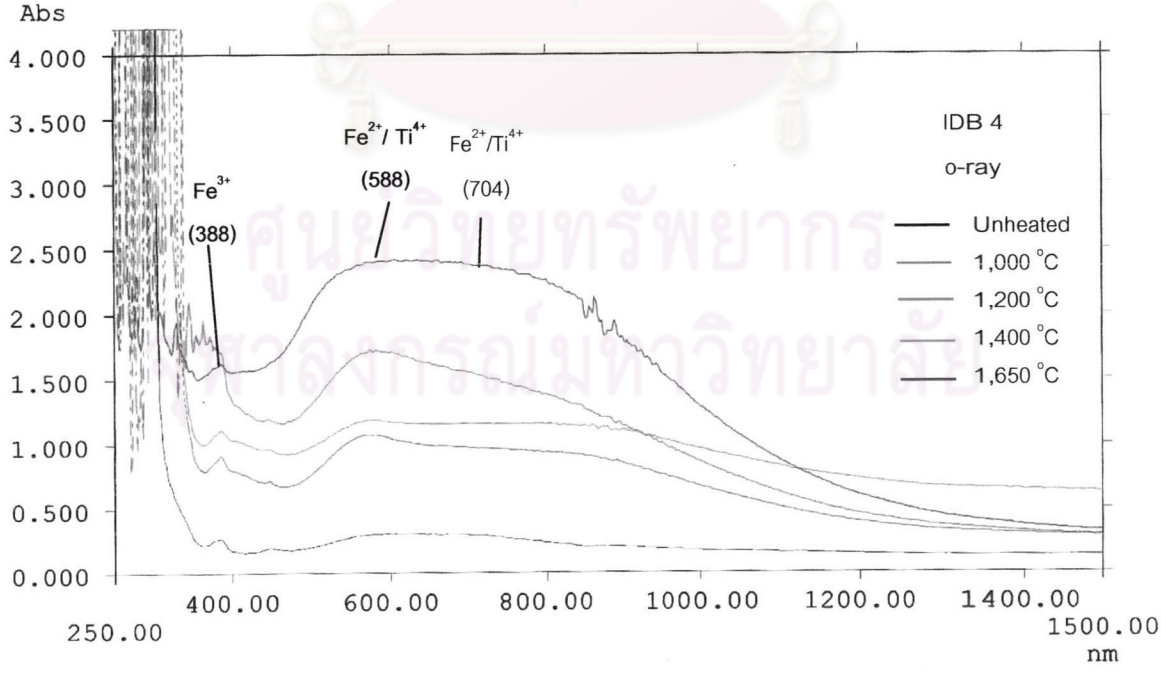


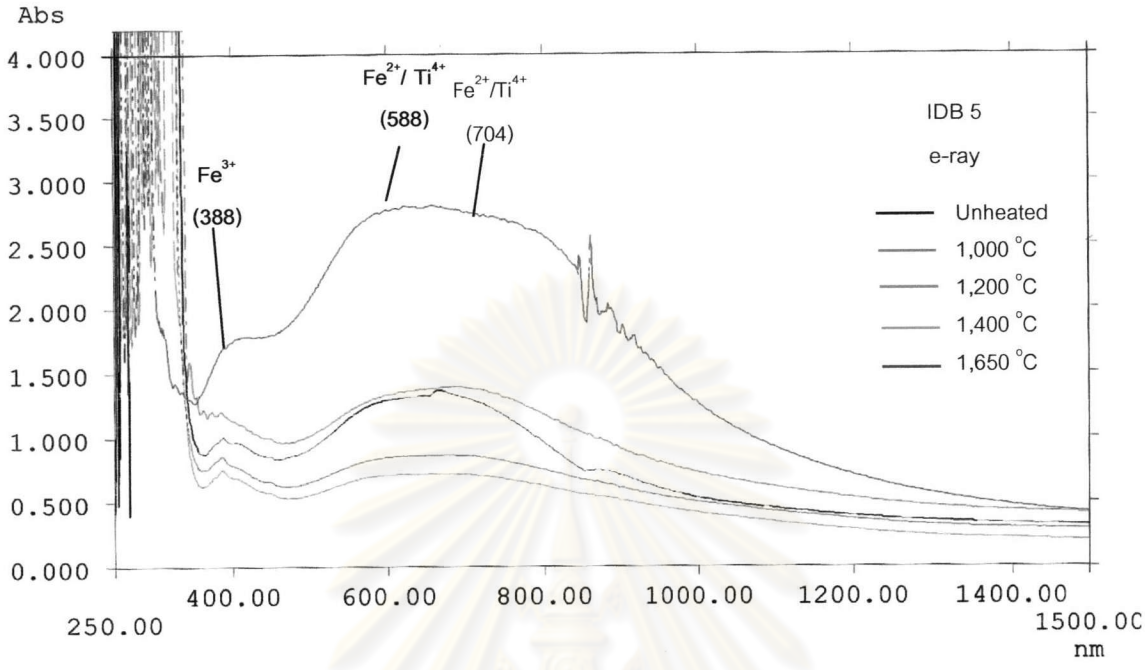


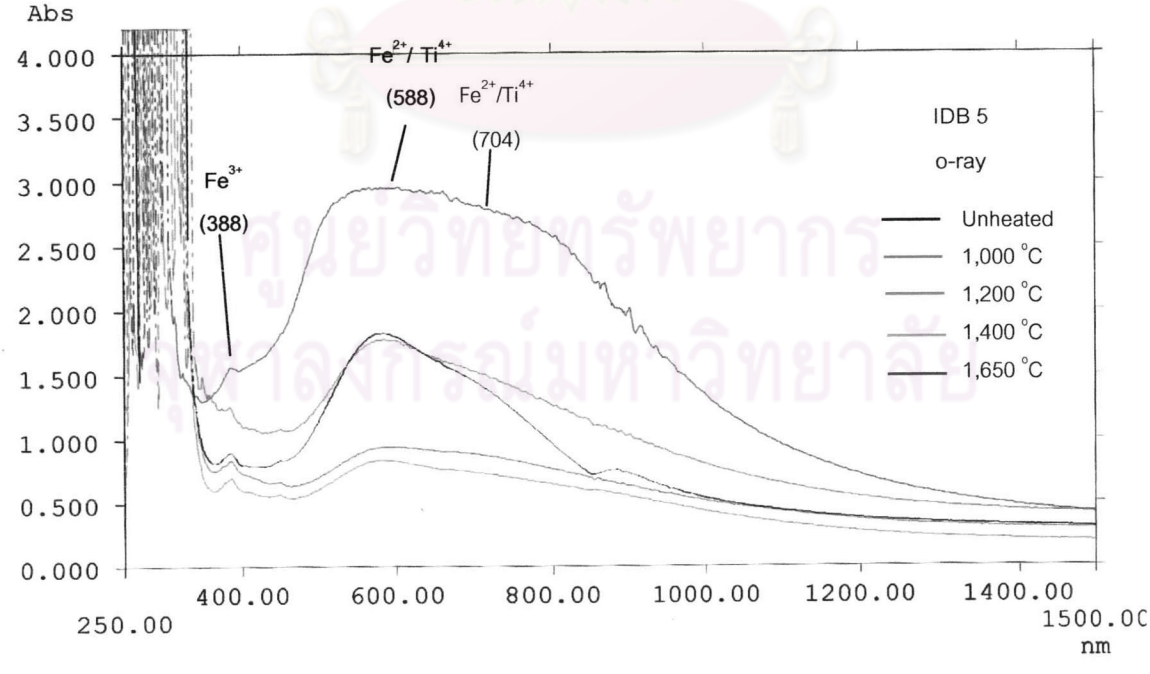


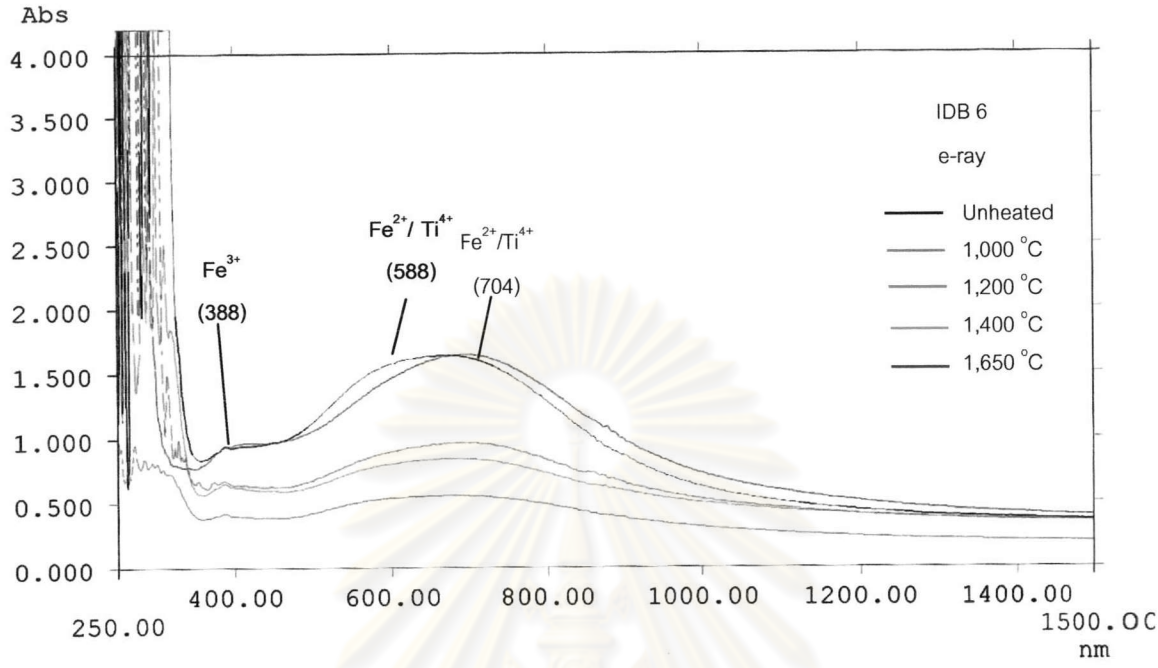


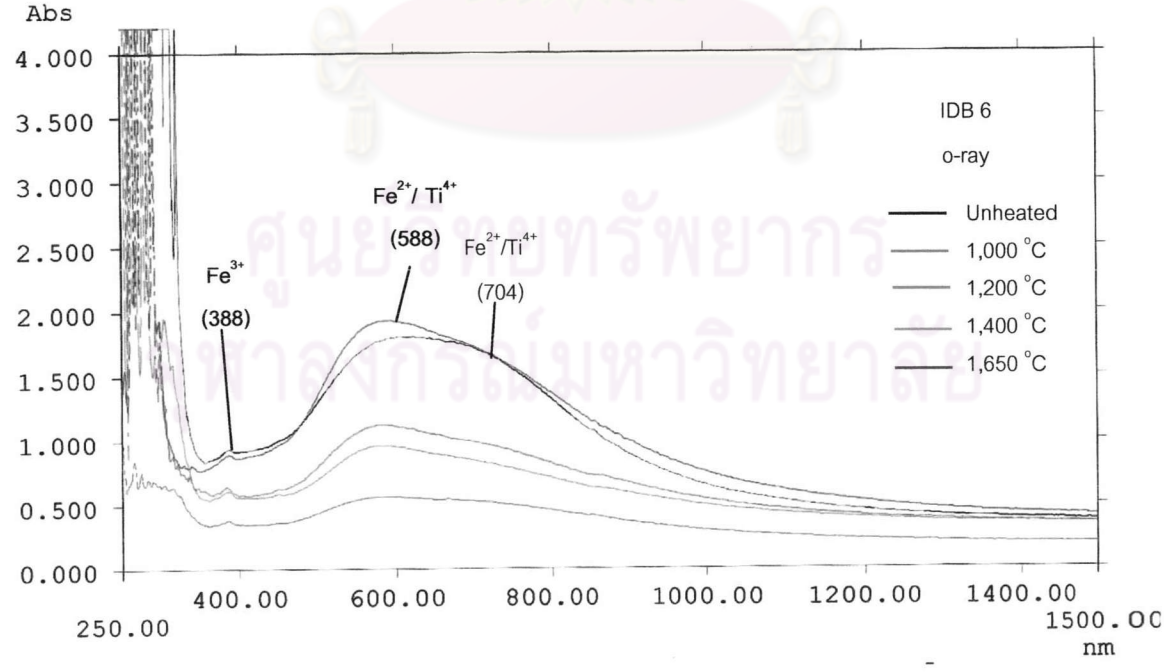


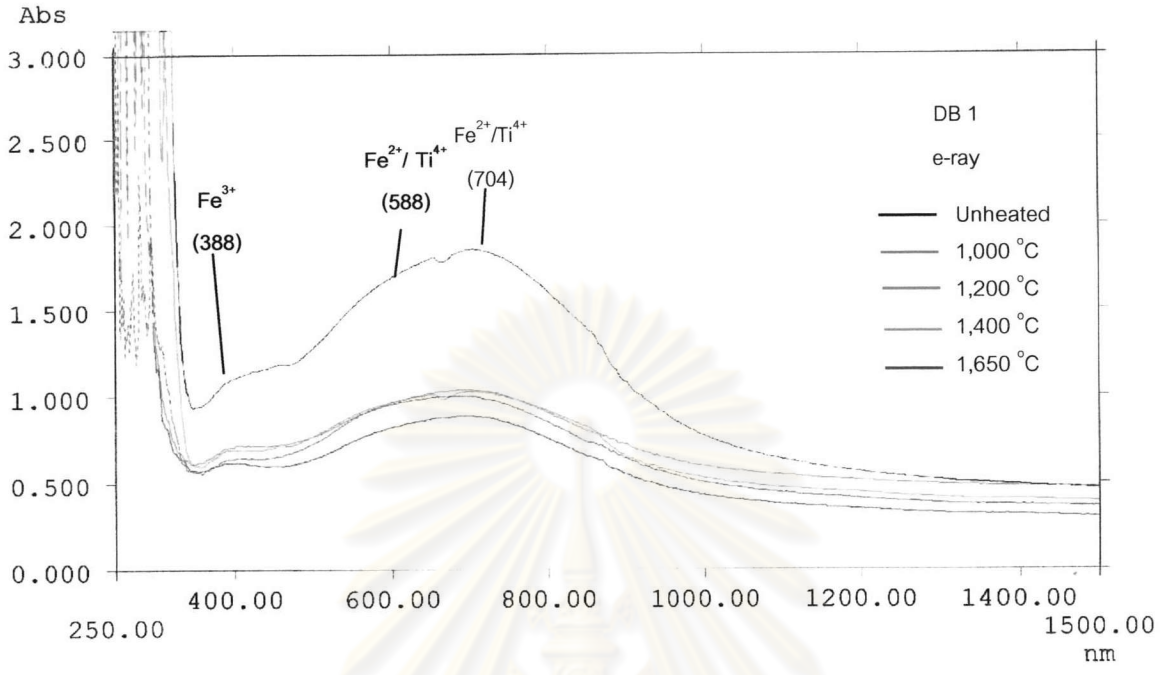


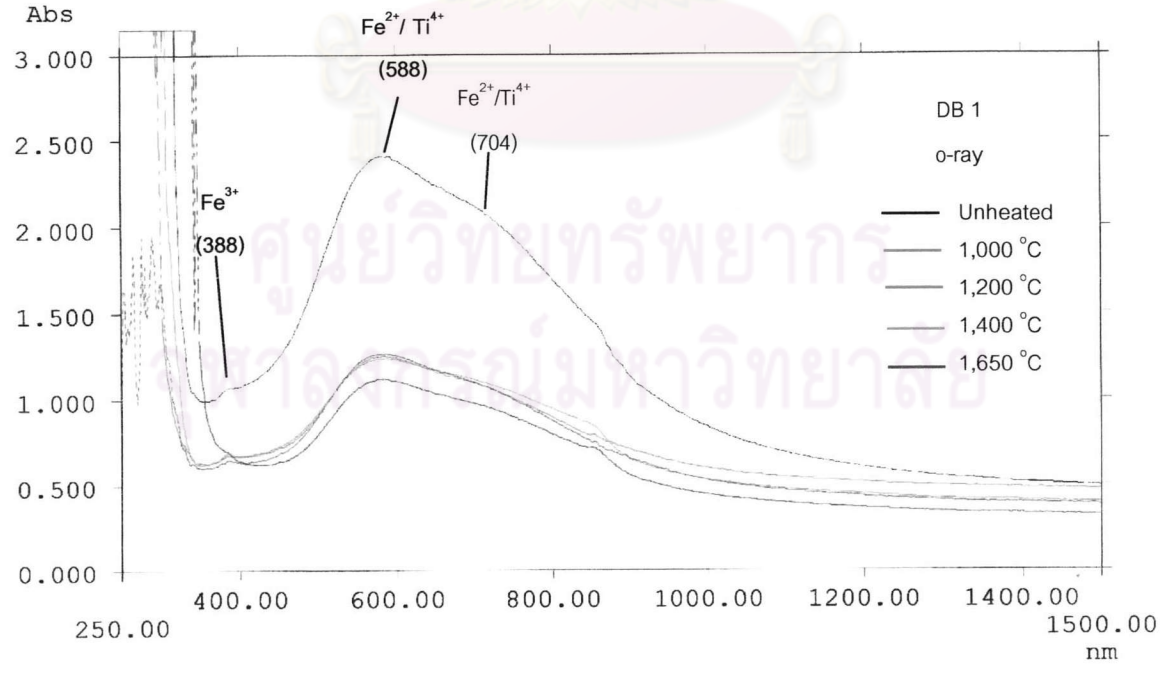

Abs
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
Fe2+/ Ti4+
(588)
Fe2+/Ti4+
(704)
Fe3+
(388)
IDB 5
e-ray
Unheated
1,000 °C
1,200 °C
1,400 °C
1,650 °C
250.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
1500.00
nm

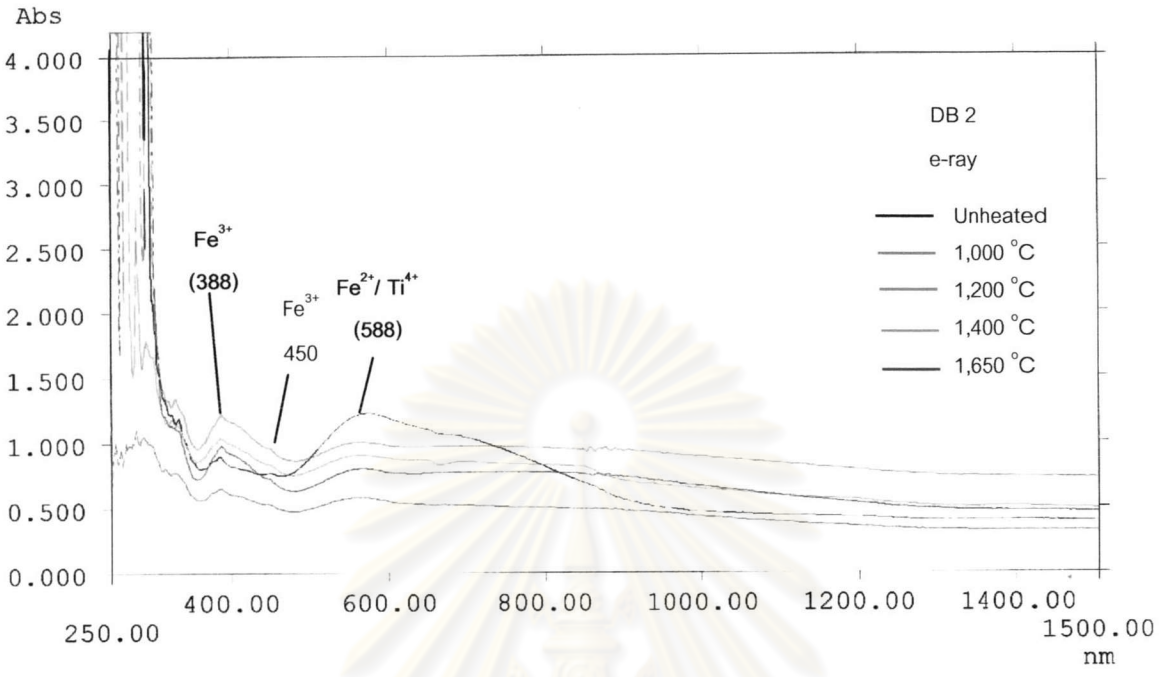

Abs
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
Fe2+/ Ti4+
(588)
Fe2+/Ti4+
(704)
Fe3+
(388)
IDB 5
o-ray
Unheated
1,000 °C
1,200 °C
1,400 °C
1,650 °C
250.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
1500.00
nm

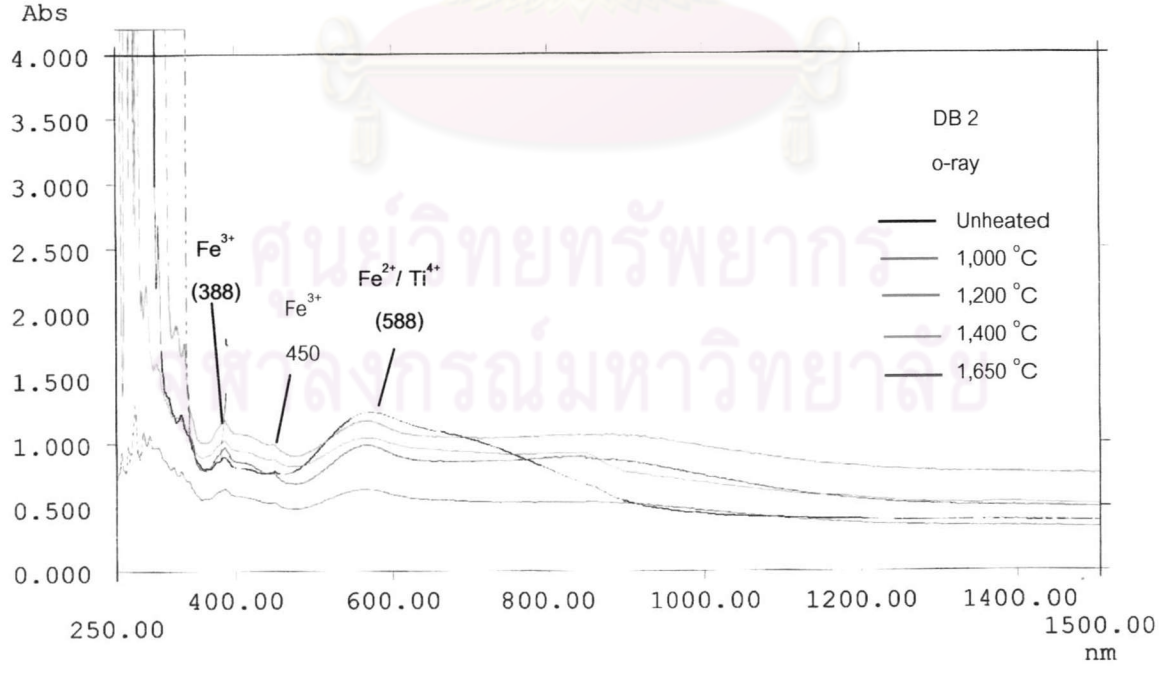


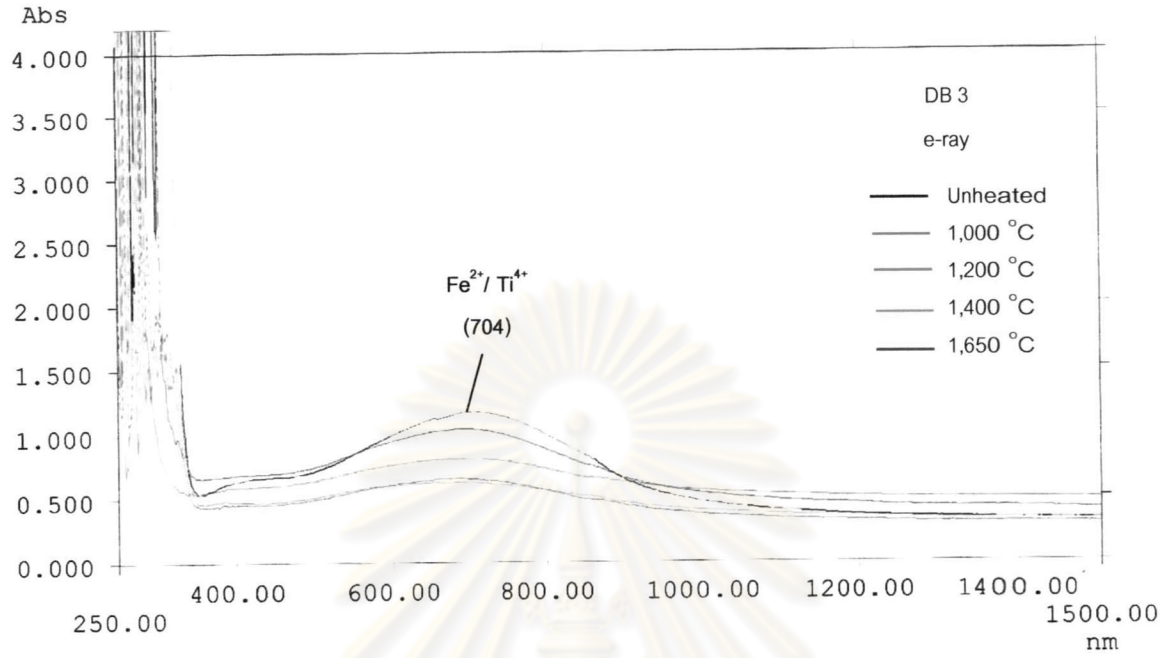


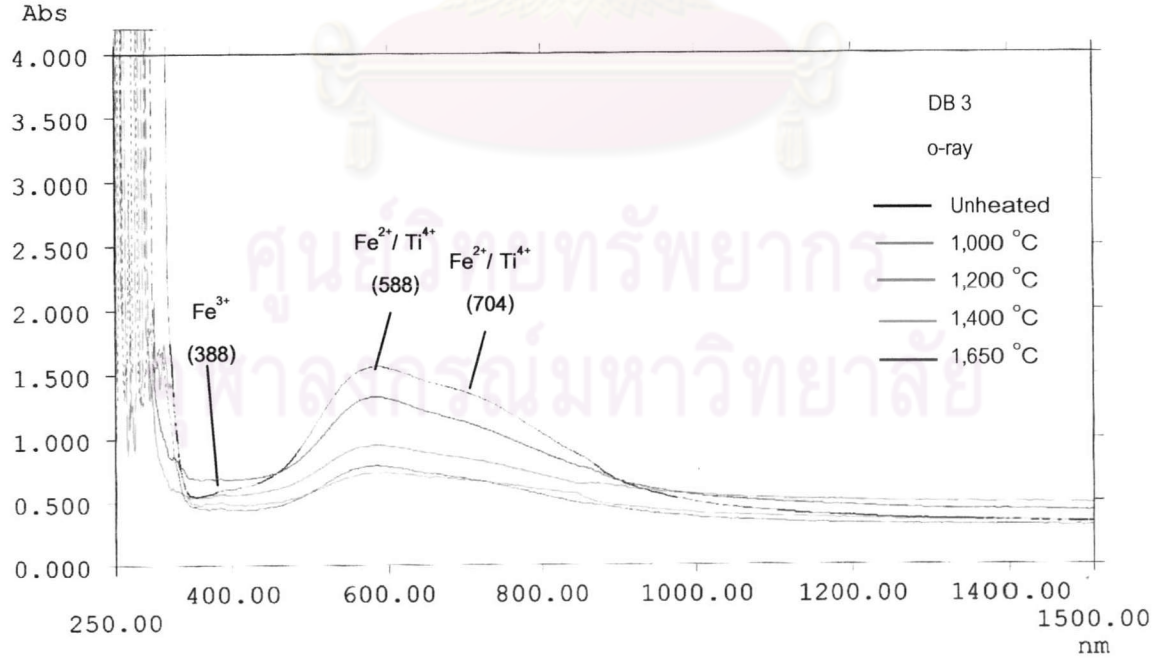

Abs
3.000
2.500
2.000
1.500
1.000
0.500
0.000
Fe3+
(388)
Fe2+/ Ti4+
(588)
Fe2+/Ti4+
(704)
DB 1
e-ray
Unheated
1,000 °C
1,200 °C
1,400 °C
1,650 °C
250.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
1500.00
nm

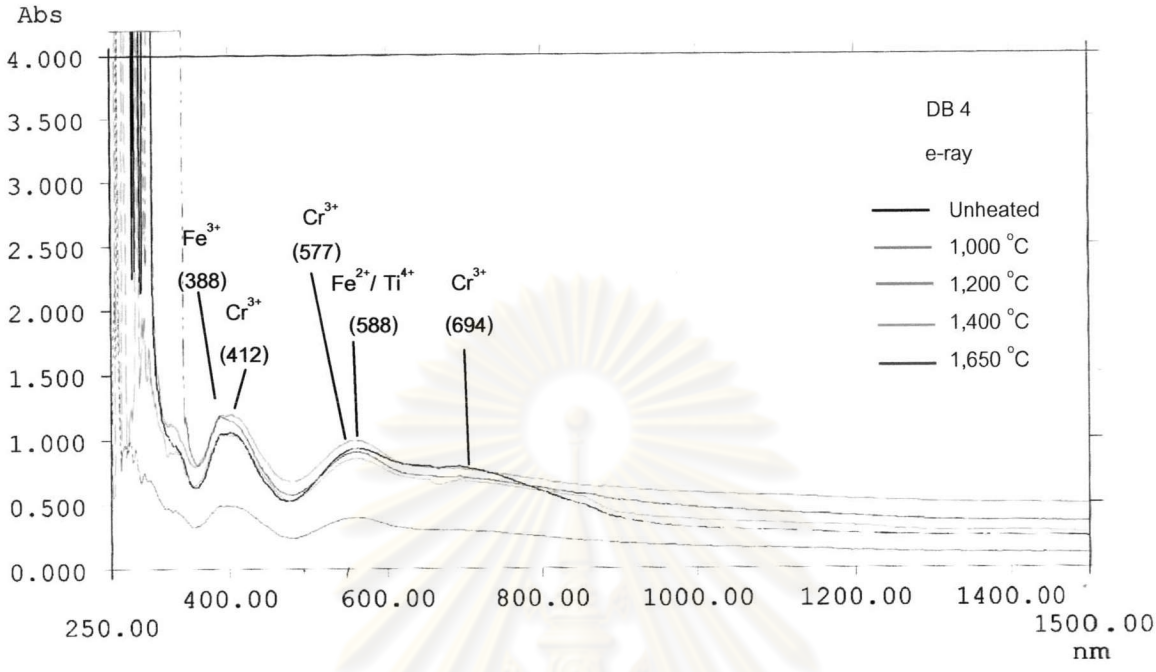

Abs
3.000
2.500
2.000
1.500
1.000
0.500
0.000
Fe2+/ Ti4+
(588)
Fe2+/Ti4+
(704)
Fe3+
(388)
DB 1
o-ray
Unheated
1,000 °C
1,200 °C
1,400 °C
1,650 °C
250.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
1500.00
nm

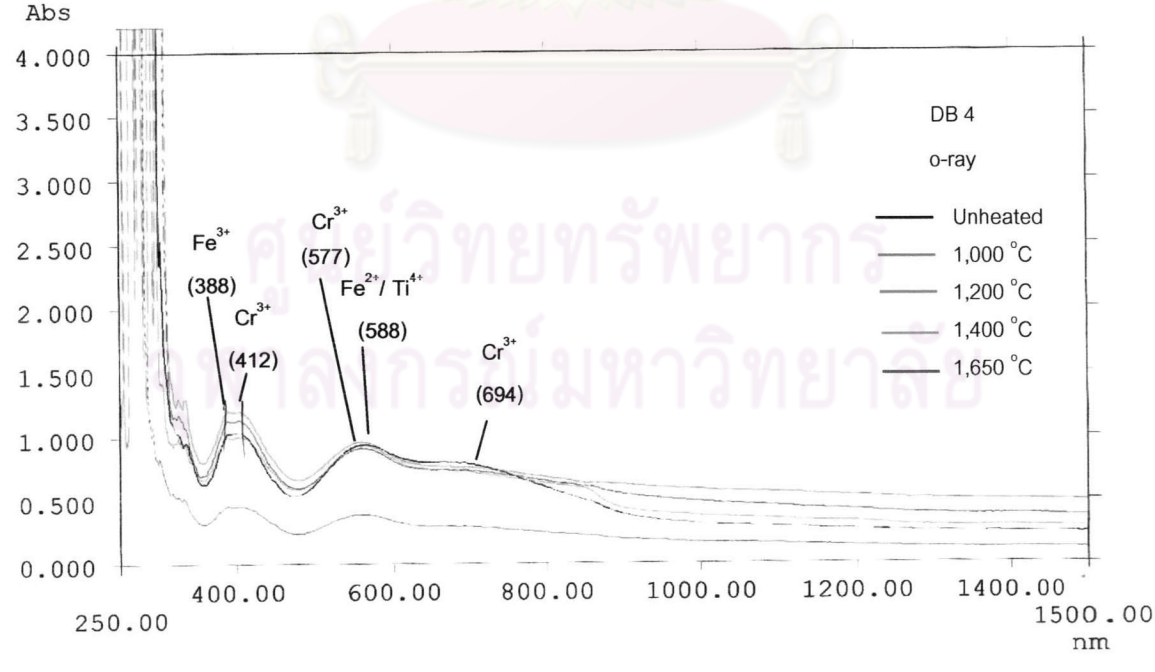


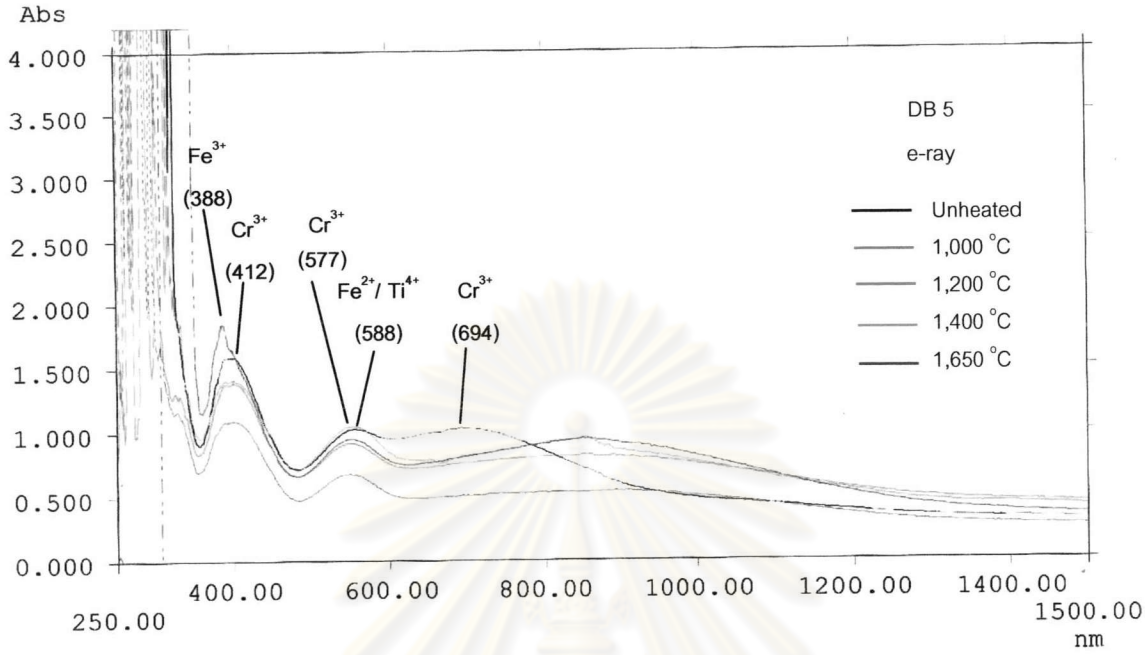


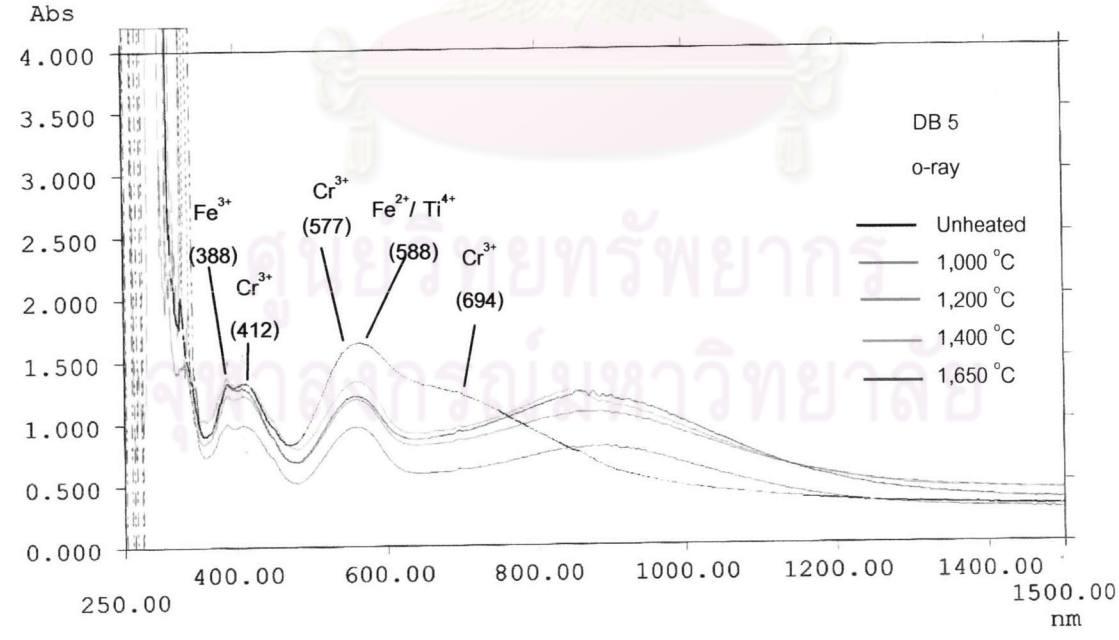

Abs
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
250.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
1500.00
nm
DB 3
e-ray
Unheated
1,000 °C
1,200 °C
1,400 °C
1,650 °C
Fe2+/ Ti4+
(704)

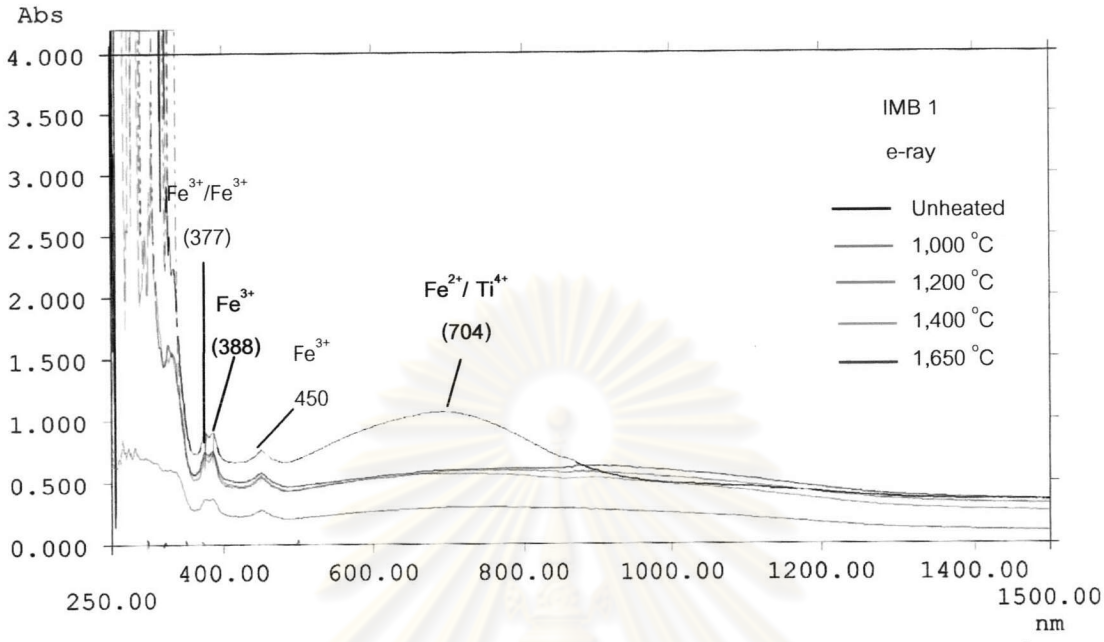

Abs
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
250.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
1500.00
nm
DB 3
o-ray
Unheated
1,000 °C
1,200 °C
1,400 °C
1,650 °C
Fe3+
(388)
Fe2+/ Ti4+
(588)
Fe2+/ Ti4+
(704)

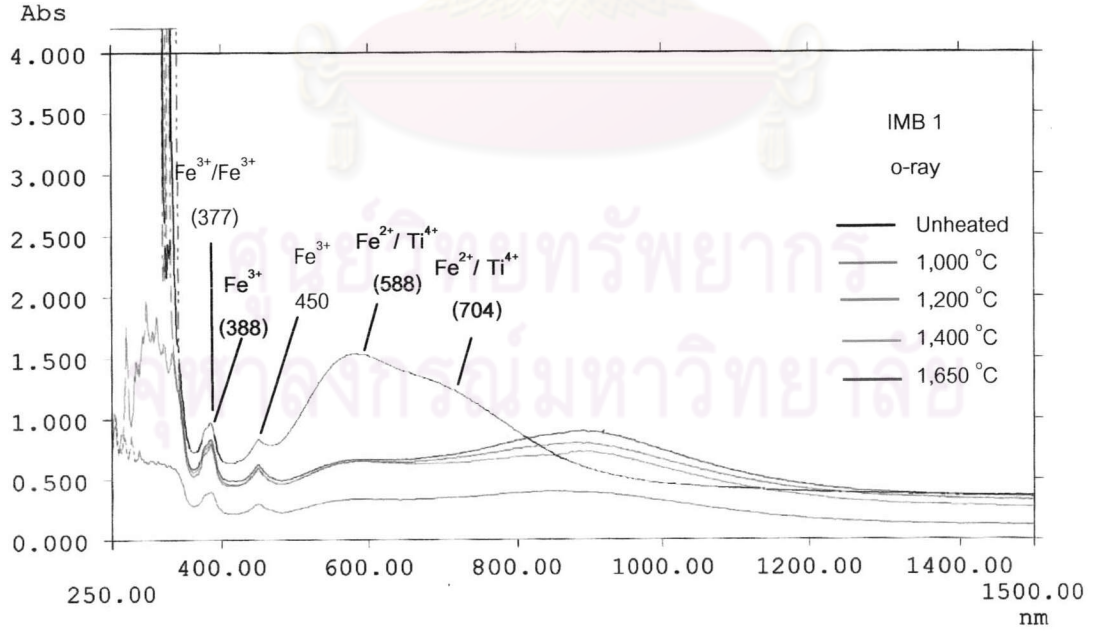

Abs
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
Fe3+
(388)
Cr3+
(412)
Cr3+
(577)
Fe2+/ Ti4+
(588)
Cr3+
(694)
DB 4
e-ray
Unheated
1,000 °C
1,200 °C
1,400 °C
1,650 °C
250.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
1500.00
nm

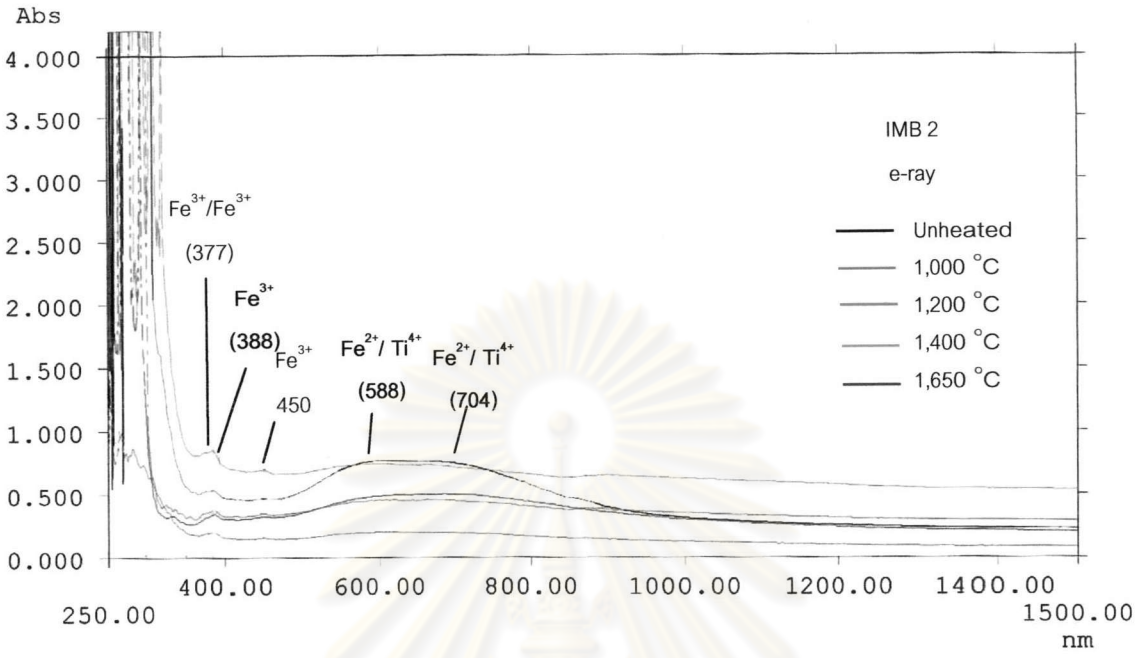

Abs
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
Fe3+
(388)
Cr3+
(412)
Cr3+
(577)
Fe2+/ Ti4+
(588)
Cr3+
(694)
DB 4
o-ray
Unheated
1,000 °C
1,200 °C
1,400 °C
1,650 °C
250.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
1500.00
nm

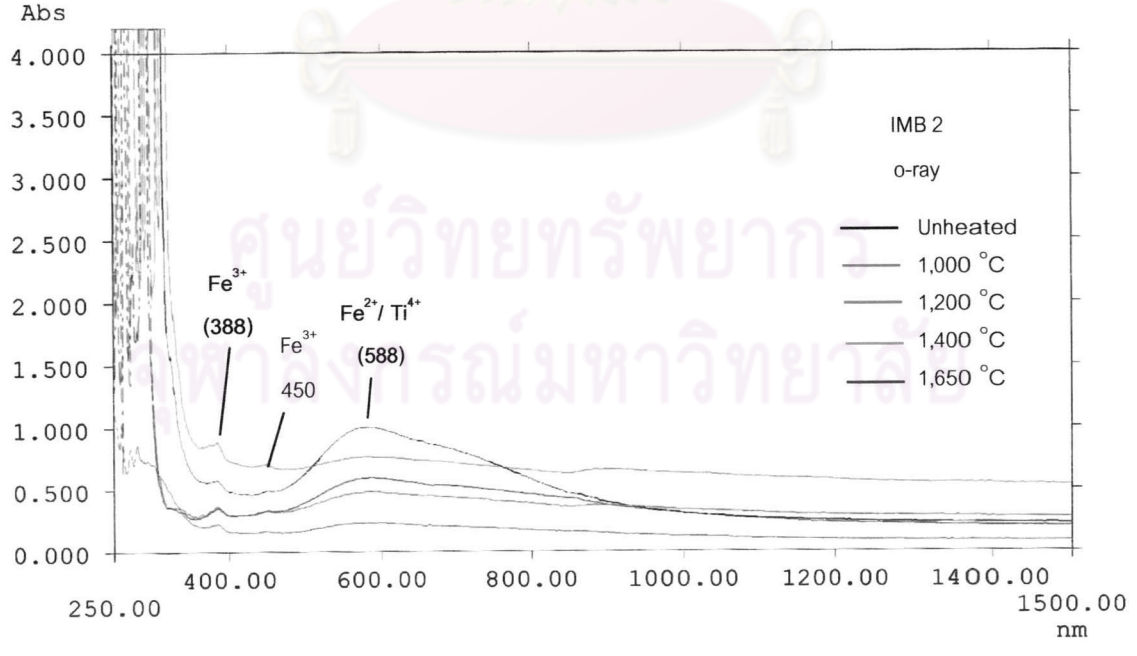

Abs
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
250.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
1500.00
nm
Fe3+
(388)
Cr3+
(412)
Cr3+
(577)
Fe2+/ Ti4+
(588)
Cr3+
(694)
DB 5
e-ray
Unheated
1,000 °C
1,200 °C
1,400 °C
1,650 °C

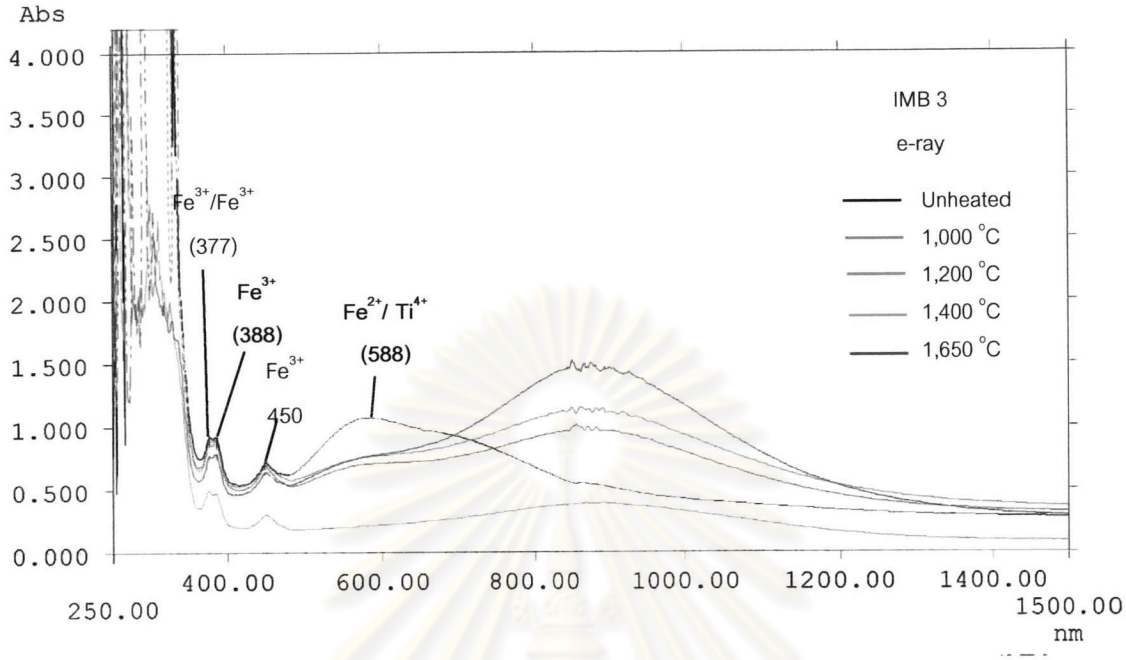

Abs
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
250.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
1500.00
nm
Fe3+
(388)
Cr3+
(412)
Cr3+
(577)
Fe2+/ Ti4+
(588)
Cr3+
(694)
DB 5
o-ray
Unheated
1,000 °C
1,200 °C
1,400 °C
1,650 °C

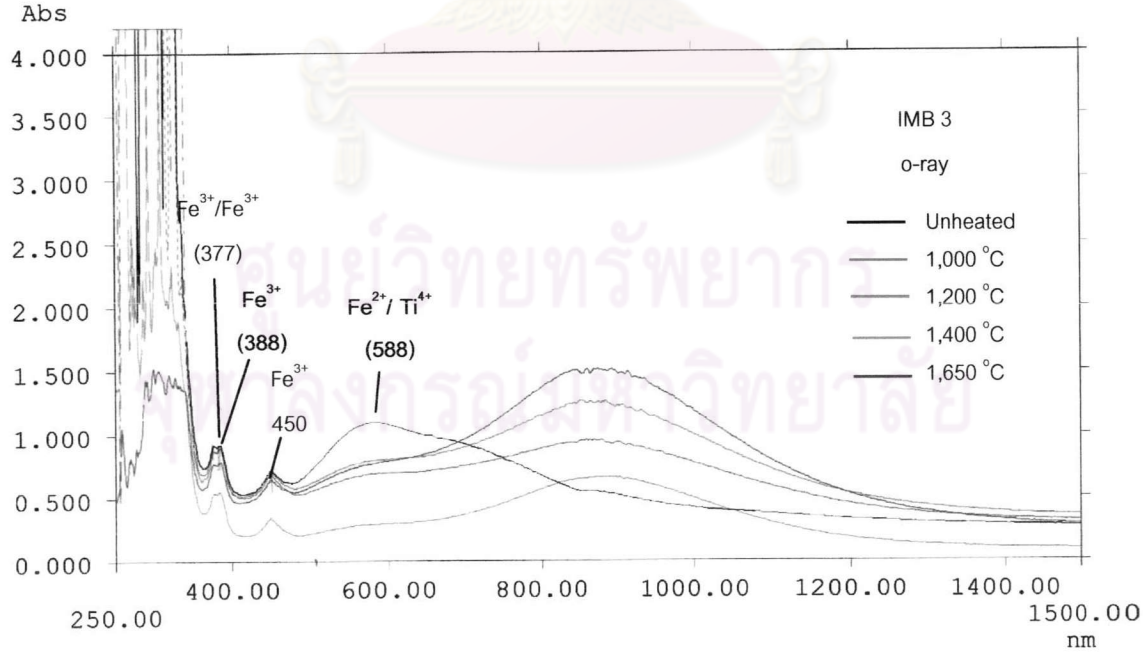

Abs
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
250.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
1500.00
nm
IMB 1
e-ray
Unheated
1,000 °C
1,200 °C
1,400 °C
1,650 °C
Fe3+/Fe3+
(377)
Fe3+
(388)
Fe3+
450
Fe2+/ Ti4+
(704)

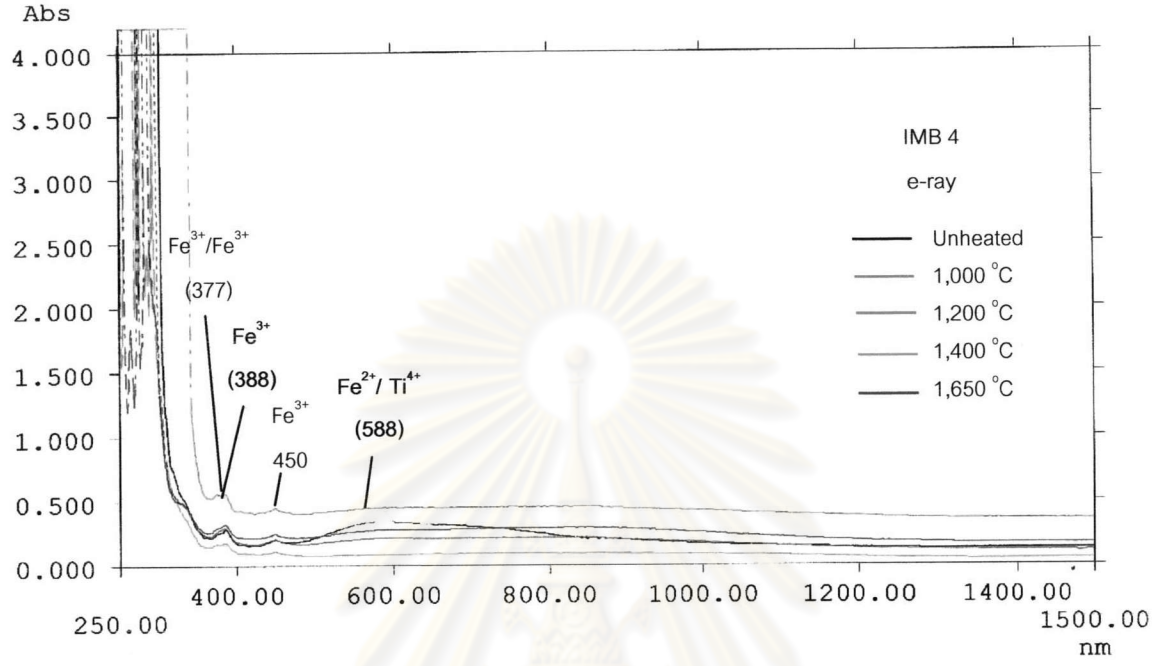

Abs
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
250.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
1500.00
nm
IMB 1
o-ray
Unheated
1,000 °C
1,200 °C
1,400 °C
1,650 °C
Fe3+/Fe3+
(377)
Fe3+
(388)
Fe3+
450
Fe2+/ Ti4+
(588)
Fe2+/ Ti4+
(704)

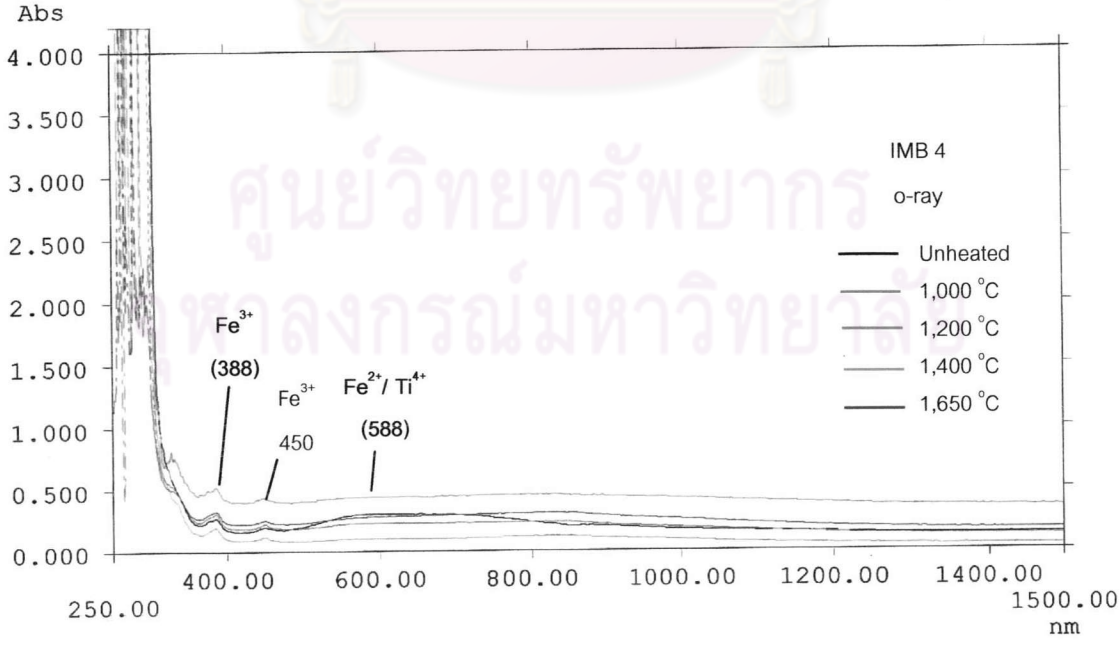


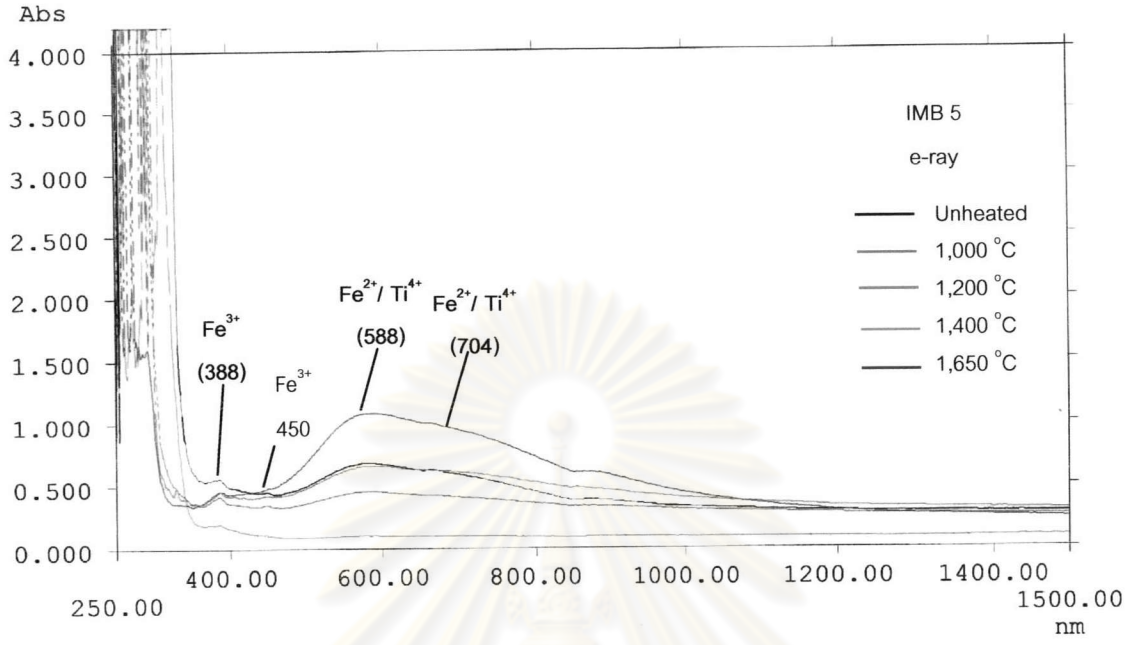


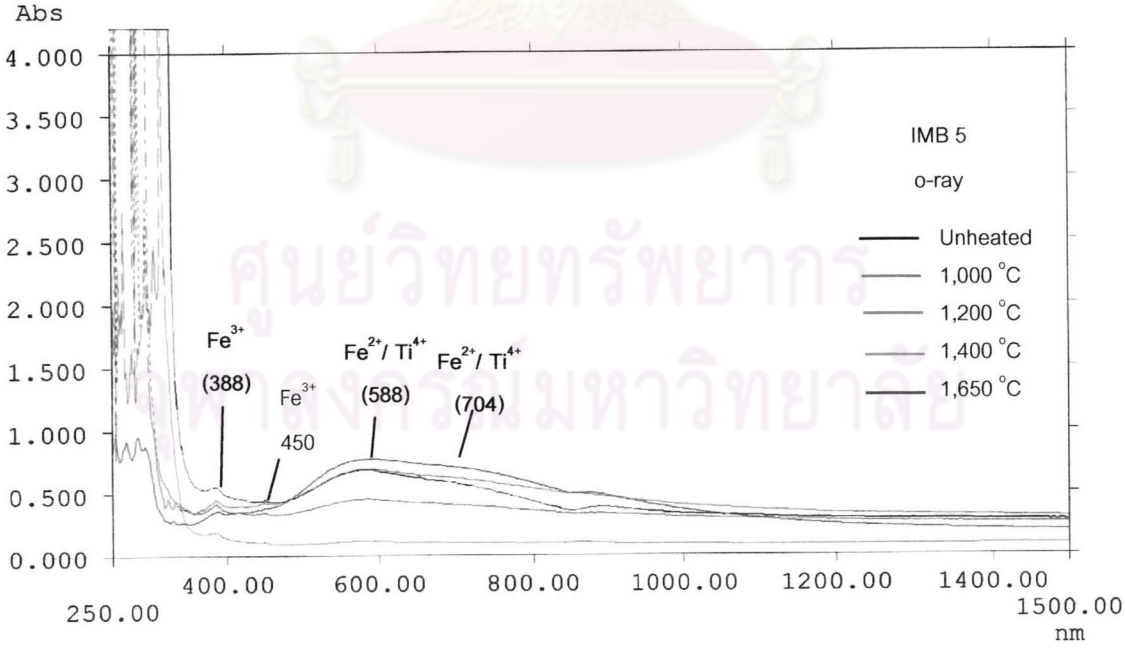

Abs
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
Fe3+/Fe3+
(377)
Fe3+
(388)
Fe3+
450
Fe2+/ Ti4+
(588)
IMB 3
e-ray
Unheated
1,000 °C
1,200 °C
1,400 °C
1,650 °C
250.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
1500.00
nm

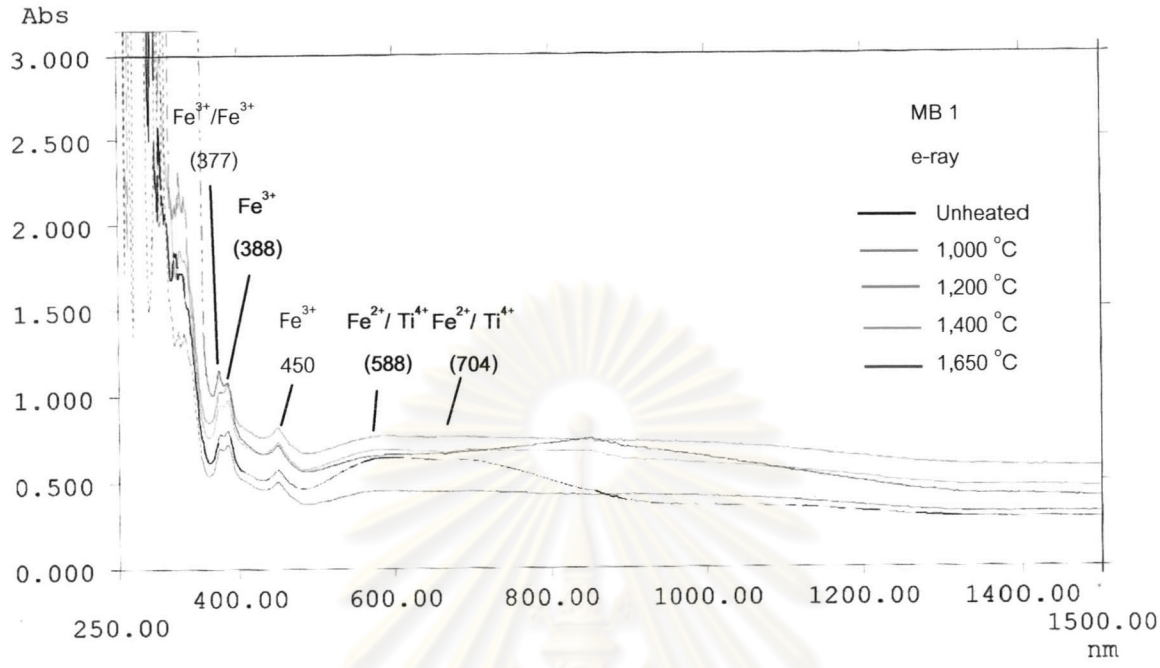

Abs
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
Fe3+/Fe3+
(377)
Fe3+
(388)
Fe3+
450
Fe2+/ Ti4+
(588)
IMB 3
o-ray
Unheated
1,000 °C
1,200 °C
1,400 °C
1,650 °C
250.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
1500.00
nm

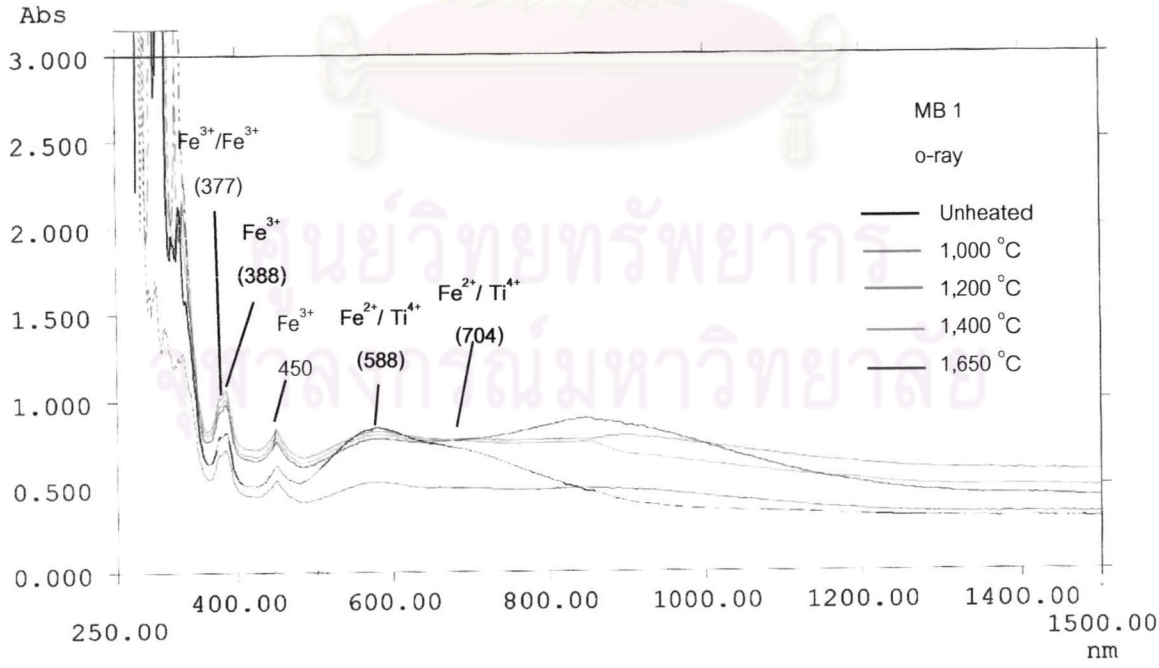


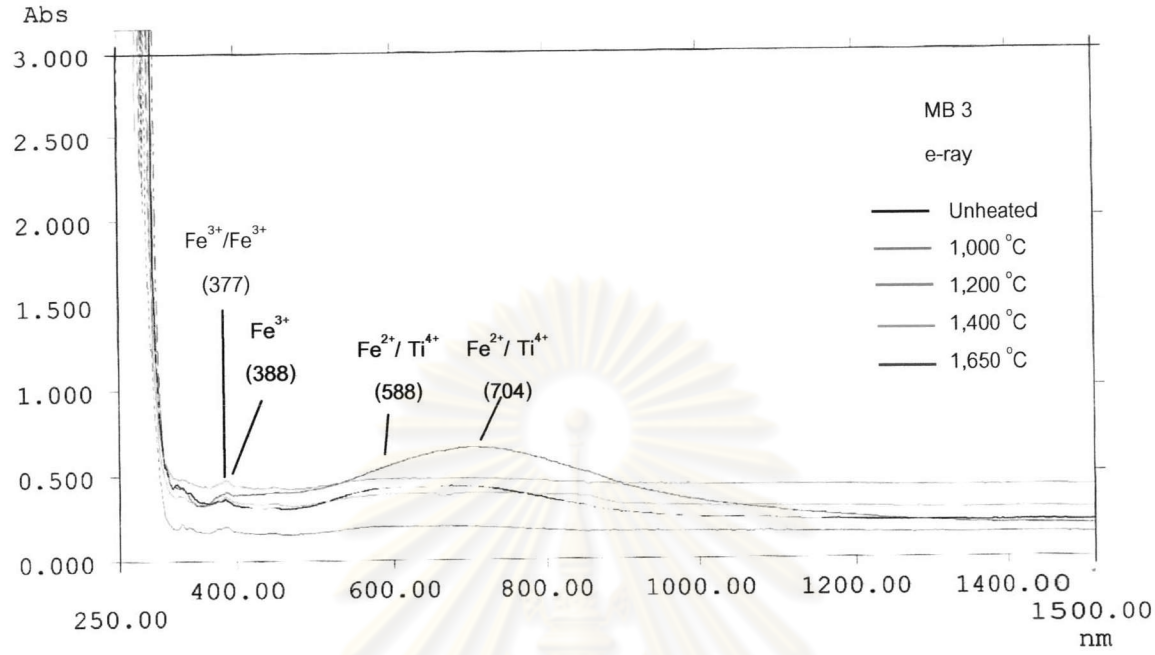


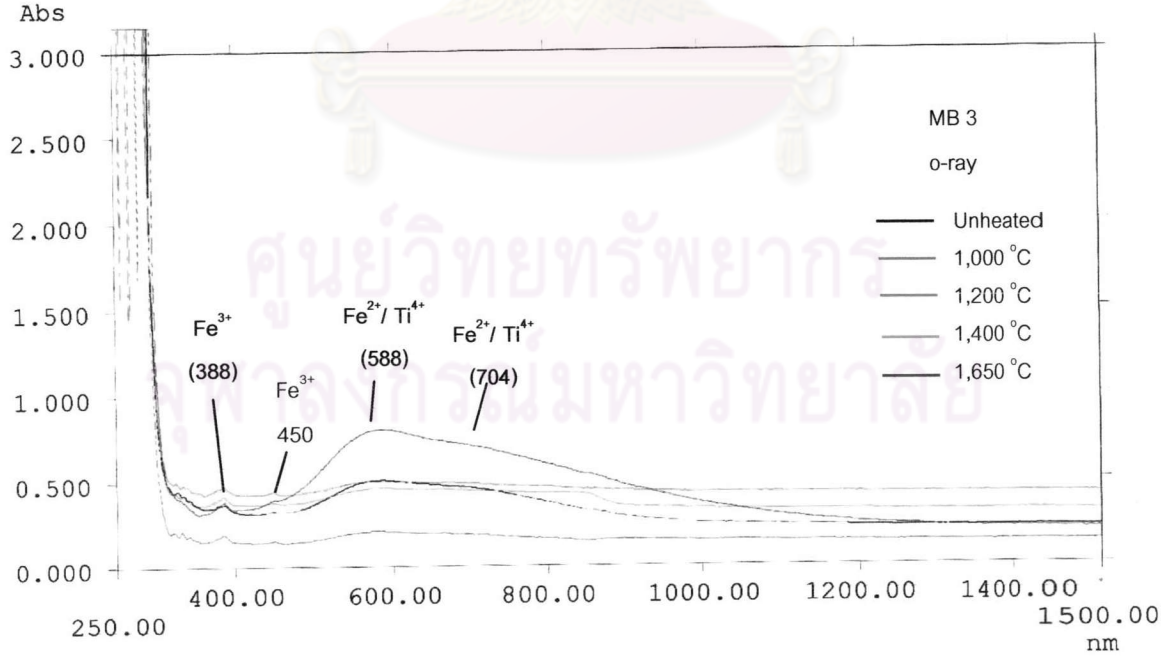


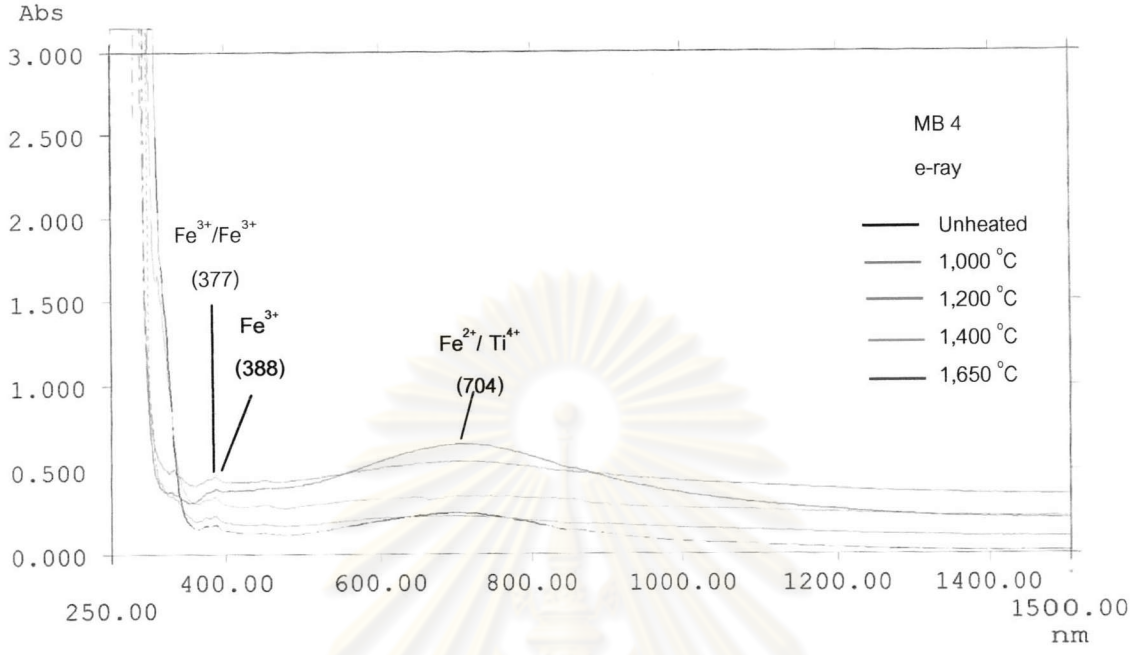


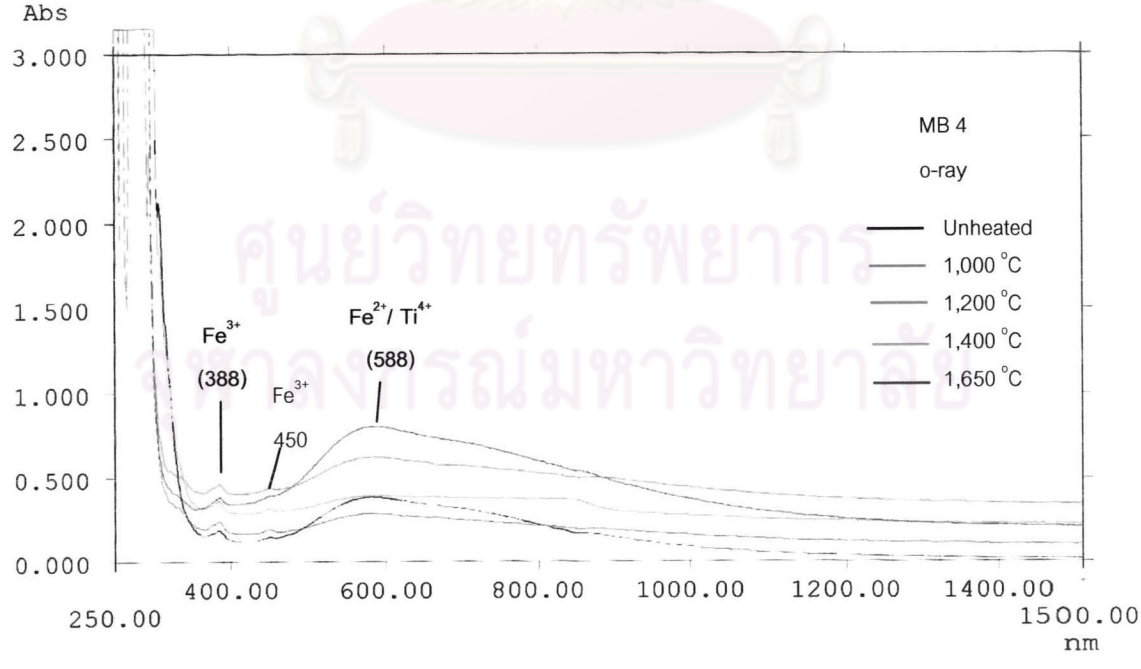

Abs
3.000
2.500
2.000
1.500
1.000
0.500
0.000
Fe3+/Fe3+
(377)
Fe3+
(388)
Fe3+
450
Fe2+/ Ti4+
(588)
Fe2+/ Ti4+
(704)
MB 1
e-ray
Unheated
1,000 °C
1,200 °C
1,400 °C
1,650 °C
250.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
1500.00
nm

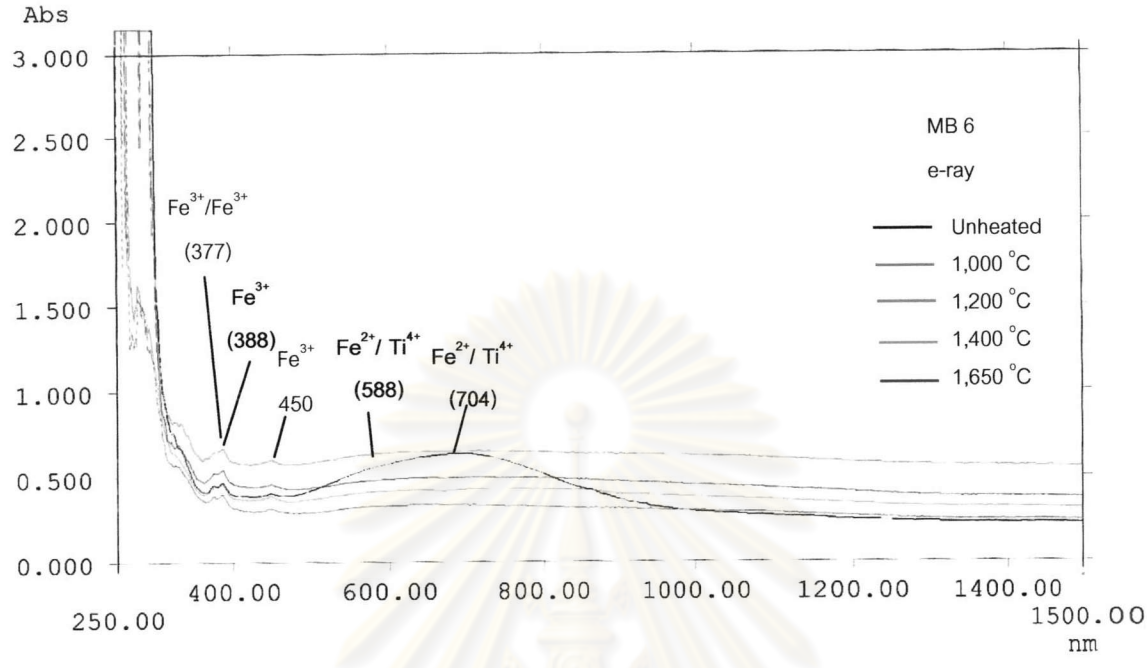

Abs
3.000
2.500
2.000
1.500
1.000
0.500
0.000
Fe3+/Fe3+
(377)
Fe3+
(388)
Fe3+
450
Fe2+/ Ti4+
(588)
Fe2+/ Ti4+
(704)
MB 1
o-ray
Unheated
1,000 °C
1,200 °C
1,400 °C
1,650 °C
250.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
1500.00
nm

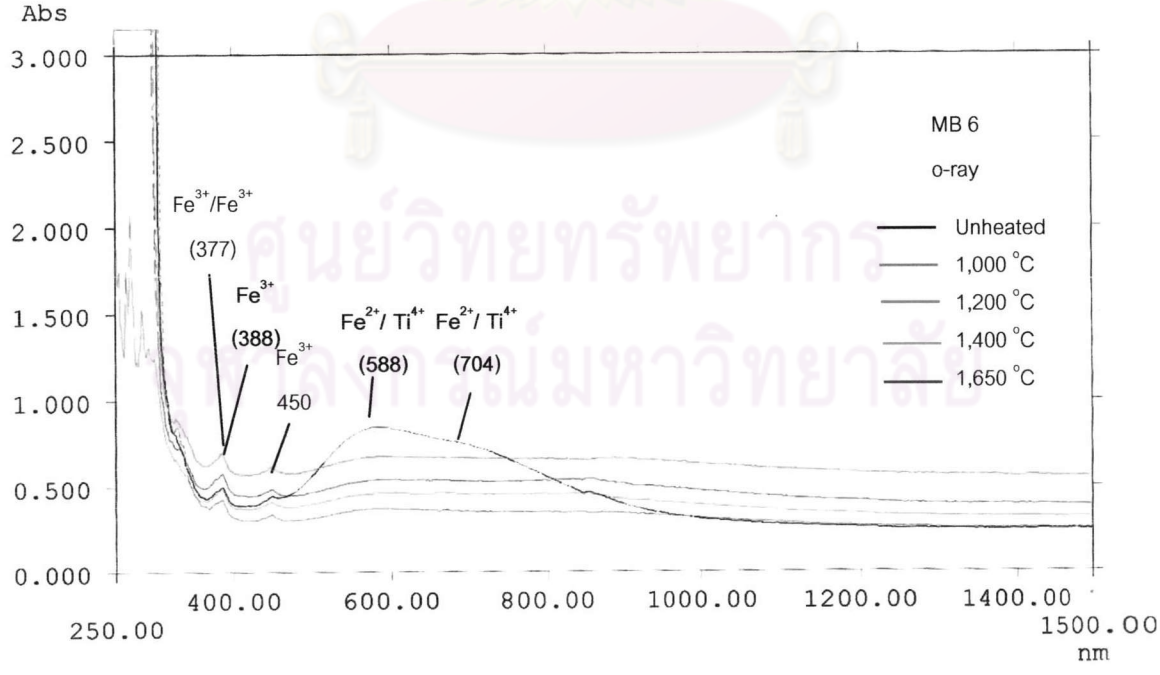


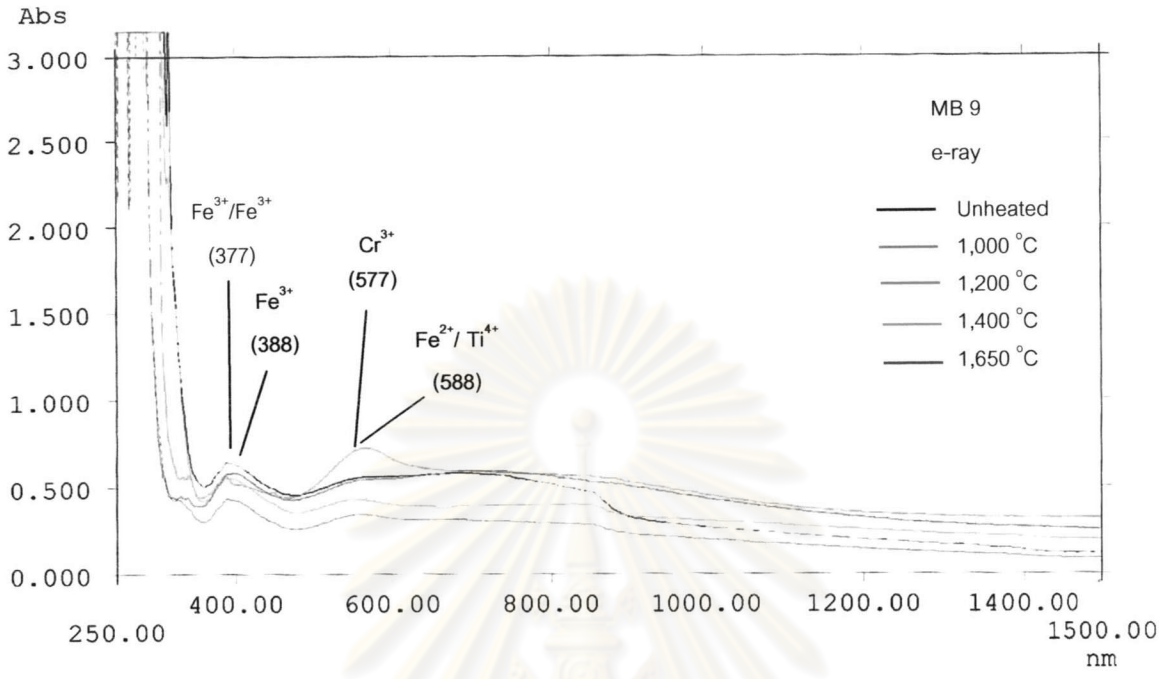


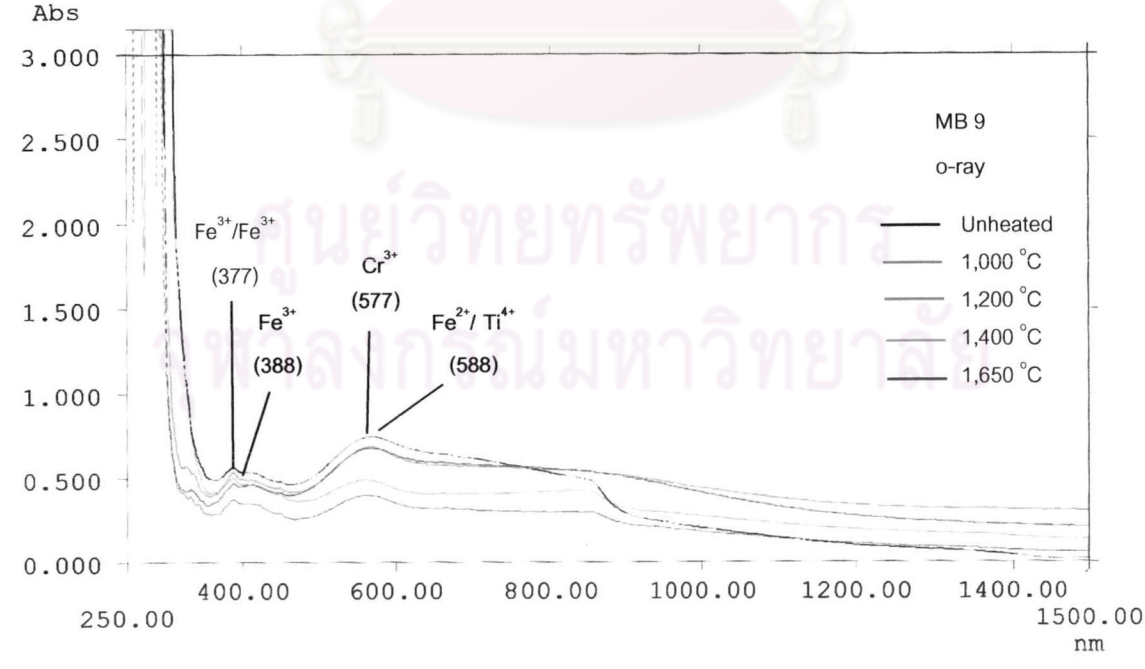


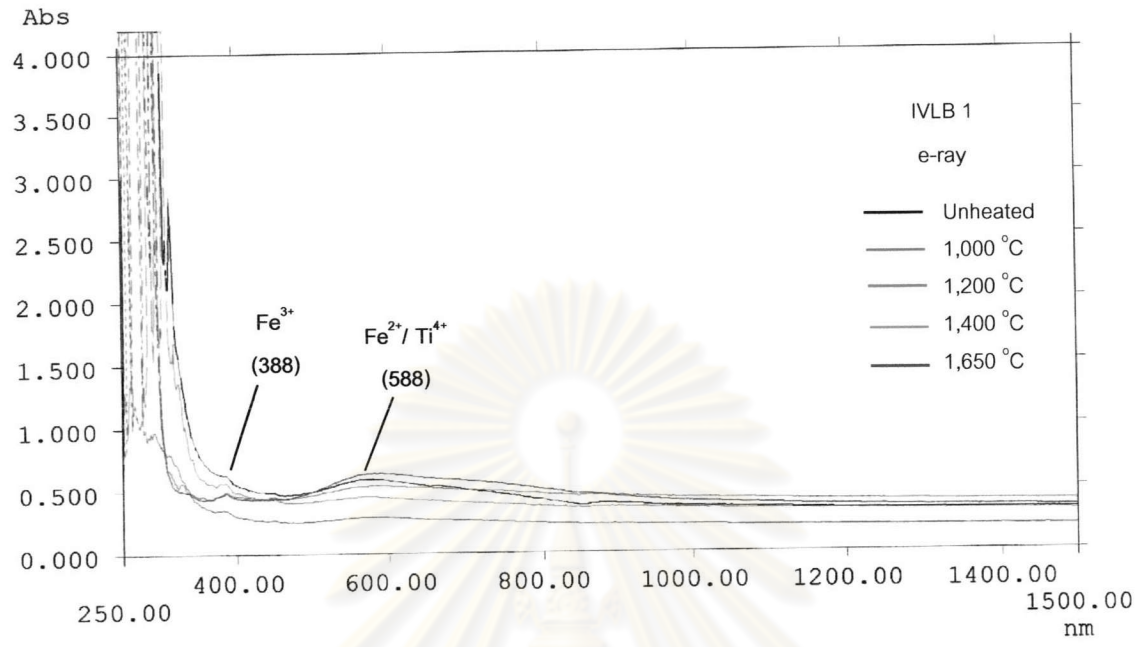


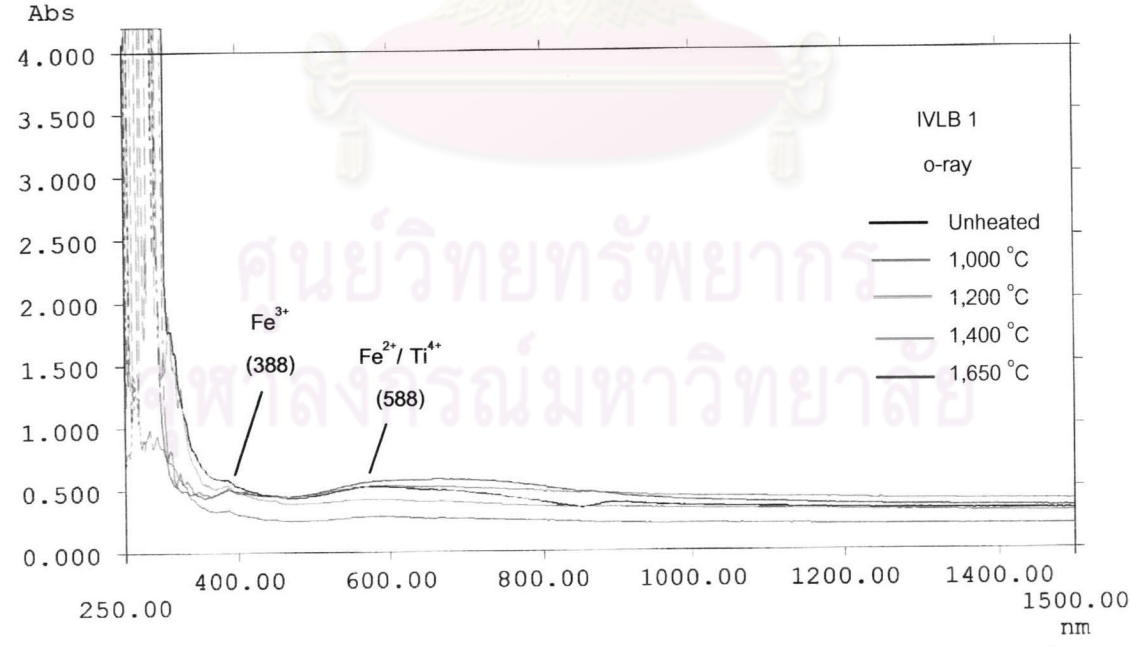


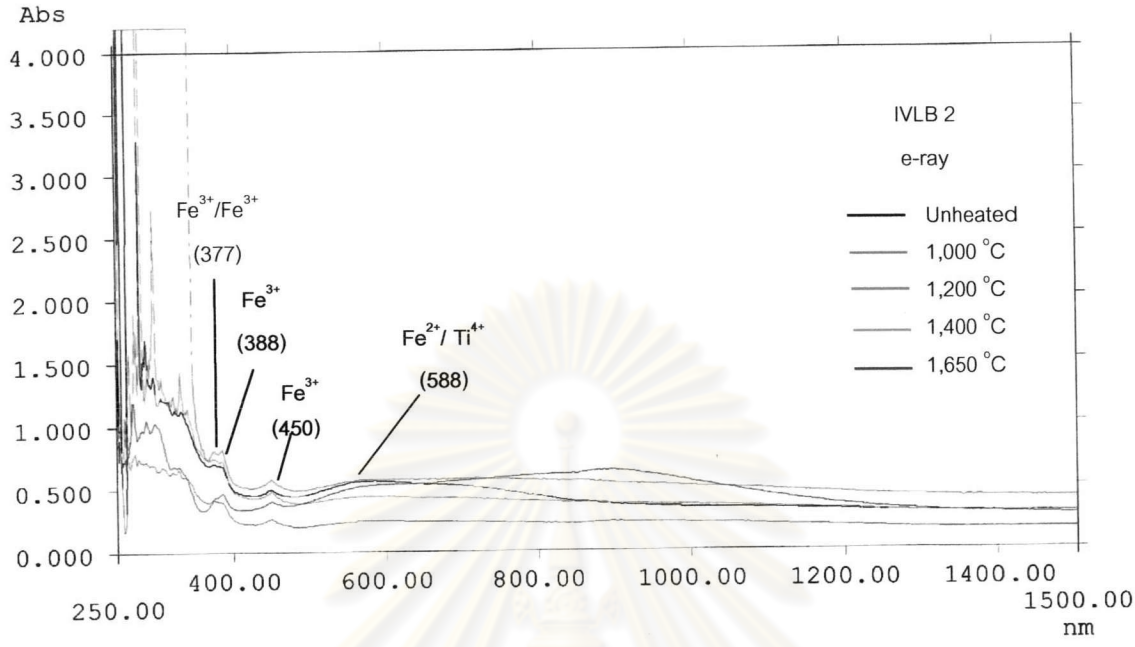


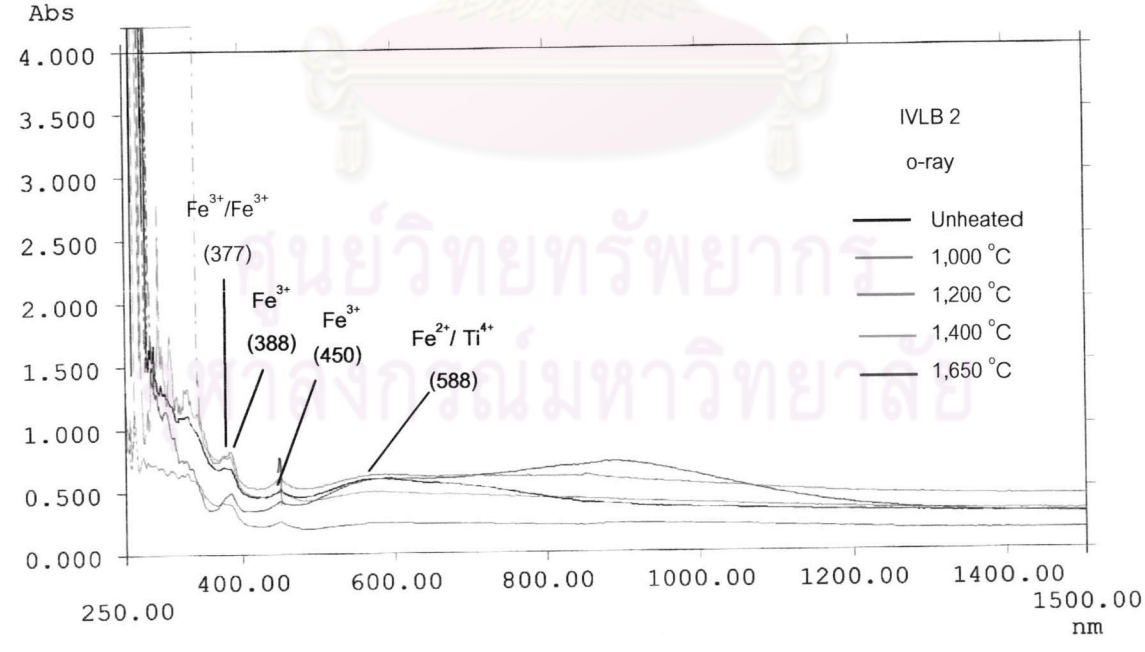


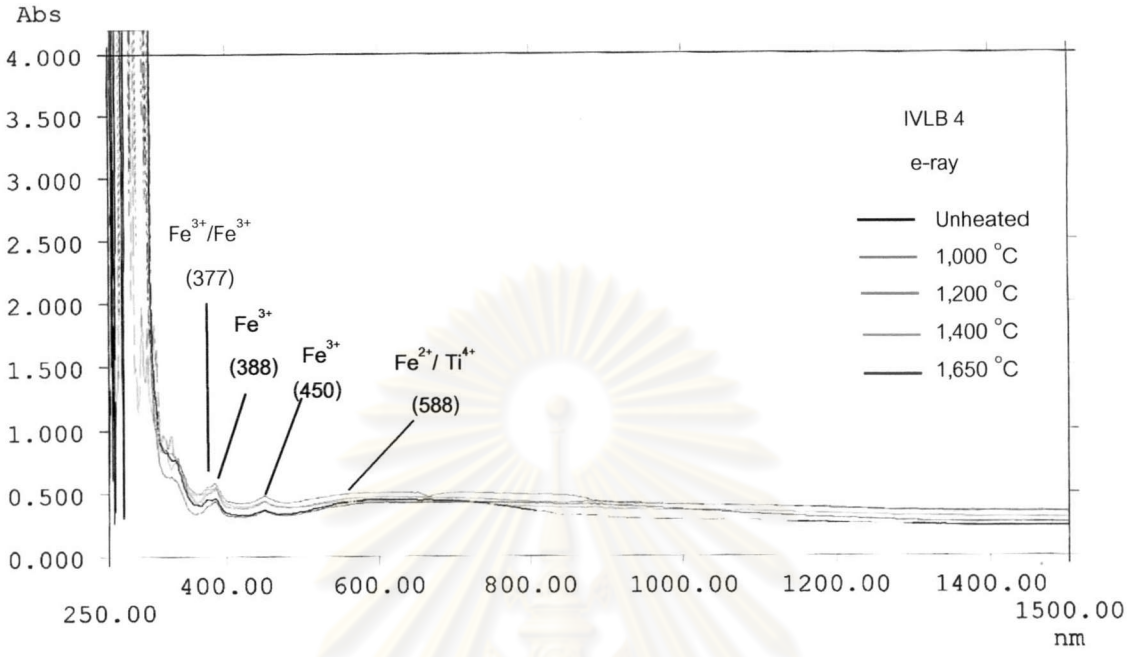


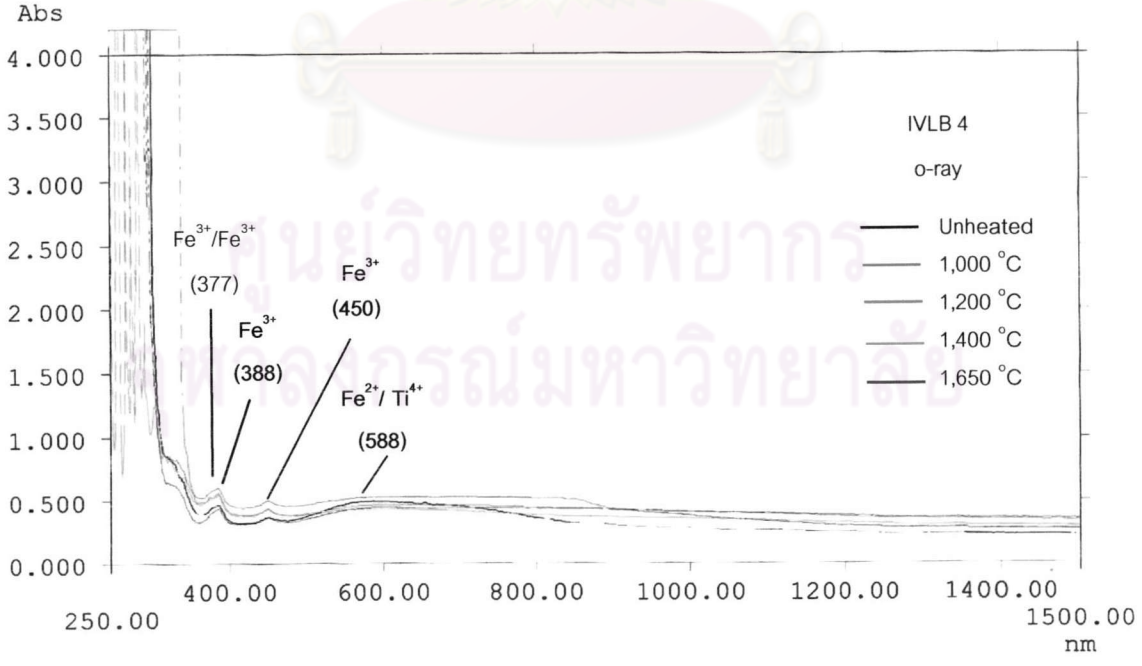


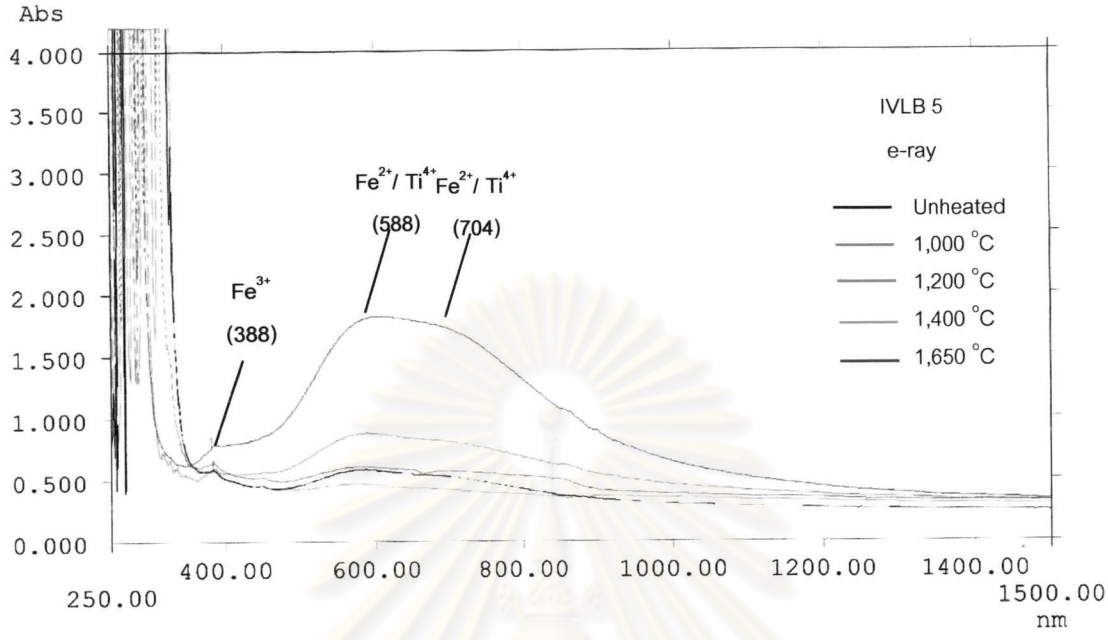


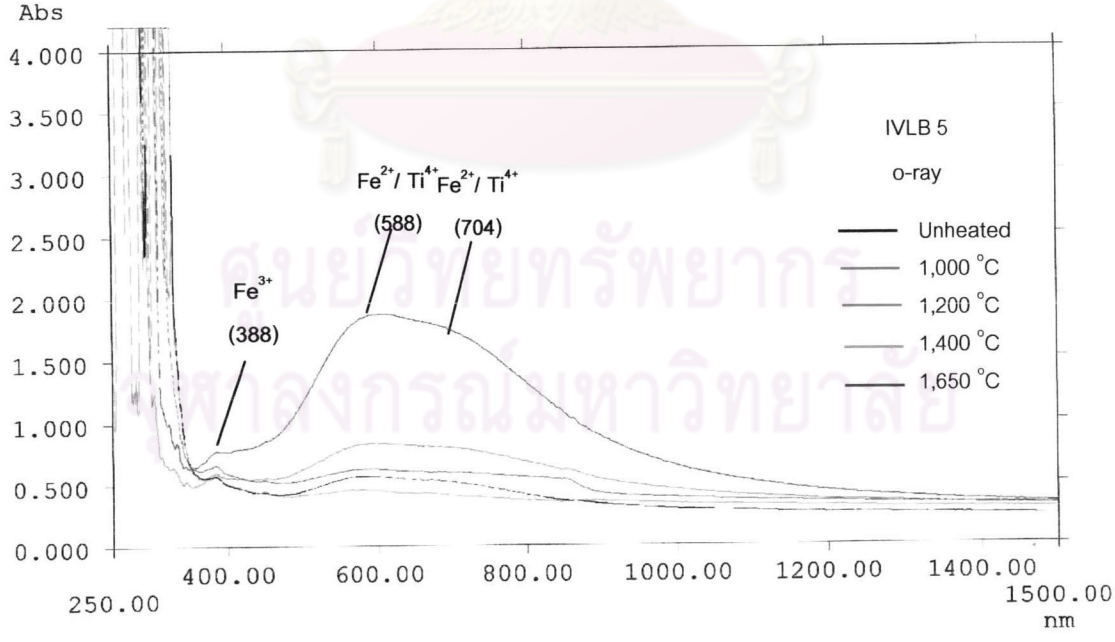


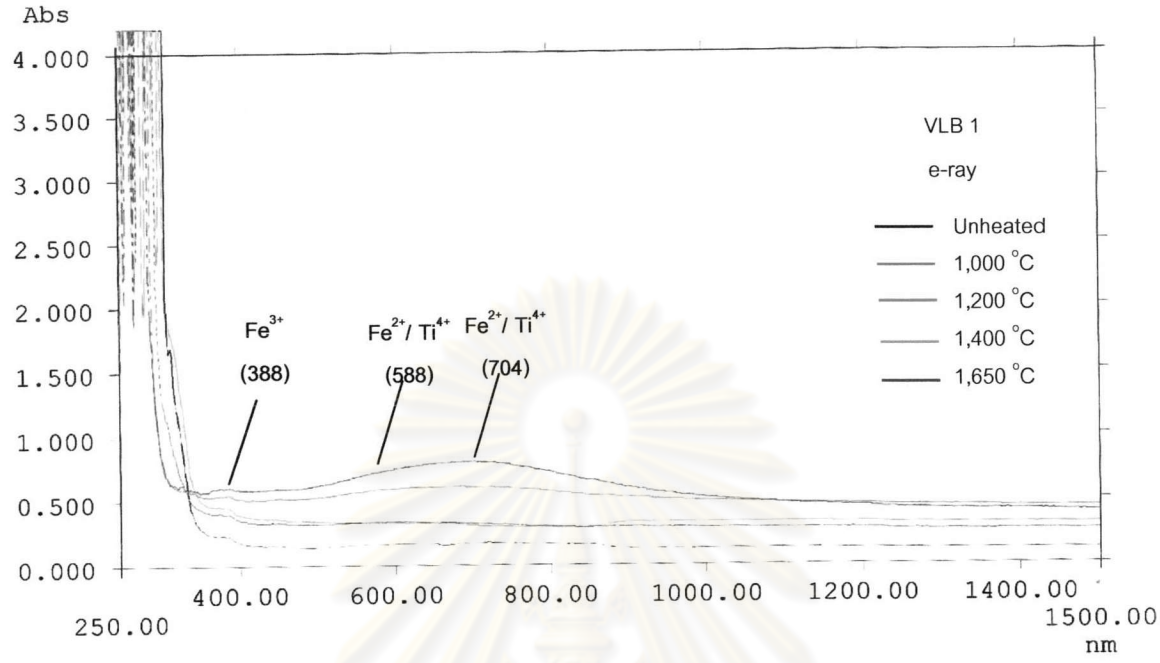


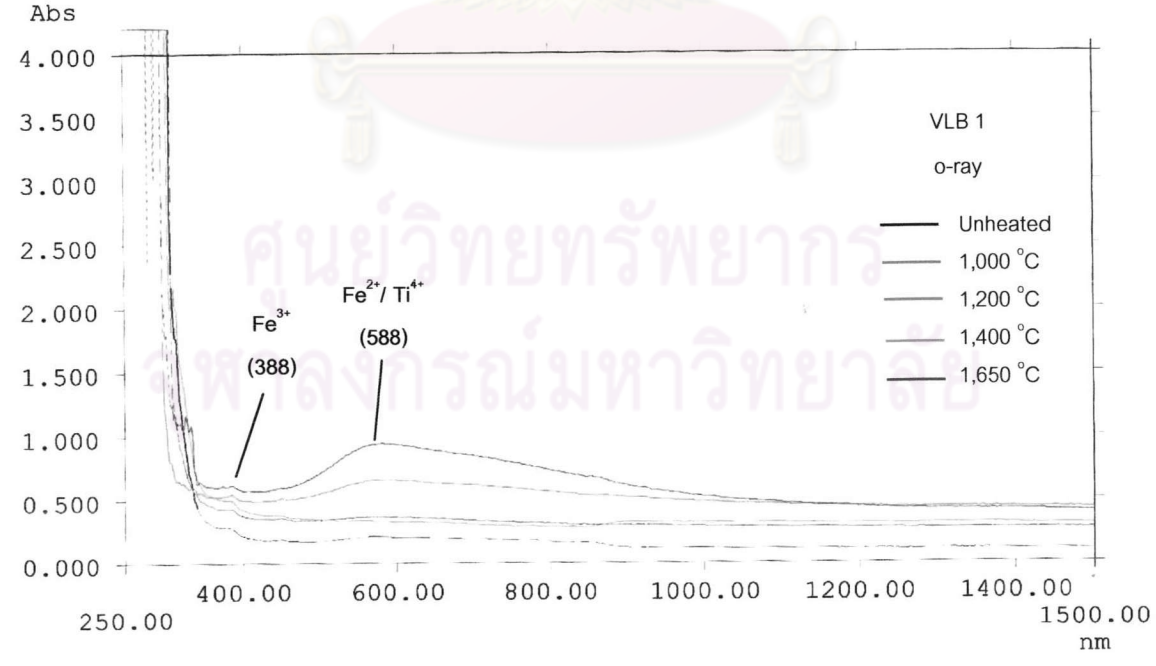


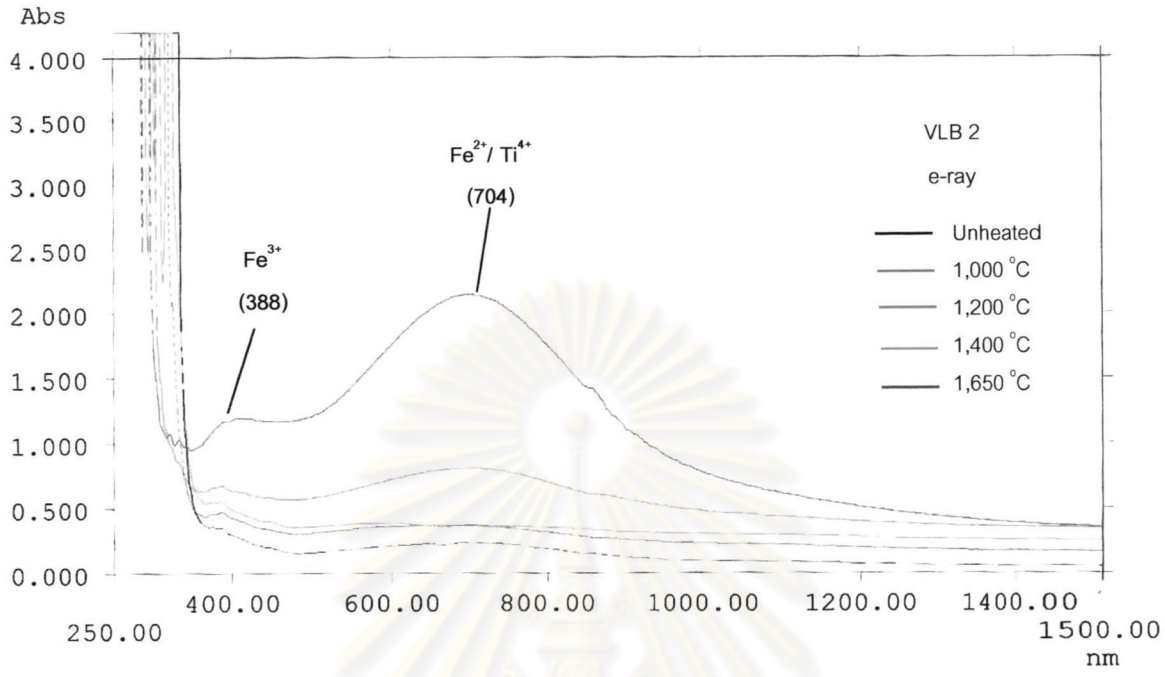


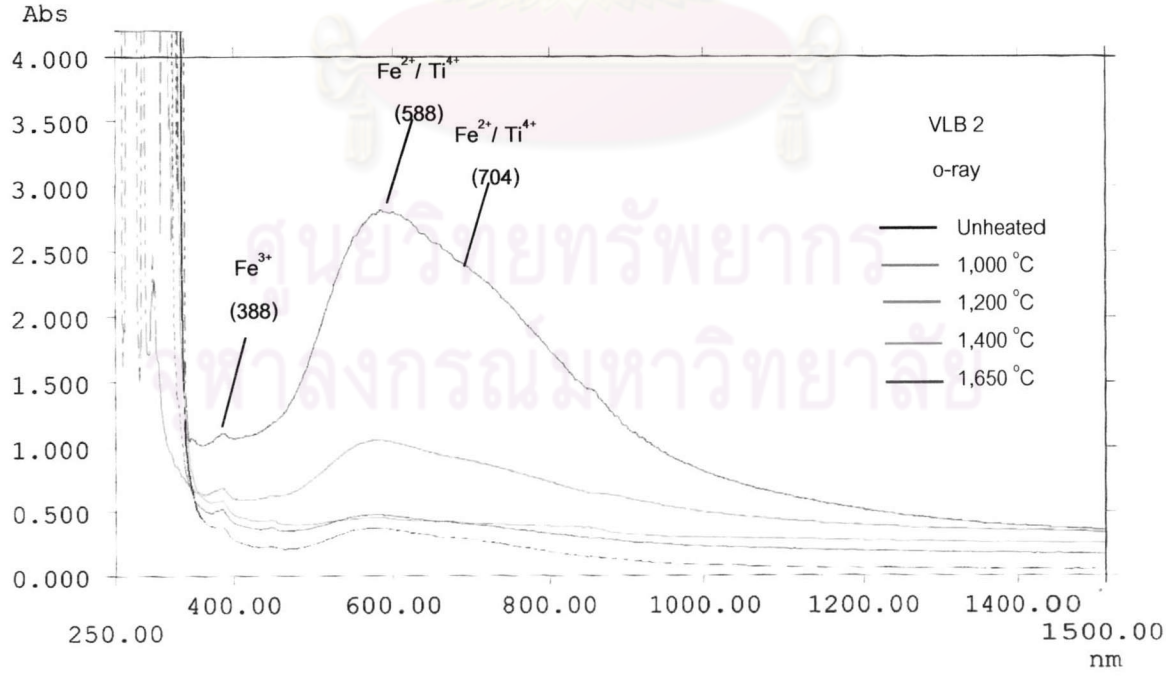

Abs
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
400.00
600.00
800.00
1000.00
1200.00
1400.00
250.00
1500.00
nm
IVLB 5
e-ray
Unheated
1,000 °C
1,200 °C
1,400 °C
1,650 °C
Fe2+/ Ti4+
Fe2+/ Ti4+
(588)
(704)
Fe3+
(388)

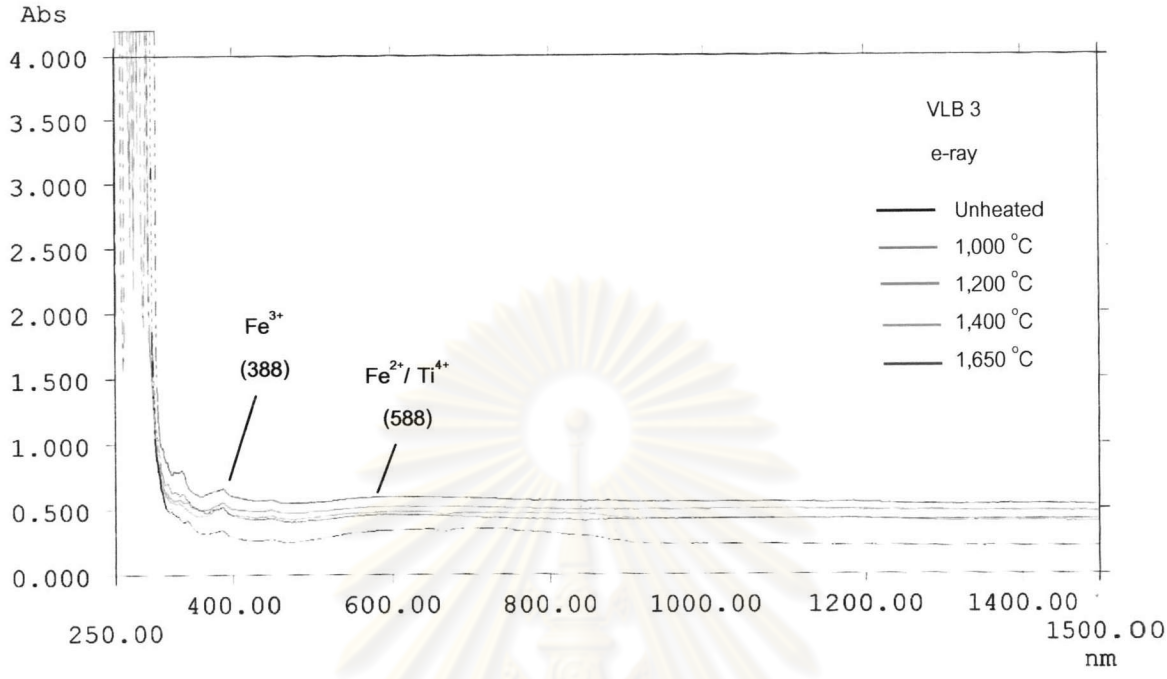

Abs
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
400.00
600.00
800.00
1000.00
1200.00
1400.00
250.00
1500.00
nm
IVLB 5
o-ray
Unheated
1,000 °C
1,200 °C
1,400 °C
1,650 °C
Fe2+/ Ti4+
Fe2+/ Ti4+
(588)
(704)
Fe3+
(388)

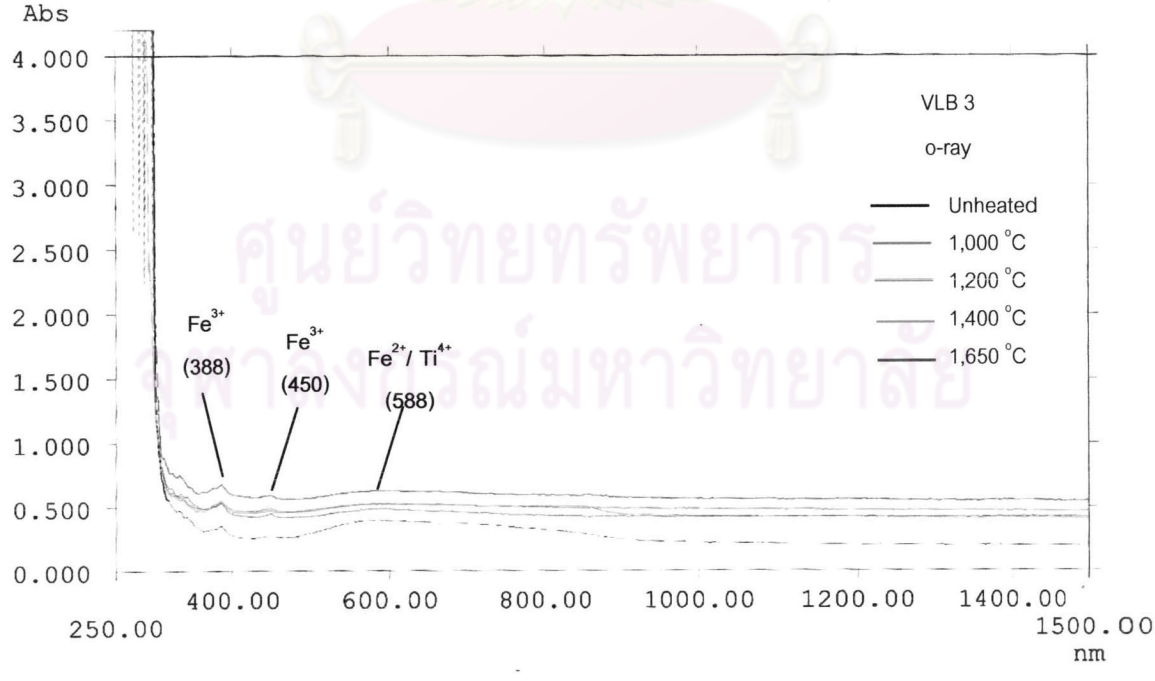


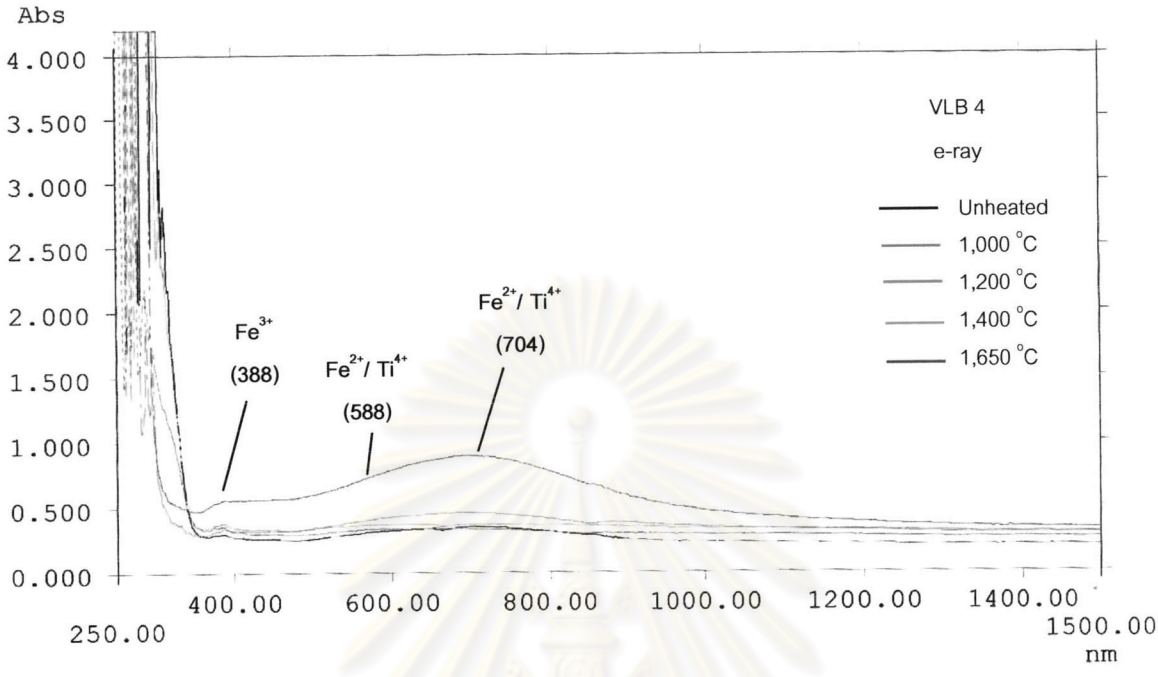


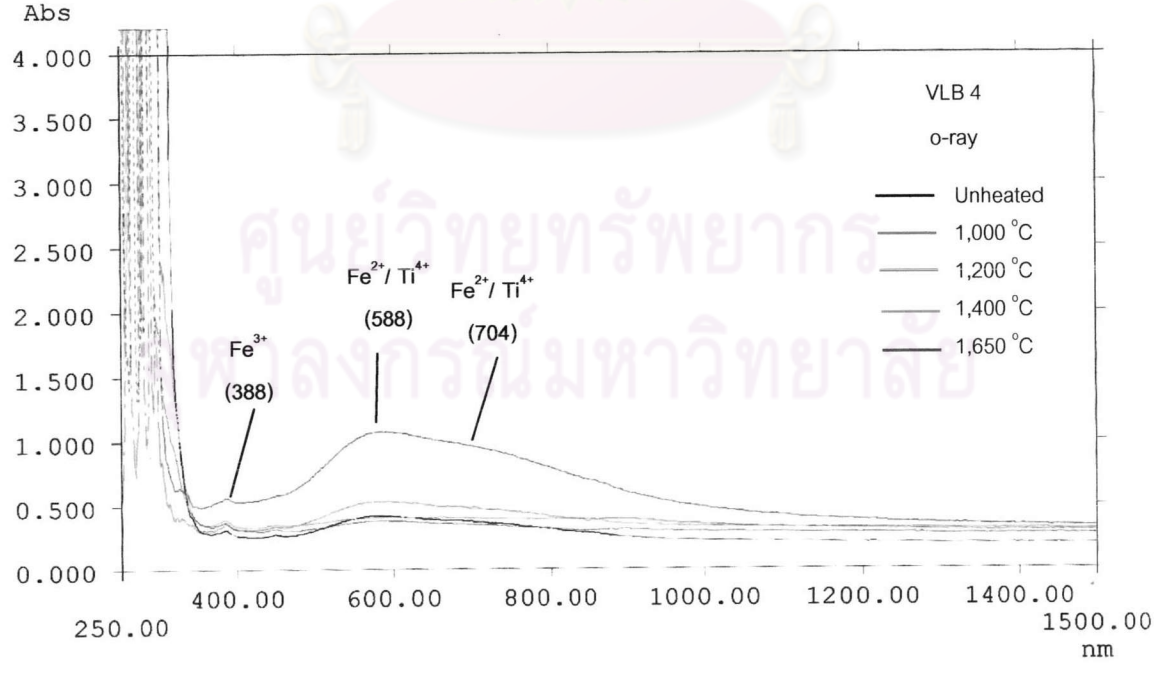


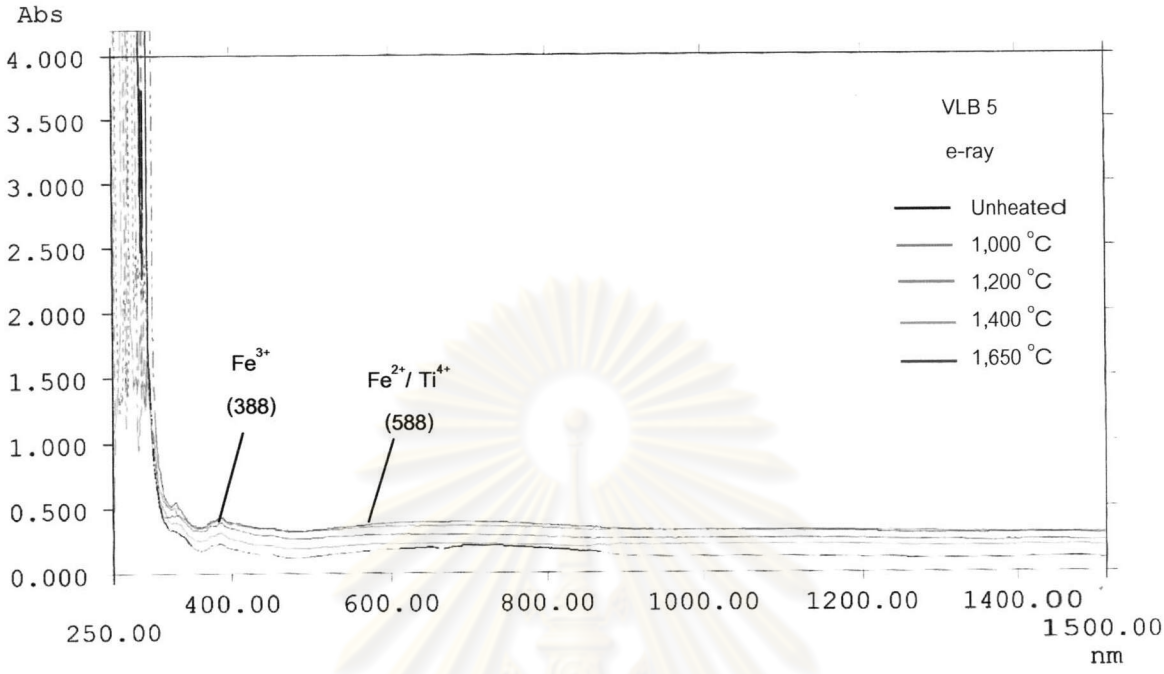


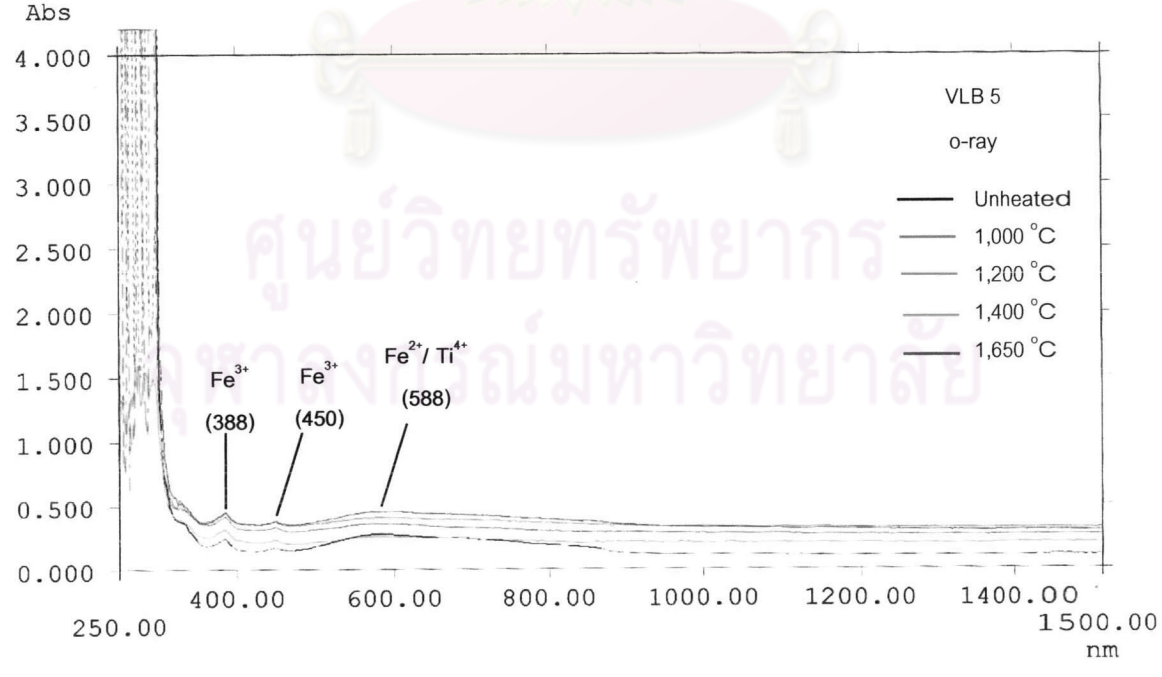


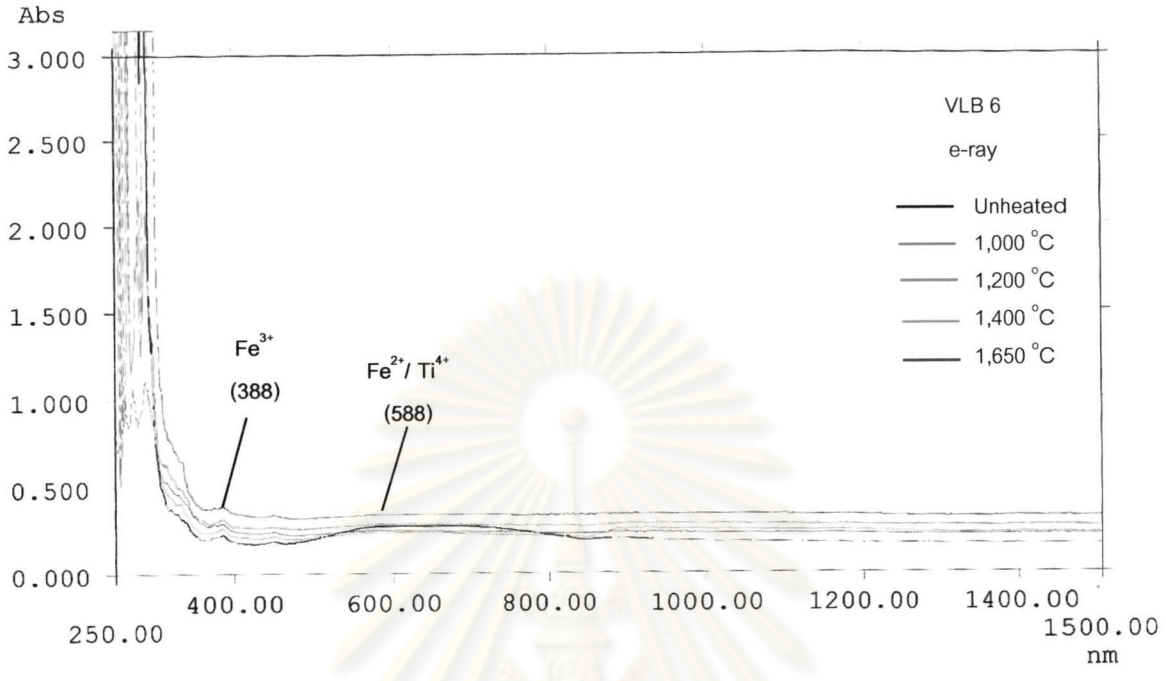


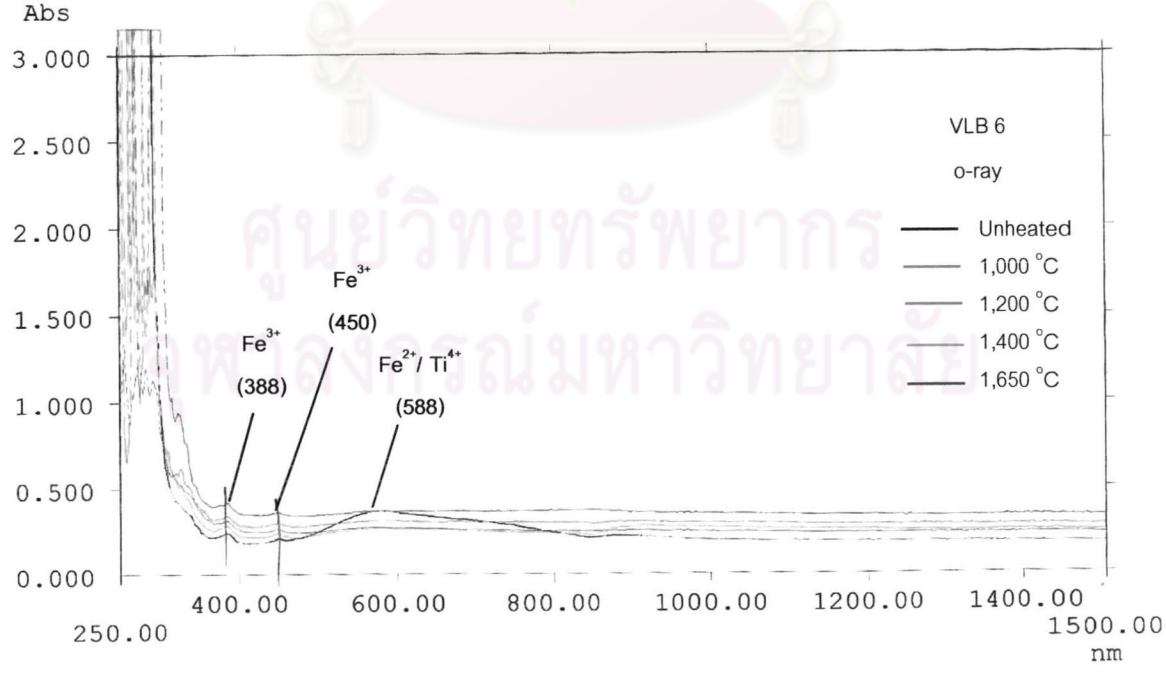


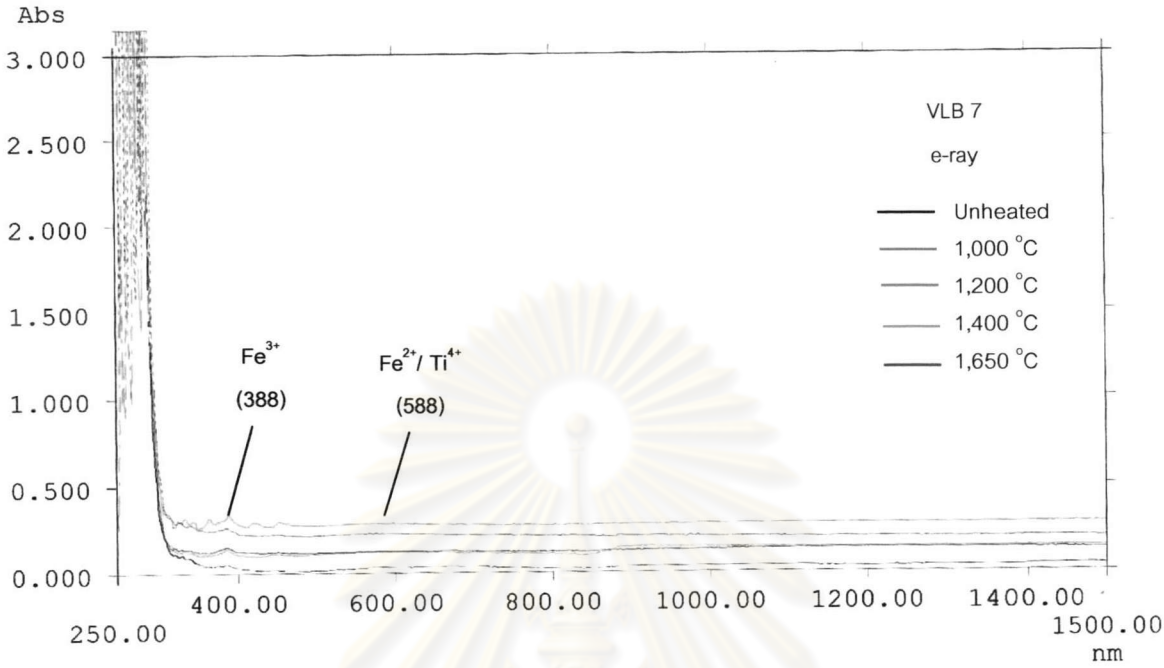


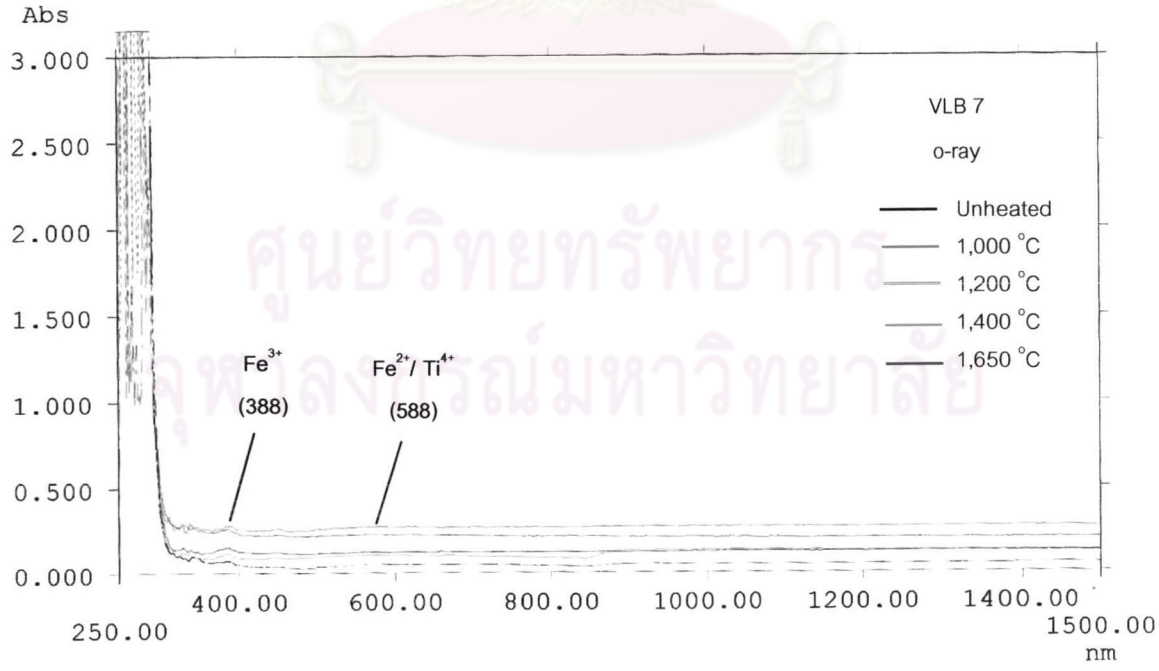


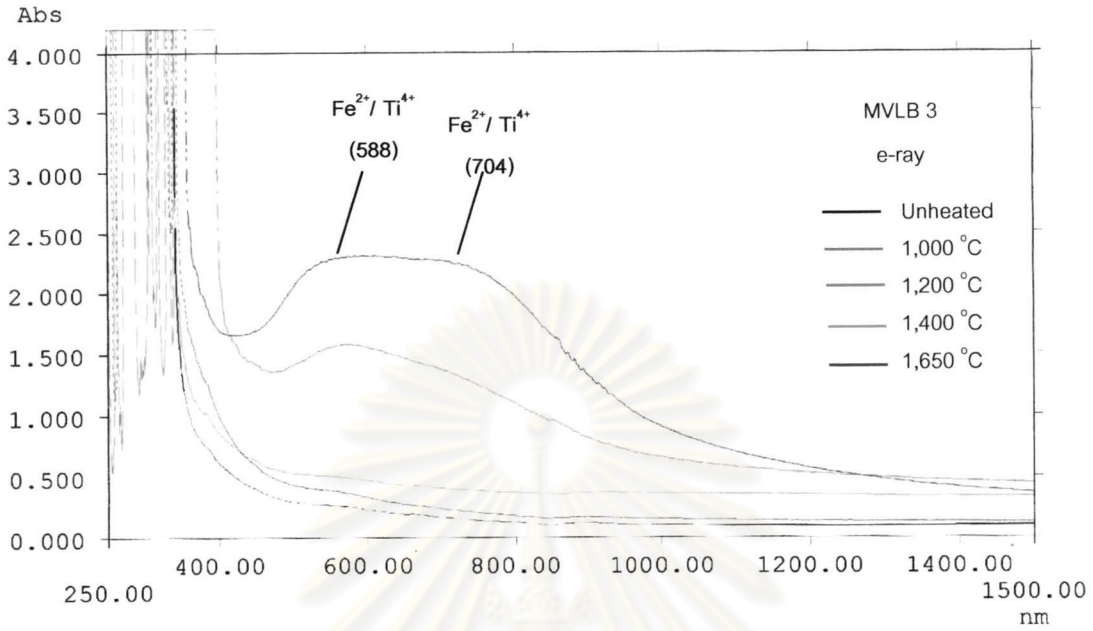


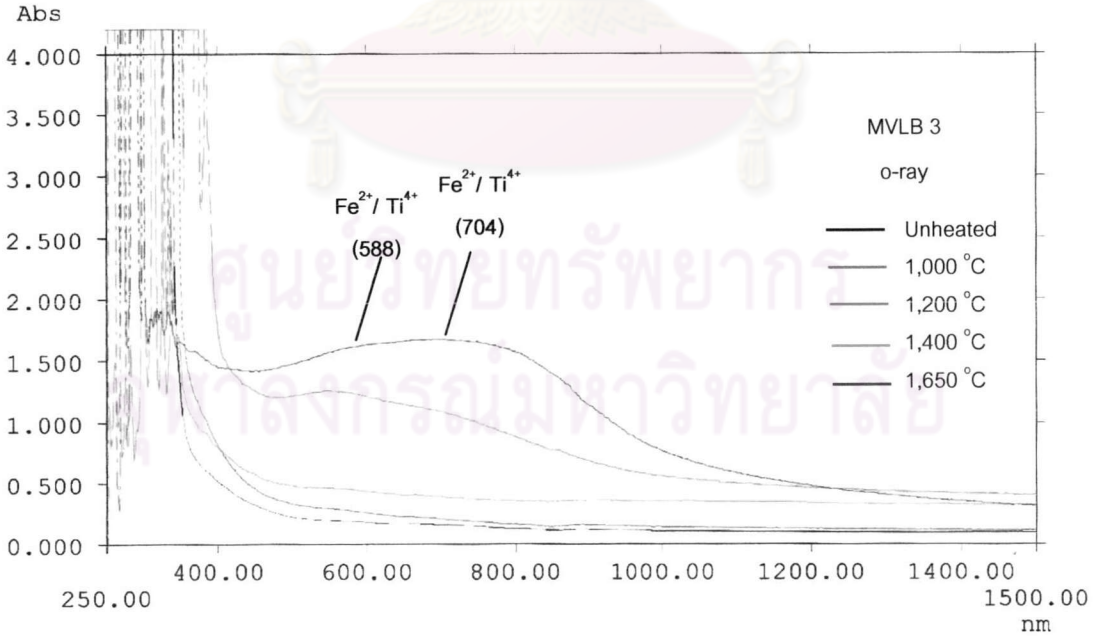


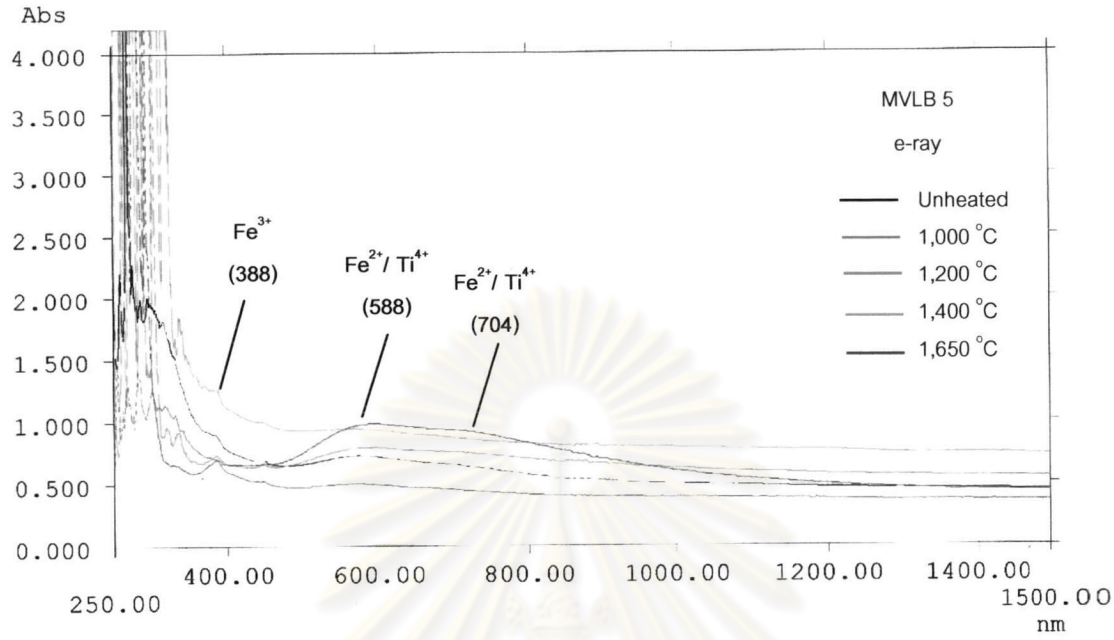


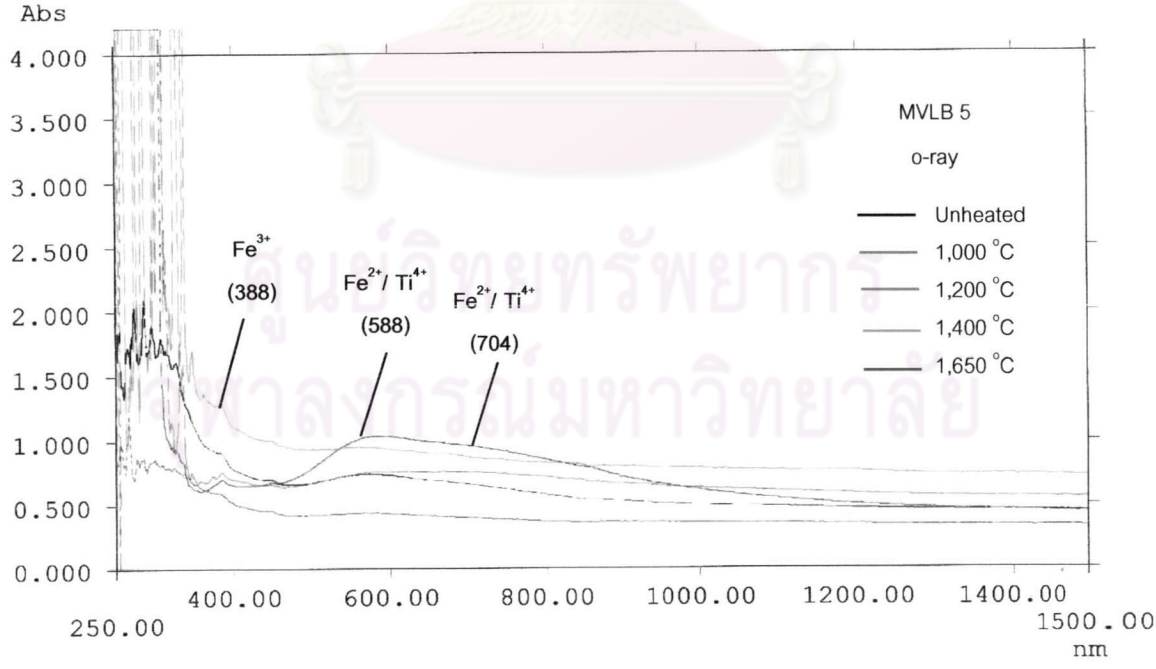


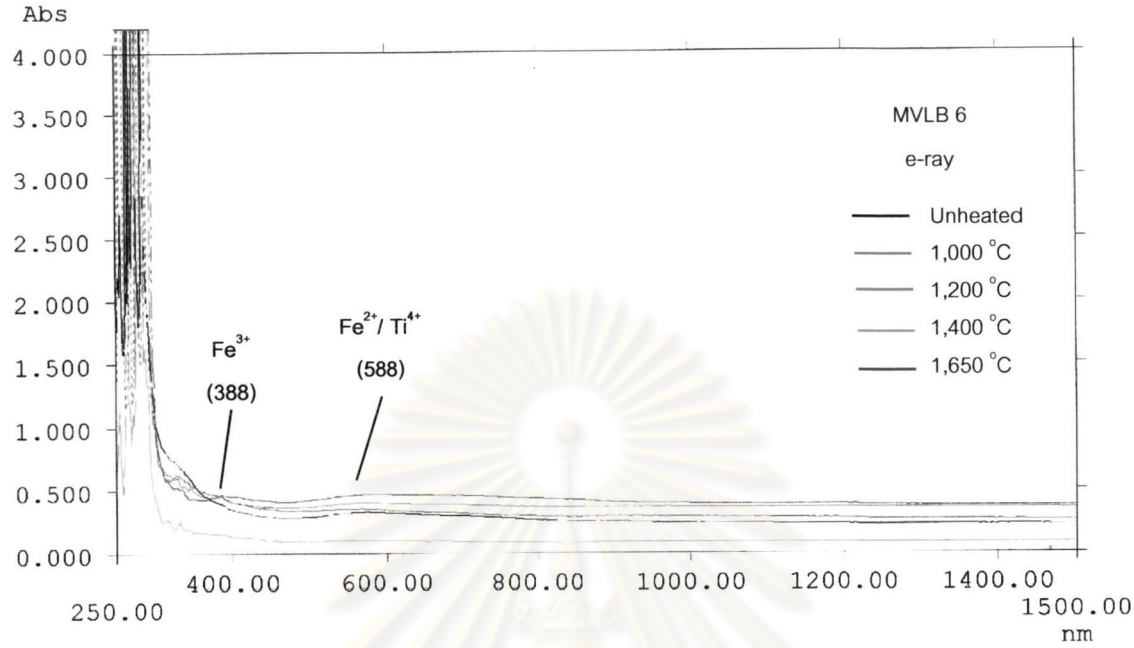


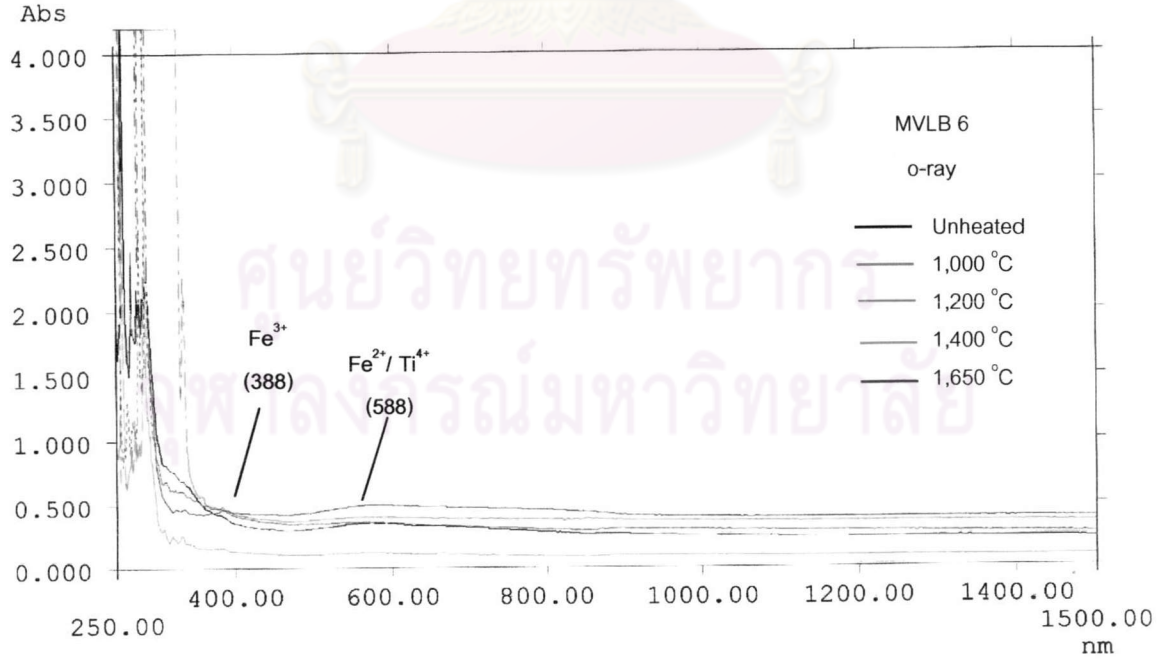


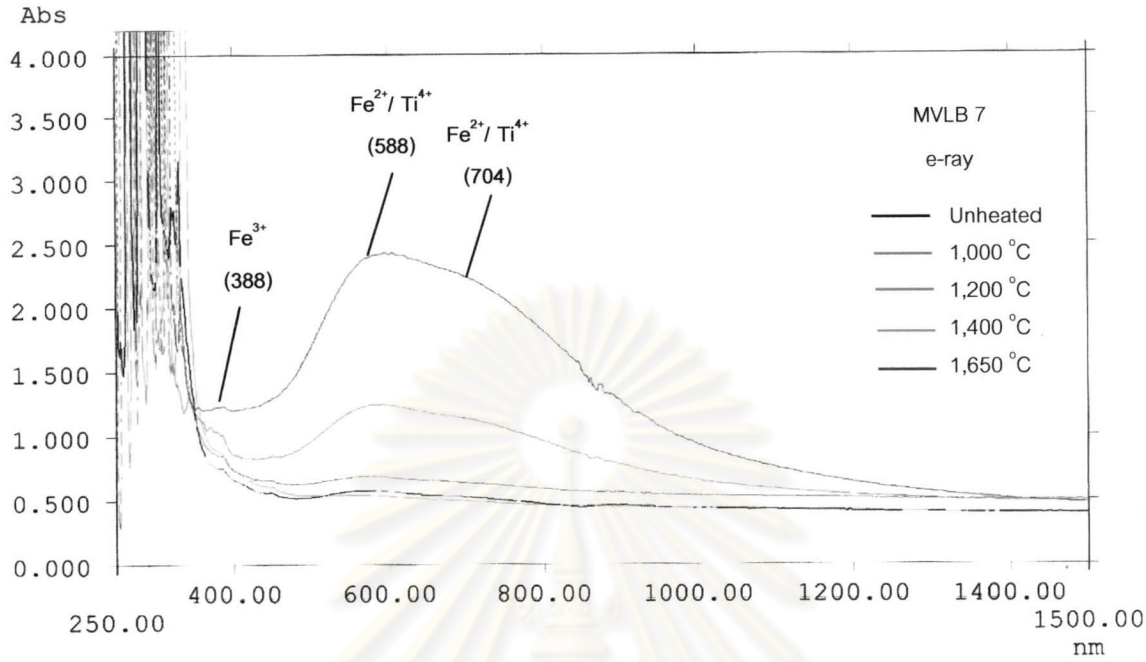


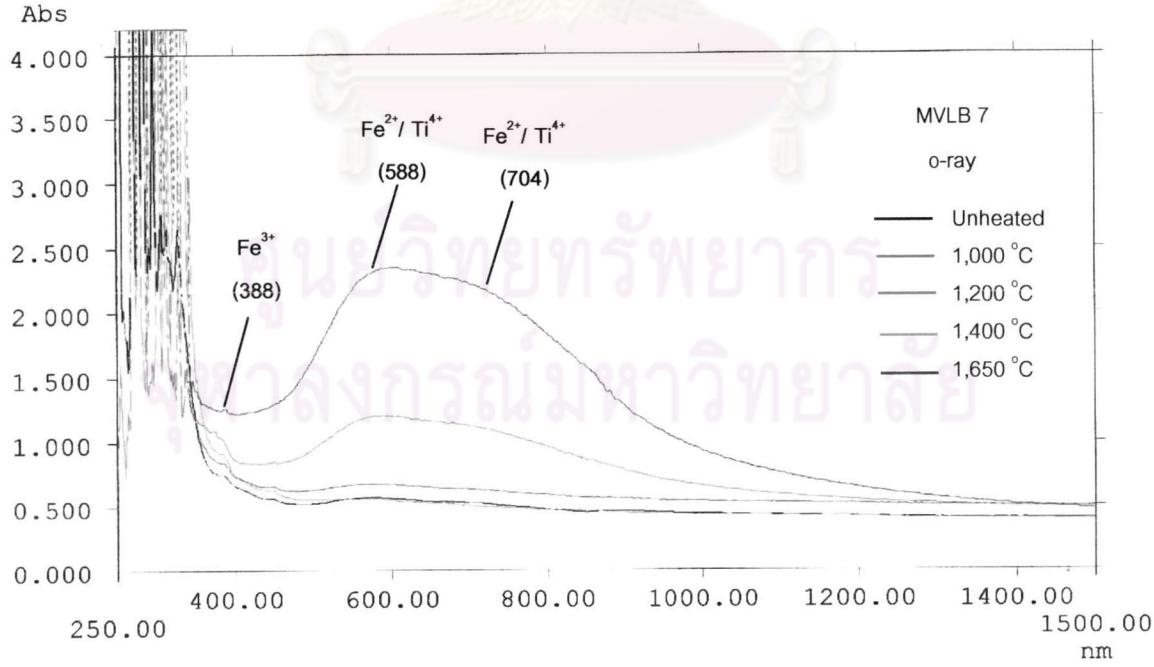


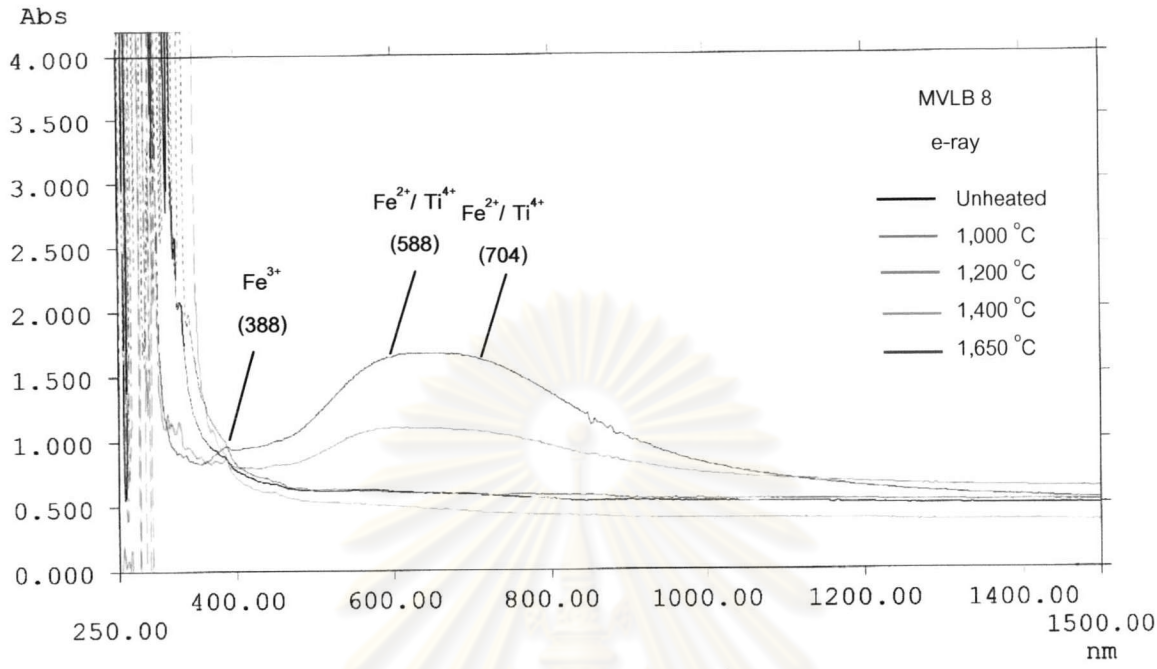


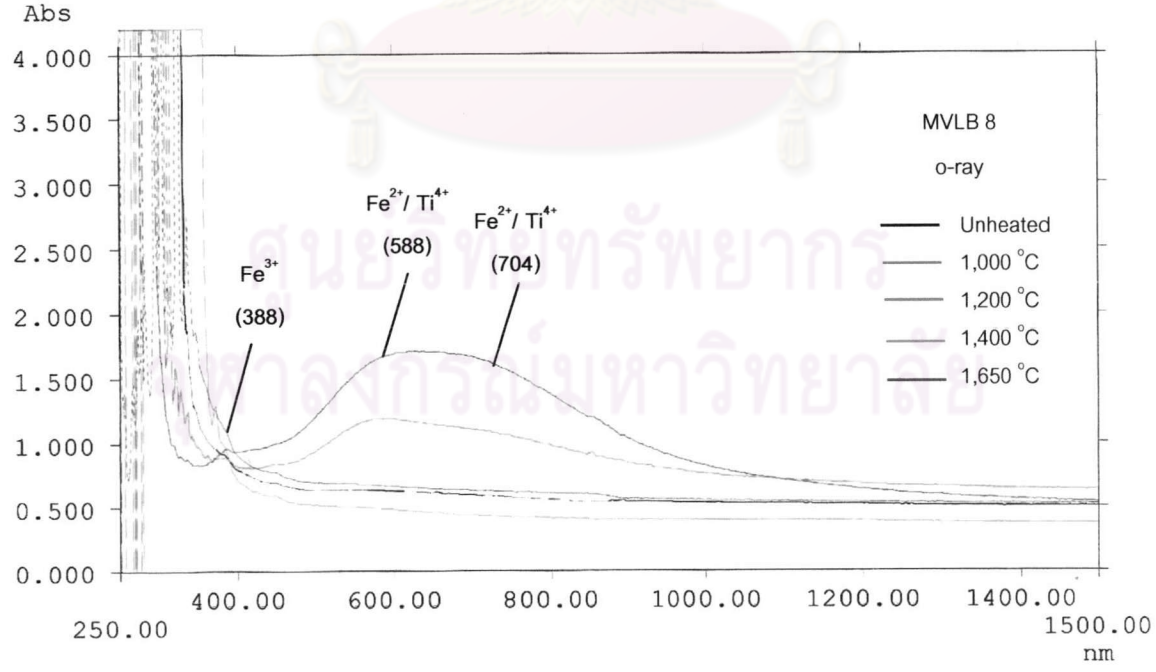


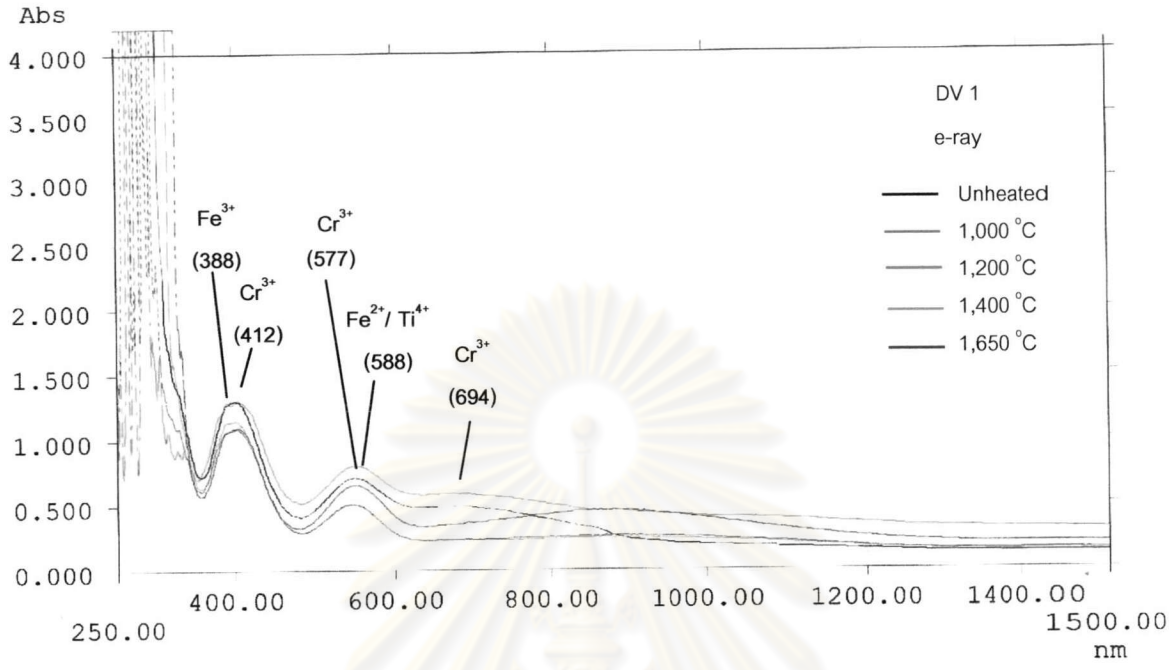


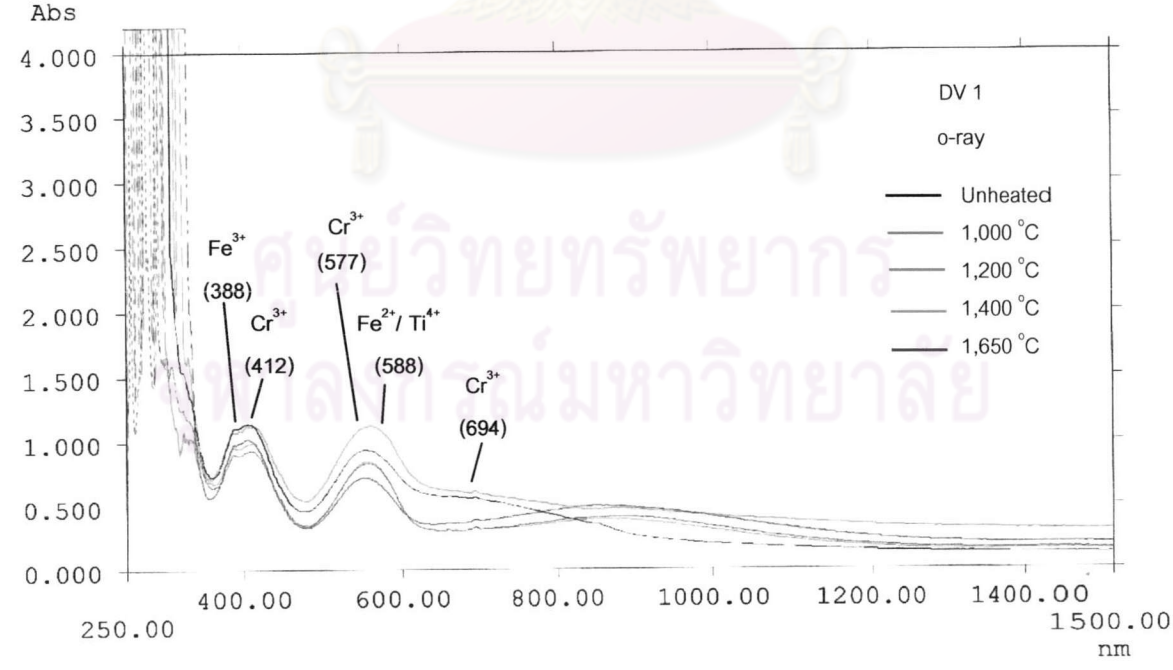

Abs
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
Fe3+
(388)
Fe2+/ Ti4+
(588)
Fe2+/ Ti4+
(704)
MVLB 7
e-ray
Unheated
1,000 °C
1,200 °C
1,400 °C
1,650 °C
250.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
1500.00
nm

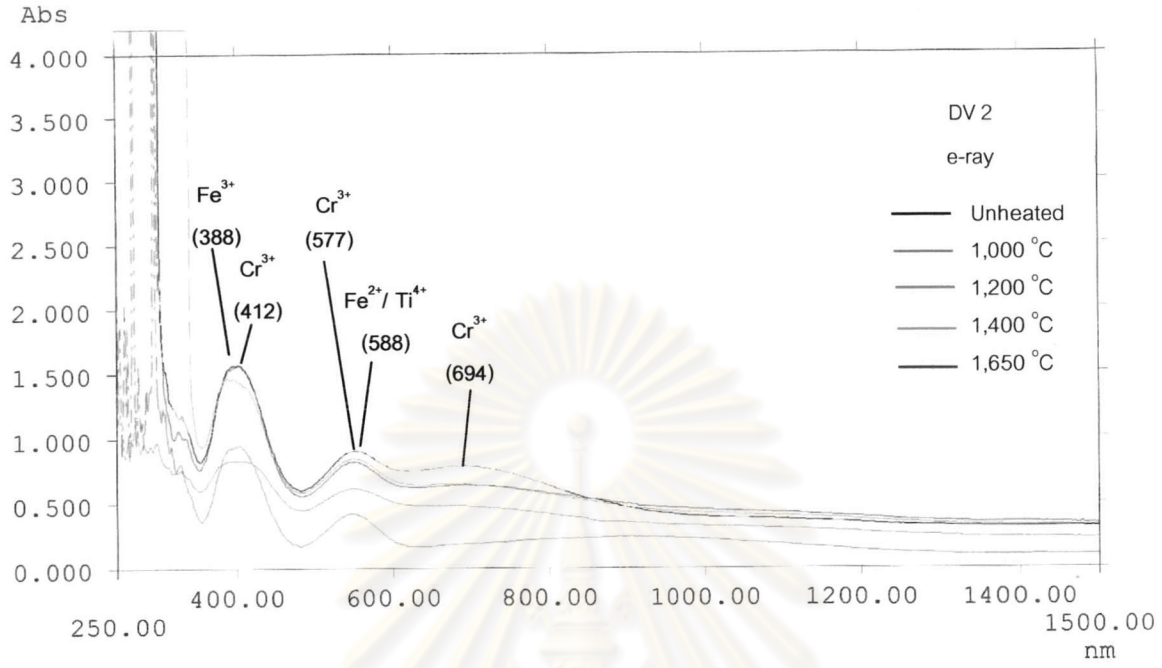

Abs
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
Fe3+
(388)
Fe2+/ Ti4+
(588)
Fe2+/ Ti4+
(704)
MVLB 7
o-ray
Unheated
1,000 °C
1,200 °C
1,400 °C
1,650 °C
250.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
1500.00
nm

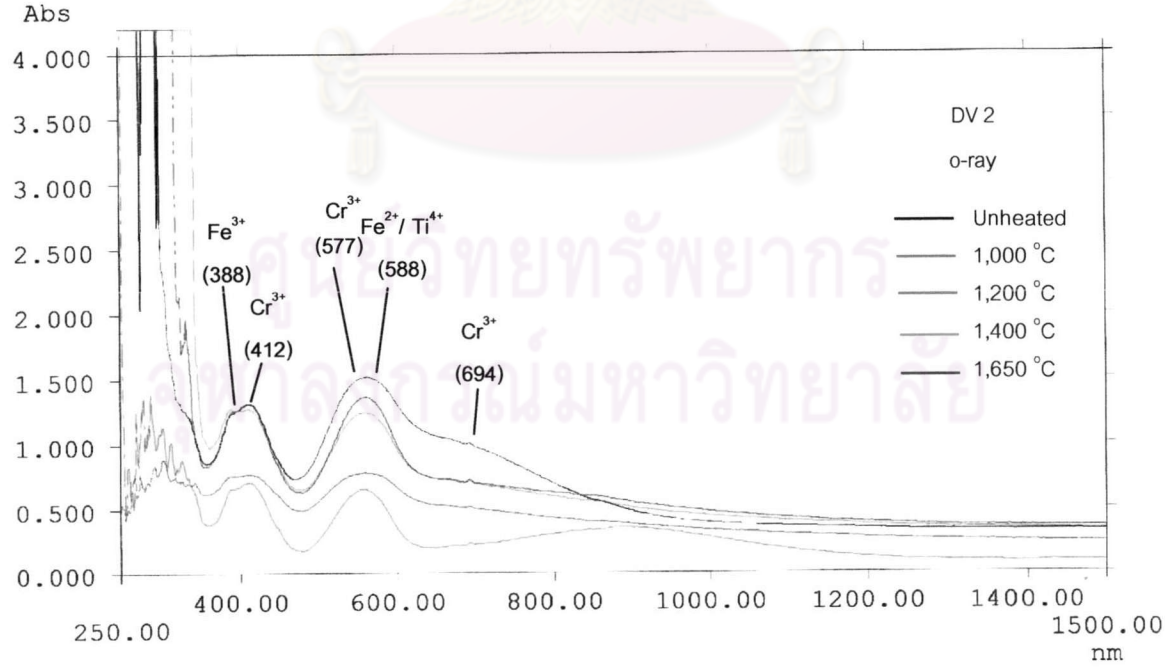


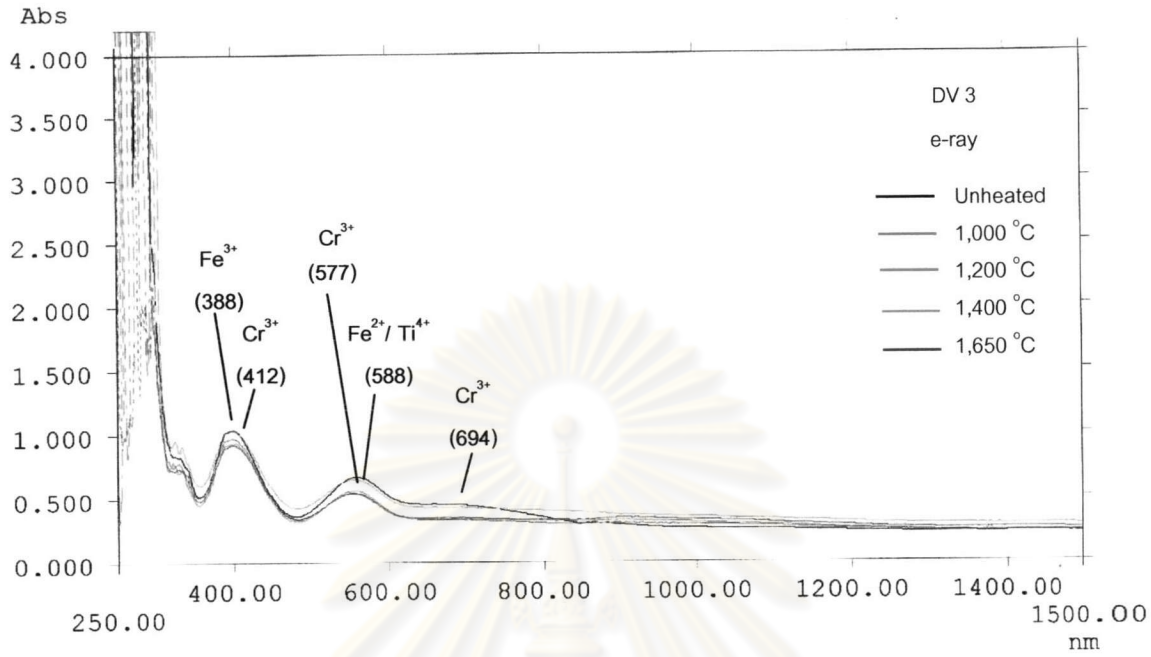


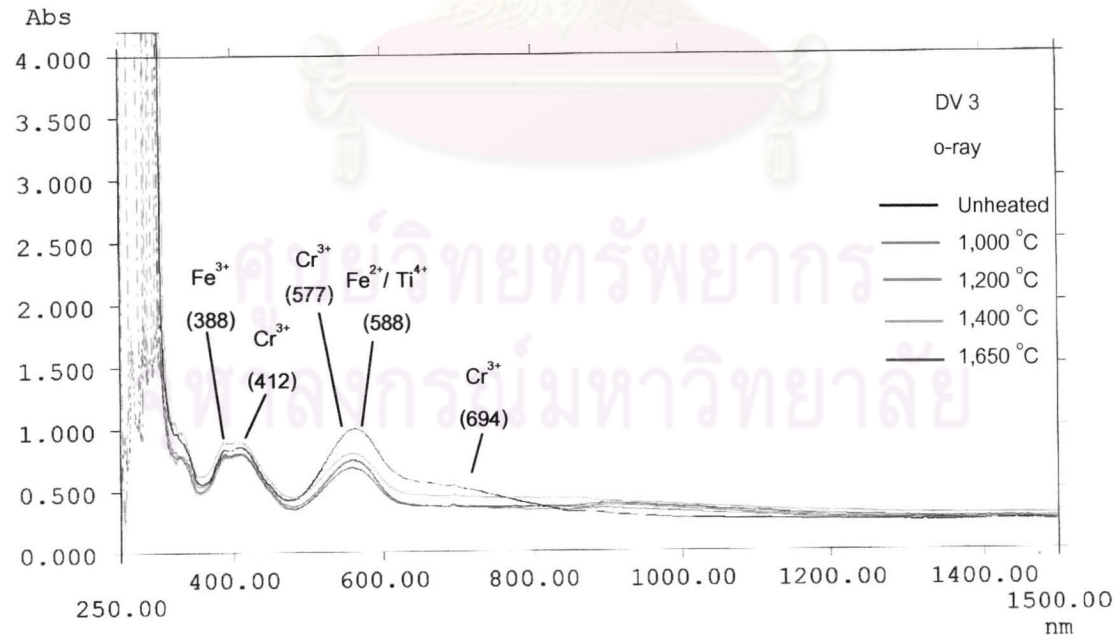


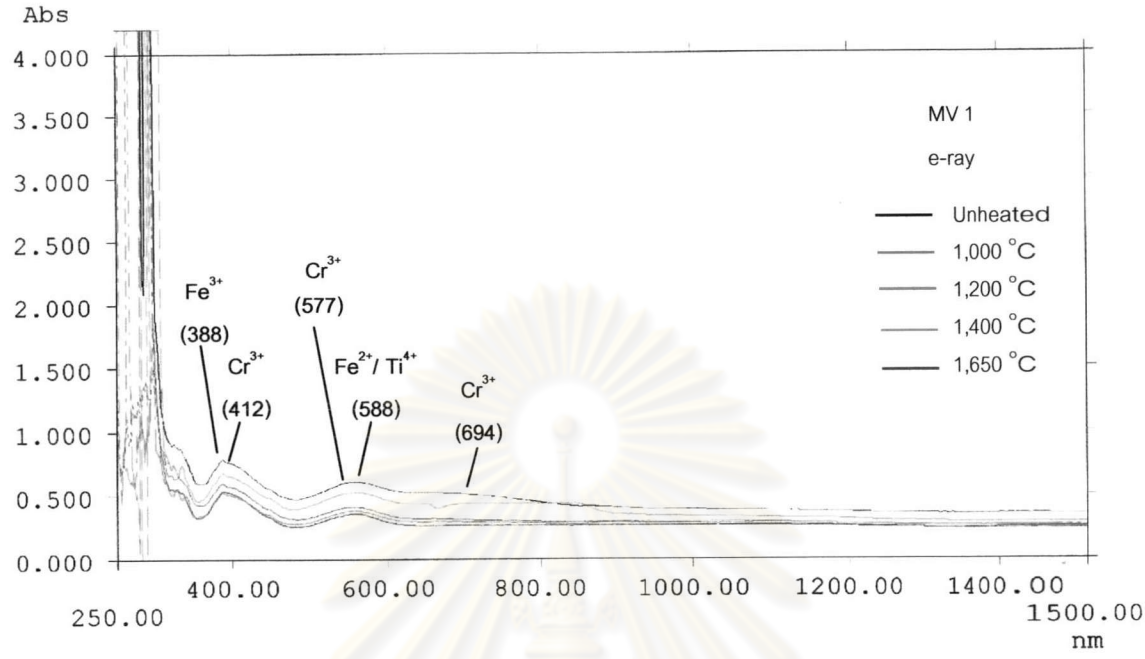


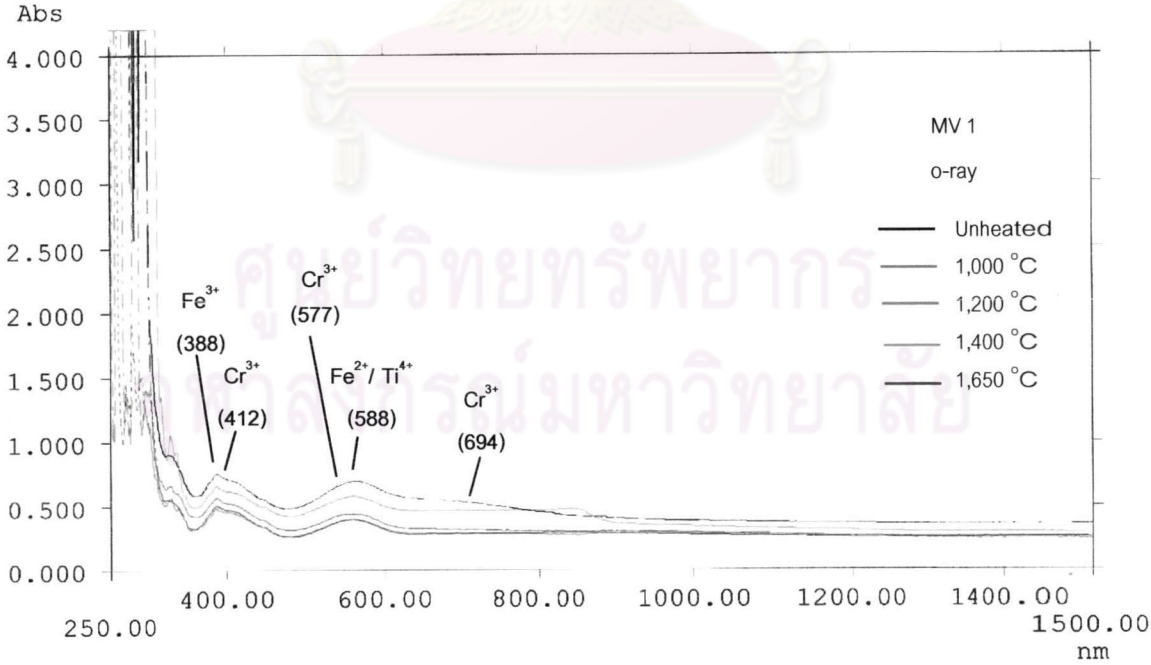

Abs
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
Fe3+
(388)
Cr3+
(412)
Cr3+
(577)
Fe2+/ Ti4+
(588)
Cr3+
(694)
DV 2
e-ray
Unheated
1,000 °C
1,200 °C
1,400 °C
1,650 °C
250.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
1500.00
nm

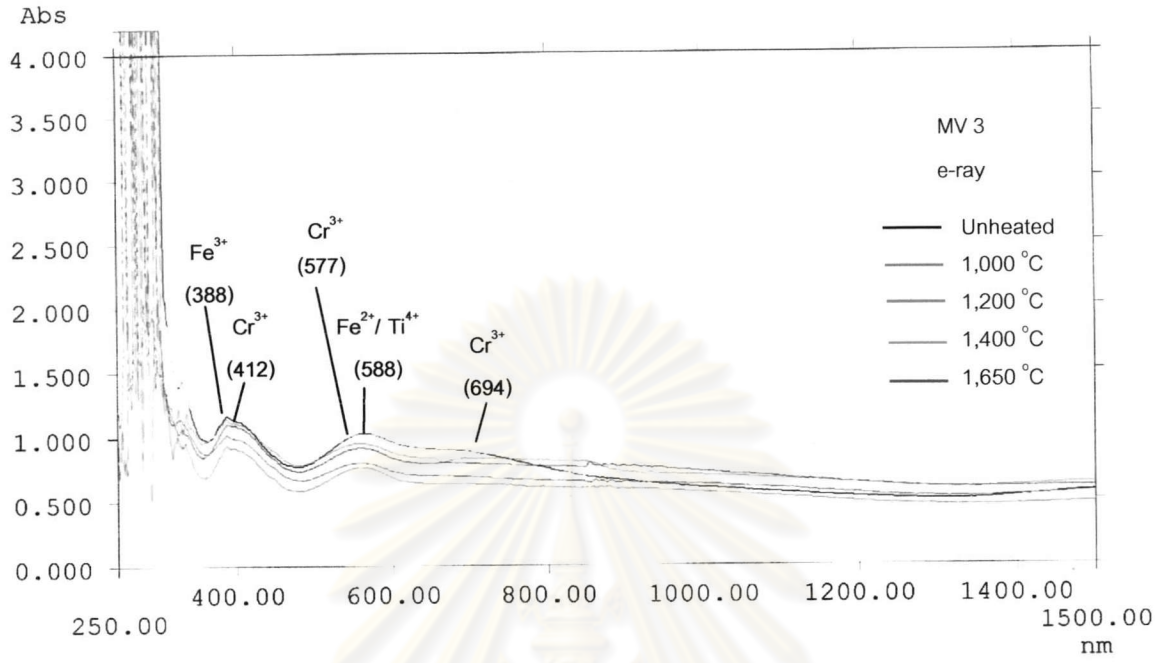

Abs
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
Fe3+
(388)
Cr3+
(412)
Cr3+
(577)
Fe2+/ Ti4+
(588)
Cr3+
(694)
DV 2
o-ray
Unheated
1,000 °C
1,200 °C
1,400 °C
1,650 °C
250.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
1500.00
nm

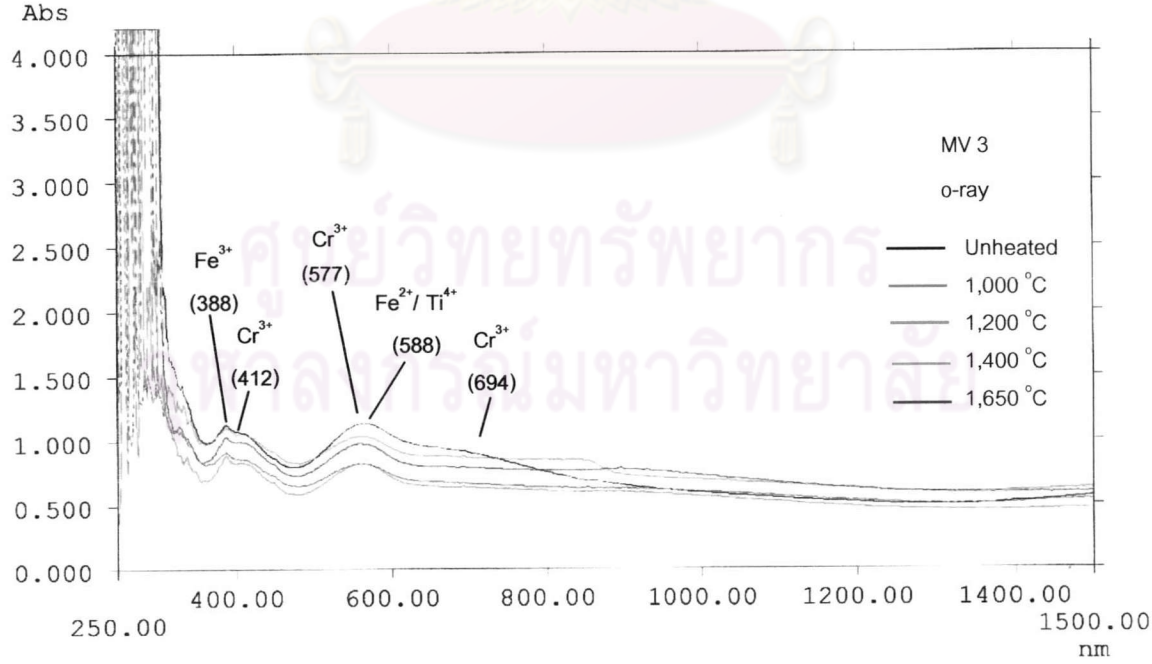


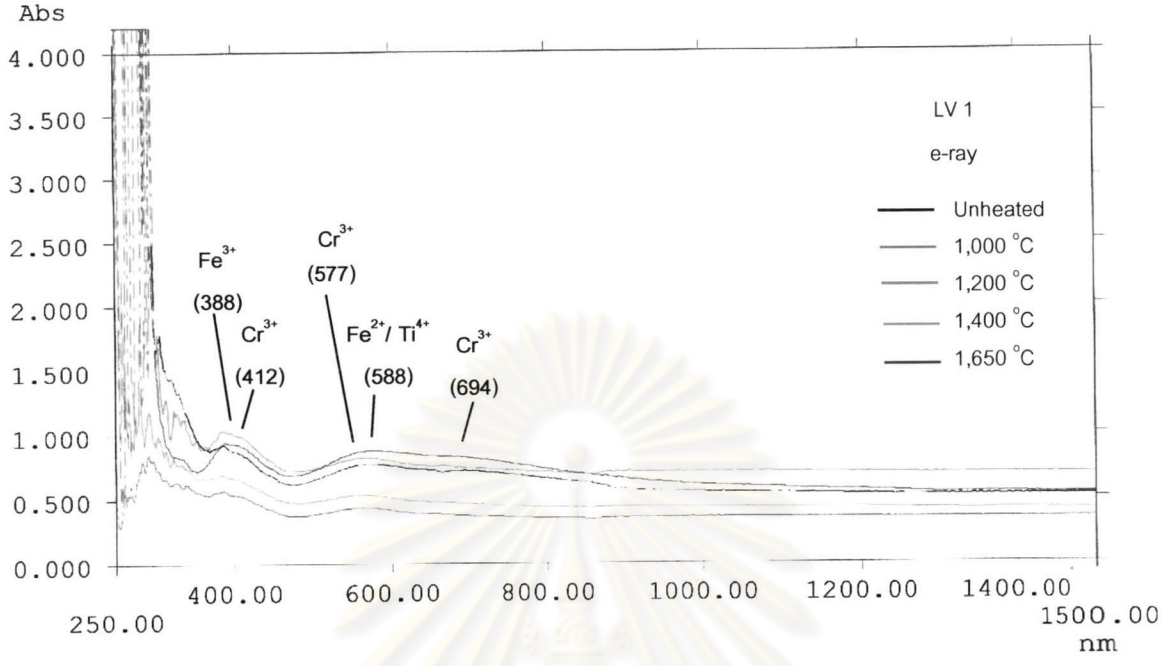


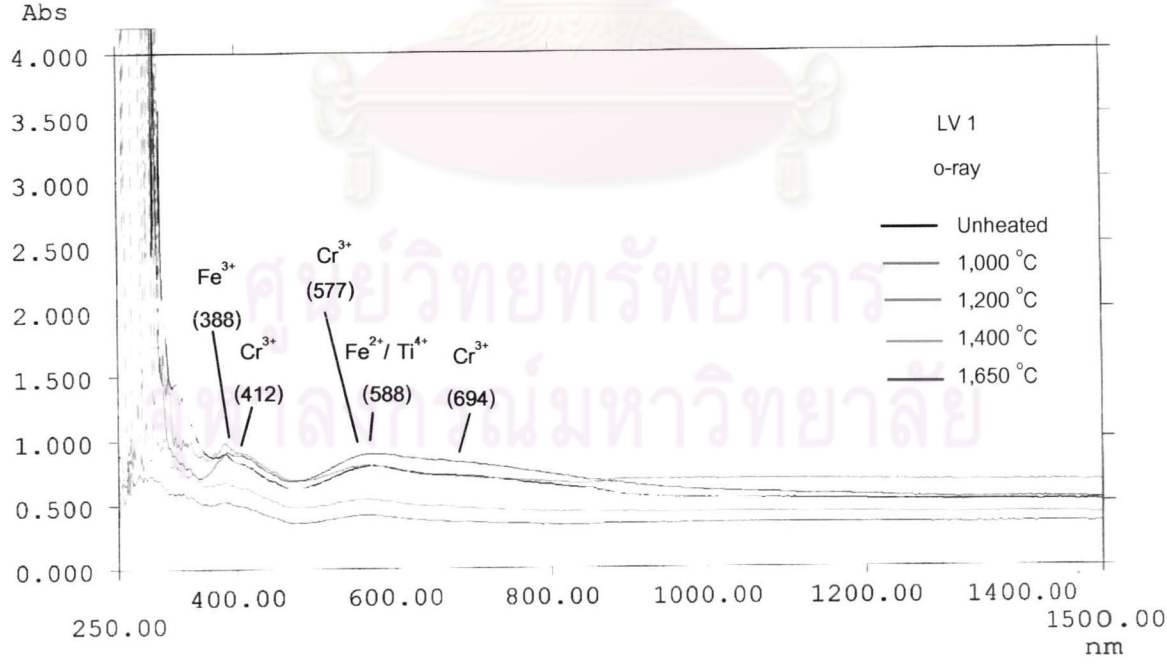


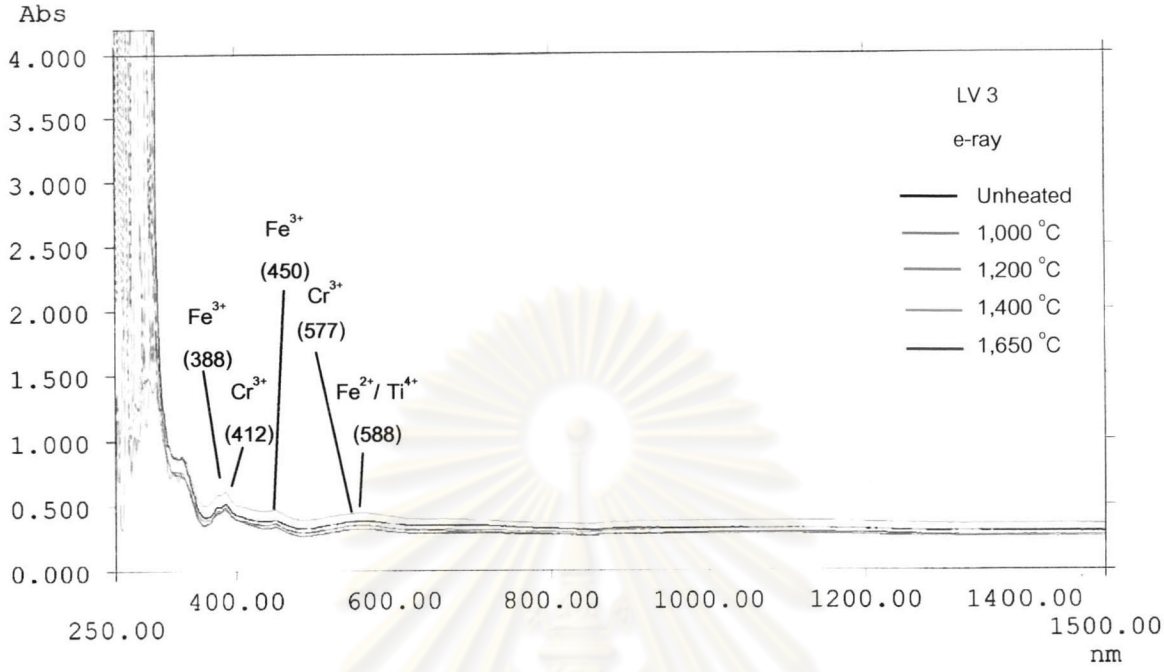


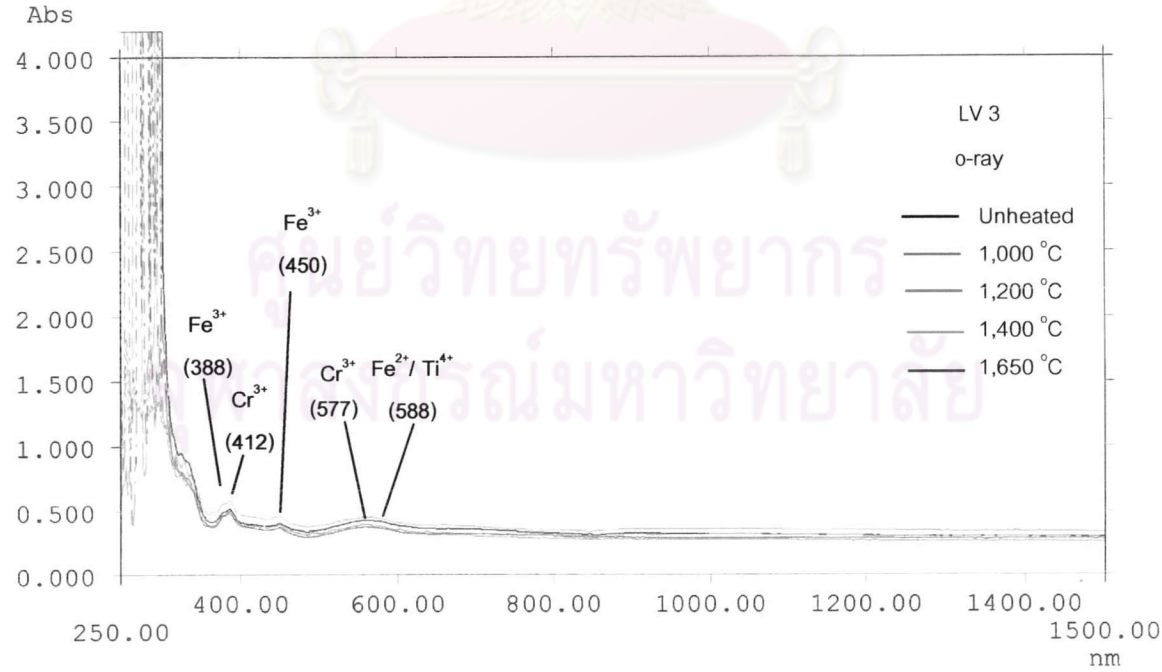












APPENDIX IV

Table IV.1 Showing trace element content of some Ilakaka– Sakaraha sapphires by Energy Dispersive X-ray Fluorescence (in weight %). The analyzes were performed before heating.

Table IV.2 Showing the major and trace elements content of some selected blue and violet sapphires by Electron Probe Micro-Analyzer. The analyzes were performed after step-heating up to 1650 ^{o}C.

Table IV.1 Showing trace element content of some Ilakaka – Sakaraha sapphires by Energy Dispersive X-ray Fluorescence (in weight %). The analyzes were performed before heating.

Sample No.	Al_2O_3 (wt%)	Cr_2O_3 (wt%)	Fe_2O_3 (wt%)	Ga_2O_3 (wt%)	TiO_2 (wt%)	V_2O_5 (wt%)
IDB1	99.5123	0.0889	0.3872	0.0147	0.0720	0.0050
IDB2	99.4080	0.0855	0.4458	0.0151	0.0298	0.0157
IDB3	99.4387	0.0902	0.4173	0.0114	0.0275	0.0148
IDB4	99.4876	0.0259	0.3479	0.0198	0.1123	0.0063
IDB5	99.5633	0.0157	0.2554	0.0256	0.1275	0.0122
IDB6	99.7227	0.0065	0.1517	0.0259	0.0898	0.0032
DB1	99.8221	0.0037	0.0963	0.0256	0.0513	0.0008
DB2	99.6271	0.0350	0.2960	0.0087	0.0251	0.0081
DB3	99.7358	0.0092	0.1391	0.0213	0.0919	0.0026
DB4	99.5718	0.0748	0.2856	0.0110	0.0471	0.0133
DB5	99.4488	0.1315	0.3898	0.0088	0.0265	0.0082
IMB1	99.5445	0.0059	0.4017	0.0238	0.0214	0.0023
IMB2	99.8092	0.0000	0.1463	0.0156	0.0269	0.0019
IMB3	99.2727	0.0023	0.6640	0.0183	0.0397	0.0028
IMB4	99.6854	0.0000	0.2015	0.0266	0.0232	0.0015
IMB 5	99.8014	0.0018	0.1414	0.0102	0.0402	0.0049
MB1	99.4586	0.0106	0.4932	0.0125	0.0176	0.0074
MB2	99.6809	0.0079	0.2276	0.0136	0.0375	0.0024
MB3	99.7776	0.0081	0.1498	0.0133	0.0273	0.0060
MB4	99.7257	0.0050	0.2018	0.0233	0.0426	0.0014
MB5	99.6689	0.0088	0.2834	0.0239	0.0146	0.0001
MB6	99.7877	0.0021	0.1879	0.0041	0.0175	0.0006
MB7	99.5926	0.0095	0.3374	0.0196	0.0391	0.0017
MB8	99.7082	0.0357	0.2006	0.0079	0.0391	0.0017
MB9	99.6282	0.0500	0.2591	0.0147	0.0420	0.0059
MB10	99.8205	0.0155	0.1223	0.0211	0.0157	0.0048

Table IV.1 Showing trace element content of some Ilakaka – Sakaraha sapphires by Energy Dispersive X-ray Fluorescence (in weight %). The analyzes were performed before heating. (continued)

Sample No.	Al_2O_3 (wt%)	Cr_2O_3 (wt%)	Fe_2O_3 (wt%)	Ga_2O_3 (wt%)	TiO_2 (wt%)	V_2O_5 (wt%)
IVLB1	99.7816	0.0081	0.1457	0.0087	0.0489	0.0069
IVLB2	99.5663	0.0009	0.3903	0.0095	0.0298	0.0030
IVLB4	99.3824	0.0118	0.4868	0.0359	0.0808	0.0023
IVLB5	99.6753	0.0066	0.2088	0.0117	0.0921	0.0054
VLB1	99.7735	0.0049	0.1706	0.0163	0.0346	0.0000
VLB2	99.6898	0.0086	0.1665	0.0119	0.1179	0.0050
VLB3	99.7594	0.0038	0.1687	0.0219	0.0427	0.0033
VLB4	99.6730	0.0067	0.2170	0.0169	0.0819	0.0044
VLB5	99.7333	0.0007	0.1892	0.0205	0.0525	0.0035
VLB6	99.7501	0.0105	0.1970	0.0128	0.0266	0.0028
VLB7	99.7473	0.0053	0.1952	0.0188	0.0308	0.0025
MVLB1	99.6853	0.0031	0.2287	0.0252	0.0552	0.0025
MVLB2	99.7018	0.0059	0.2351	0.0155	0.0389	0.0027
MVLB3	99.5813	0.0058	0.1183	0.0127	0.2737	0.0081
MVLB5	99.7616	0.0020	0.1615	0.0184	0.0504	0.0060
MVLB6	99.8333	0.0062	0.1001	0.0113	0.0457	0.0029
MVLB7	99.7237	0.0065	0.1591	0.0068	0.1001	0.0037
MVLB8	99.7467	0.0010	0.1647	0.0180	0.0675	0.0019
DV1	99.5751	0.1156	0.2756	0.0157	0.0143	0.0036
DV2	99.5033	0.1428	0.2814	0.0196	0.0400	0.0128
DV3	99.4060	0.1359	0.3870	0.0162	0.0447	0.0101
MV1	99.5674	0.0476	0.3281	0.0192	0.0443	0.0048
MV3	99.5756	0.0530	0.3263	0.0076	0.0289	0.0083
LV1	99.7408	0.0148	0.1550	0.0193	0.0595	0.0104
LV2	99.7197	0.0231	0.2001	0.0173	0.0377	0.0019
LV3	99.4052	0.0266	0.5035	0.0184	0.0439	0.0023

Table IV.2 Showing the major and trace elements content of some selected blue and violet sapphires by Electron Probe Micro-Analyzer. The analyzes were performed after step-heating up to 1650 °C.

	Dark blue sapphire type														
	db1.1/1	db1.1/2	db1.1/3	db3.1/1	db3.1/2	db3.1/3	db3.2/1	db3.2/2	db3.2/3	db5.1/1	db5.1/2	db5.1/3	db5.2/1	db5.2/2	db5.2/3
Al_2O_3	100.02	100.07	99.45	99.72	100.20	99.75	99.87	99.68	99.61	99.07	99.53	99.11	99.42	99.39	99.59
TiO_2	0.02	0.02	0.01	0.09	0.08	0.07	0.05	0.05	0.05	0.03	0.02	0.02	0.01	0.01	0.01
V_2O_3	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.01
Ga_2O_3	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.03	0.00	0.01	0.00	0.01	0.00	0.01
FeO	0.04	0.05	0.05	0.05	0.06	0.06	0.05	0.05	0.05	0.27	0.27	0.27	0.26	0.26	0.28
SiO_2	0.03	0.03	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.04	0.06	0.05	0.04	0.03	0.03
Cr_2O_3	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.09	0.08	0.09	0.08	0.08	0.08
MnO	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01
MgO	0.00	0.00	0.00	0.04	0.04	0.02	0.01	0.00	0.00	0.02	0.02	0.01	0.01	0.00	0.01
Total	100.14	100.17	99.54	99.96	100.42	99.95	100.02	99.82	99.77	99.51	99.99	99.56	99.84	99.77	100.02
Formula 3(O)															
Al	1.9982	1.9984	1.9986	1.9962	1.9965	1.9969	1.9976	1.9978	1.9976	1.9937	1.9933	1.9936	1.9941	1.9948	1.9941
Ti	0.0002	0.0002	0.0001	0.0012	0.0010	0.0009	0.0006	0.0006	0.0006	0.0004	0.0003	0.0002	0.0002	0.0001	0.0001
V	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0001	0.0001	0.0001	0.0000	0.0001
Ga	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0002	0.0003	0.0000	0.0001	0.0000	0.0001	0.0000	0.0001
Fe	0.0005	0.0006	0.0006	0.0007	0.0007	0.0008	0.0006	0.0006	0.0006	0.0035	0.0034	0.0035	0.0034	0.0033	0.0036
Si	0.0004	0.0004	0.0003	0.0003	0.0005	0.0005	0.0005	0.0004	0.0004	0.0007	0.0009	0.0008	0.0006	0.0005	0.0005
Cr	0.0000	0.0000	0.0000	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0012	0.0011	0.0012	0.0011	0.0011	0.0011
Mn	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001
Mg	0.0000	0.0000	0.0000	0.0011	0.0009	0.0006	0.0003	0.0000	0.0000	0.0004	0.0005	0.0003	0.0003	0.0000	0.0003
Total*	1.9998	1.9998	1.9998	1.9999	1.9998	1.9997	1.9998	1.9997	1.9997	1.9998	1.9997	1.9998	1.9998	1.9998	1.9999
Mg^{2+}	0.000	0.000	0.000	37.016	33.612	24.411	17.411	0.000	0.000	10.094	10.851	8.209	6.675	0.000	6.416
Fe_{total}	71.195	72.316	83.934	23.462	27.628	35.283	43.061	50.011	51.557	80.919	81.849	85.738	88.610	96.270	90.347
Ti^{4+}	28.805	27.684	16.066	39.521	38.760	40.306	39.528	49.989	48.443	8.987	7.299	6.053	4.715	3.730	3.237

Table IV.2 Showing the major and trace elements content of some selected blue and violet sapphires by Electron Probe Micro-Analyzer. The analyzes were performed after step-heating up to 1650 °C. (continued)

	Dark blue sapphire type														
	idb1.1/1	idb1.1/2	idb1.1/3	idb1.2/1	idb1.2/2	idb1.2/3	idb1.3/1	idb1.3/2	idb1.3/3	idb3.1/1	idb3.1/2	idb3.1/3	idb3.2/1	idb3.2/2	idb3.2/3
Al_2O_3	99.58	99.65	99.70	99.90	99.81	99.74	99.63	99.73	99.40	99.66	99.50	99.75	99.72	99.76	99.76
TiO_2	0.07	0.06	0.05	0.05	0.06	0.05	0.06	0.06	0.05	0.01	0.02	0.02	0.02	0.02	0.02
V_2O_3	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.02	0.01	0.02	0.02	0.01	0.01
Ga_2O_3	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.02	0.01	0.02	0.01	0.02	0.01
FeO	0.25	0.25	0.25	0.26	0.25	0.26	0.23	0.23	0.22	0.29	0.29	0.29	0.37	0.37	0.36
SiO_2	0.03	0.04	0.04	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.01
Cr_2O_3	0.04	0.04	0.04	0.05	0.05	0.04	0.05	0.05	0.04	0.11	0.11	0.10	0.04	0.05	0.05
MnO	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
MgO	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.01
Total	100.00	100.07	100.09	100.32	100.21	100.13	100.02	100.09	99.74	100.15	99.97	100.22	100.20	100.27	100.24
Formula 3(O)															
Al	1.9941	1.9940	1.9944	1.9942	1.9945	1.9946	1.9945	1.9950	1.9953	1.9935	1.9936	1.9937	1.9935	1.9931	1.9936
Ti	0.0009	0.0007	0.0006	0.0007	0.0007	0.0006	0.0008	0.0007	0.0006	0.0002	0.0002	0.0002	0.0002	0.0003	0.0002
V	0.0002	0.0002	0.0000	0.0001	0.0002	0.0001	0.0001	0.0000	0.0001	0.0003	0.0001	0.0002	0.0002	0.0002	0.0001
Ga	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001
Fe	0.0032	0.0032	0.0032	0.0033	0.0032	0.0033	0.0030	0.0029	0.0028	0.0037	0.0038	0.0037	0.0047	0.0048	0.0046
Si	0.0005	0.0007	0.0007	0.0004	0.0003	0.0003	0.0004	0.0003	0.0003	0.0003	0.0004	0.0004	0.0004	0.0005	0.0002
Cr	0.0005	0.0006	0.0005	0.0006	0.0007	0.0006	0.0006	0.0006	0.0005	0.0014	0.0015	0.0014	0.0006	0.0006	0.0007
Mn	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
Mg	0.0000	0.0003	0.0002	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0003	0.0000	0.0003	0.0003	0.0003
Total*	1.9996	1.9996	1.9997	1.9997	1.9997	1.9997	1.9996	1.9997	1.9997	2.0000	1.9999	1.9998	1.9999	1.9998	1.9999
Mg^{2+}	0.000	6.138	5.719	5.900	0.000	0.000	0.000	0.000	0.000	6.100	6.007	0.000	4.943	4.800	4.968
Fe_{total}	78.824	76.521	79.535	78.025	82.207	83.940	79.188	80.572	82.096	90.207	89.143	95.100	91.316	90.358	91.272
Ti^{4+}	21.176	17.341	14.746	16.074	17.793	16.060	20.812	19.428	17.904	3.693	4.849	4.900	3.741	4.843	3.760

Table IV.2 Showing the major and trace elements content of some selected blue and violet sapphires by Electron Probe Micro-Analyzer. The analyzes were performed after step-heating up to 1650 °C. (continued)

	Dark blue sapphire type														
	idb5.1/1	idb5.1/2	idb5.1/3	idb5.2/1	idb5.2/2	idb5.2/3	idb6.1/1	idb6.1/2	idb6.1/3	idb6.2/1	idb6.2/2	idb6.2/3	idb6.3/1	idb6.3/2	idb6.3/3
Al_2O_3	99.97	99.93	100.00	100.02	99.49	99.90	100.29	100.09	100.07	100.28	100.21	100.42	99.93	100.10	99.90
TiO_2	0.17	0.18	0.05	0.18	0.40	0.13	0.05	0.06	0.07	0.01	0.01	0.02	0.05	0.05	0.04
V_2O_3	0.02	0.01	0.00	0.02	0.02	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Ga_2O_3	0.03	0.03	0.01	0.01	0.03	0.02	0.03	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02
FeO	0.24	0.26	0.09	0.24	0.31	0.21	0.12	0.13	0.11	0.07	0.07	0.08	0.12	0.11	0.10
SiO_2	0.03	0.03	0.02	0.03	0.04	0.04	0.02	0.02	0.03	0.02	0.02	0.02	0.03	0.02	0.04
Cr_2O_3	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00
MnO	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.01
MgO	0.01	0.01	0.00	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Total	100.48	100.44	100.20	100.51	100.32	100.33	100.54	100.34	100.33	100.40	100.35	100.57	100.16	100.31	100.12
Formula 3(O)															
Al	1.9924	1.9925	1.9971	1.9928	1.9873	1.9936	1.9965	1.9964	1.9962	1.9982	1.9981	1.9980	1.9966	1.9969	1.9967
Ti	0.0022	0.0022	0.0007	0.0022	0.0051	0.0017	0.0007	0.0008	0.0008	0.0001	0.0002	0.0002	0.0007	0.0006	0.0005
V	0.0003	0.0001	0.0000	0.0002	0.0002	0.0002	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ga	0.0003	0.0003	0.0001	0.0001	0.0003	0.0002	0.0003	0.0002	0.0003	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Fe	0.0030	0.0033	0.0012	0.0031	0.0040	0.0026	0.0016	0.0016	0.0015	0.0009	0.0009	0.0010	0.0015	0.0014	0.0013
Si	0.0005	0.0005	0.0003	0.0004	0.0007	0.0006	0.0004	0.0004	0.0004	0.0004	0.0003	0.0003	0.0004	0.0004	0.0006
Cr	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000
Mn	0.0001	0.0000	0.0001	0.0001	0.0000	0.0001	0.0001	0.0001	0.0001	0.0000	0.0001	0.0001	0.0001	0.0000	0.0001
Mg	0.0003	0.0003	0.0000	0.0004	0.0006	0.0003	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0003	0.0003
Total*	1.9992	1.9992	1.9997	1.9993	1.9982	1.9994	1.9998	1.9997	1.9996	1.9998	1.9999	1.9999	1.9997	1.9997	1.9997
Mg^{2+}	5.898	5.640	0.000	6.669	6.001	7.024	10.119	0.000	0.000	0.000	0.000	0.000	10.439	11.271	12.023
Fe_{total}	54.731	56.057	63.275	54.079	41.217	56.450	62.312	67.752	63.697	87.956	83.957	83.877	61.121	60.299	62.502
Ti^{4+}	39.371	38.303	36.725	39.252	52.782	36.526	27.569	32.248	36.303	12.044	16.043	16.123	28.440	28.430	25.475

Table IV.2 Showing the major and trace elements content of some selected blue and violet sapphires by Electron Probe Micro-Analyzer. The analyzes were performed after step-heating up to 1650 °C. (continued)

	Dark blue sapphire type			Medium blue sapphire type											
	idb6.4/1	idb6.4/2	idb6.4/3	mb3.1/1	mb3.1/2	mb3.1/3	mb4.1/1	mb4.1/2	mb4.1/3	mb4.2/1	mb4.2/2	mb4.2/3	mb4.3/1	mb4.3/2	mb4.3/3
Al_2O_3	99.59	100.07	99.89	98.90	98.86	99.46	99.75	99.56	99.54	99.64	99.76	99.10	99.88	99.89	100.04
TiO_2	0.09	0.10	0.08	0.02	0.03	0.03	0.04	0.03	0.03	0.05	0.05	0.04	0.00	0.00	0.00
V_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01
Ga_2O_3	0.02	0.02	0.03	0.02	0.01	0.02	0.02	0.02	0.02	0.01	0.03	0.03	0.02	0.02	0.03
FeO	0.12	0.13	0.13	0.08	0.08	0.08	0.11	0.12	0.11	0.16	0.34	0.27	0.09	0.12	0.13
SiO_2	0.02	0.02	0.02	0.03	0.02	0.02	0.01	0.03	0.02	0.03	0.02	0.02	0.02	0.02	0.02
Cr_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01
MgO	0.01	0.00	0.01	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	99.87	100.34	100.16	99.06	99.01	99.63	99.94	99.75	99.72	99.89	100.21	99.47	100.02	100.06	100.23
Formula 3(O)															
Al	1.9959	1.9960	1.9961	1.9975	1.9977	1.9975	1.9974	1.9973	1.9975	1.9964	1.9939	1.9950	1.9980	1.9977	1.9974
Ti	0.0011	0.0013	0.0011	0.0003	0.0004	0.0004	0.0004	0.0003	0.0004	0.0007	0.0007	0.0006	0.0000	0.0000	0.0000
V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0001
Ga	0.0002	0.0002	0.0003	0.0002	0.0001	0.0002	0.0002	0.0002	0.0002	0.0001	0.0003	0.0003	0.0002	0.0002	0.0003
Fe	0.0016	0.0017	0.0016	0.0010	0.0010	0.0010	0.0015	0.0015	0.0013	0.0020	0.0044	0.0034	0.0012	0.0015	0.0016
Si	0.0004	0.0003	0.0003	0.0005	0.0003	0.0003	0.0002	0.0004	0.0003	0.0004	0.0003	0.0003	0.0004	0.0003	0.0003
Cr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Mn	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0001	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001
Mg	0.0003	0.0000	0.0003	0.0003	0.0003	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total*	1.9996	1.9995	1.9996	1.9998	1.9999	1.9999	1.9998	1.9997	1.9998	1.9996	1.9997	1.9998	1.9999	1.9999	1.9999
Mg^{2+}	8.585	0.000	8.623	18.464	17.908	21.611	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe_{total}	53.732	56.907	54.836	62.905	58.752	55.220	76.518	81.697	78.366	74.537	87.061	86.044	100.000	100.000	100.000
Ti^{4+}	37.683	43.093	36.541	18.630	23.340	23.169	23.482	18.303	21.634	25.463	12.939	13.956	0.000	0.000	0.000

Table IV.2 Showing the major and trace elements content of some selected blue and violet sapphires by Electron Probe Micro-Analyzer. The analyzes were performed after step-heating up to 1650 °C. (continued)

Medium blue sapphire type

	mb9.1/1	mb9.1/2	mb9.1/3	mb9.1/4	mb9.2/1	mb9.2/2	mb9.2/3	mb9.3/1	mb9.3/2	mb9.3/3	imb1.1/1	imb1.1/2	imb1.1/3	vlb1.1/1	vlb1.1/2
Al_2O_3	100.01	99.71	99.47	99.09	98.97	99.22	99.43	99.07	98.55	98.44	99.65	99.62	99.45	99.39	99.35
TiO_2	0.00	0.01	0.01	0.01	0.09	0.10	0.08	0.03	0.01	0.01	0.01	0.01	0.01	0.02	0.03
V_2O_3	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Ga_2O_3	0.01	0.00	0.01	0.01	0.00	0.02	0.01	0.01	0.00	0.01	0.01	0.01	0.02	0.00	0.01
FeO	0.14	0.14	0.18	0.19	0.17	0.17	0.16	0.18	0.14	0.15	0.33	0.33	0.34	0.12	0.08
SiO_2	0.03	0.02	0.03	0.02	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.03	0.04	0.02	0.03
Cr_2O_3	0.02	0.02	0.02	0.02	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00
MnO	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01
MgO	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.00
Total	100.23	99.91	99.72	99.35	99.28	99.55	99.73	99.33	98.75	98.64	100.04	100.03	99.87	99.56	99.52
Formula 3(O)															
Al	1.9970	1.9973	1.9964	1.9963	1.9952	1.9951	1.9955	1.9964	1.9971	1.9972	1.9948	1.9944	1.9943	1.9975	1.9975
Ti	0.0000	0.0001	0.0002	0.0001	0.0011	0.0012	0.0011	0.0003	0.0002	0.0001	0.0002	0.0002	0.0001	0.0003	0.0004
V	0.0000	0.0000	0.0000	0.0001	0.0000	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ga	0.0001	0.0000	0.0001	0.0001	0.0000	0.0002	0.0001	0.0001	0.0000	0.0002	0.0002	0.0001	0.0002	0.0000	0.0001
Fe	0.0018	0.0018	0.0023	0.0025	0.0021	0.0021	0.0021	0.0023	0.0018	0.0019	0.0042	0.0042	0.0043	0.0015	0.0011
Si	0.0005	0.0003	0.0005	0.0004	0.0007	0.0004	0.0005	0.0004	0.0004	0.0004	0.0004	0.0005	0.0006	0.0004	0.0005
Cr	0.0003	0.0002	0.0003	0.0003	0.0000	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000
Mn	0.0002	0.0001	0.0000	0.0000	0.0001	0.0002	0.0000	0.0001	0.0001	0.0001	0.0000	0.0000	0.0001	0.0001	0.0001
Mg	0.0000	0.0000	0.0000	0.0000	0.0002	0.0003	0.0000	0.0000	0.0003	0.0000	0.0002	0.0003	0.0003	0.0000	0.0000
Total*	1.9999	1.9999	1.9998	1.9998	1.9995	1.9996	1.9995	1.9998	1.9999	1.9999	1.9999	1.9999	1.9999	1.9998	1.9997
Mg^{2+}	0.000	0.000	0.000	0.000	6.585	7.082	0.000	0.000	11.334	0.000	4.969	5.431	5.416	0.000	0.000
Fe_{total}	100.000	93.467	93.370	95.502	61.671	58.977	66.132	87.505	80.661	94.158	91.688	91.007	91.851	82.985	70.699
Ti^{4+}	0.000	6.533	6.630	4.498	31.745	33.941	33.868	12.495	8.005	5.842	3.343	3.562	2.732	17.015	29.301

Table IV.2 Showing the major and trace elements content of some selected blue and violet sapphires by Electron Probe Micro-Analyzer. The analyzes were performed after step-heating up to 1650 °C. (continued)

	Very light blue sapphire type															
	vlb1.1/3	vlb1.2/1	vlb1.2/2	vlb1.2/3	vlb1.3/1	vlb1.3/2	vlb1.3/3	vlb2.1/1	vlb2.1/2	vlb2.1/3	vlb2.2/1	vlb2.2/2	vlb2.2/3	vlb4.1/1	vlb4.1/2	vlb4.1/3
Al_2O_3	99.54	100.08	99.86	99.87	100.19	100.28	100.32	100.15	99.92	99.64	99.73	99.14	98.43	99.37	99.58	99.77
TiO_2	0.02	0.07	0.07	0.07	0.03	0.03	0.03	0.05	0.05	0.09	0.06	0.06	0.06	0.14	0.17	0.15
V_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
Ga_2O_3	0.01	0.01	0.01	0.02	0.00	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01
FeO	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.09	0.09	0.11	0.10	0.10	0.11	0.13	0.13	0.13
SiO_2	0.05	0.02	0.02	0.02	0.03	0.03	0.02	0.03	0.02	0.02	0.04	0.04	0.09	0.02	0.02	0.01
Cr_2O_3	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00
MnO	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.01	0.01
MgO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.03	0.03	0.03	0.02	0.02
Total	99.70	100.27	100.05	100.07	100.33	100.43	100.49	100.35	100.12	99.91	99.98	99.39	98.75	99.71	99.94	100.09
Formula 3(O)																
Al	1.9975	1.9972	1.9971	1.9970	1.9978	1.9977	1.9976	1.9970	1.9971	1.9960	1.9961	1.9961	1.9946	1.9947	1.9945	1.9951
Ti	0.0002	0.0009	0.0008	0.0009	0.0004	0.0004	0.0004	0.0006	0.0007	0.0011	0.0007	0.0007	0.0008	0.0018	0.0021	0.0019
V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0000	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000
Ga	0.0001	0.0001	0.0001	0.0002	0.0000	0.0001	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0002	0.0002	0.0001	0.0002
Fe	0.0011	0.0011	0.0011	0.0010	0.0010	0.0011	0.0010	0.0011	0.0012	0.0014	0.0013	0.0013	0.0014	0.0016	0.0017	0.0016
Si	0.0008	0.0003	0.0003	0.0004	0.0005	0.0004	0.0004	0.0004	0.0003	0.0004	0.0006	0.0006	0.0016	0.0004	0.0003	0.0002
Cr	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000
Mn	0.0000	0.0001	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0001	0.0000	0.0001	0.0000	0.0001	0.0001
Mg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0003	0.0004	0.0007	0.0008	0.0007	0.0008	0.0005	0.0004
Total*	1.9997	1.9997	1.9996	1.9996	1.9997	1.9997	1.9998	1.9998	1.9998	1.9997	1.9998	1.9998	1.9995	1.9995	1.9994	1.9995
Mg^{2+}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	16.124	14.825	12.883	26.547	28.639	24.264	19.793	10.595	11.093
Fe_{total}	84.621	56.785	57.154	54.011	72.486	73.693	70.545	54.465	54.106	48.986	47.128	46.075	48.533	38.145	39.514	41.170
Ti^{4+}	15.379	43.215	42.846	45.989	27.514	26.307	29.455	29.411	31.069	38.131	26.325	25.285	27.203	42.062	49.891	47.736

Table IV.2 Showing the major and trace elements content of some selected blue and violet sapphires by Electron Probe Micro-Analyzer. The analyzes were performed after step-heating up to 1650 °C. (continued)

	Very light blue sapphire type														
	vlb4.2/1	vlb4.2/2	vlb4.2/3	vlb5.1/1	vlb5.1/2	vlb5.1/3	vlb6.1/1	vlb6.1/2	vlb6.1/3	ivlb2.1/1	ivlb2.1/2	ivlb2.1/3	ivlb2.2/1	ivlb2.2/2	ivlb2.2/3
Al_2O_3	99.19	99.61	99.40	100.27	99.84	100.06	98.81	98.76	98.59	100.44	100.29	100.23	100.55	100.12	100.31
TiO_2	0.02	0.02	0.01	0.04	0.03	0.05	0.01	0.00	0.01	0.03	0.04	0.03	0.01	0.01	0.01
V_2O_3	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Ga_2O_3	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.00	0.00	0.01	0.00	0.00	0.00
FeO	0.09	0.09	0.10	0.13	0.12	0.12	0.11	0.12	0.12	0.18	0.21	0.22	0.26	0.31	0.32
SiO_2	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02
Cr_2O_3	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01
MgO	0.01	0.01	0.01	0.03	0.01	0.02	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.00
Total	99.36	99.78	99.56	100.53	100.07	100.29	98.97	98.93	98.78	100.69	100.58	100.50	100.86	100.48	100.67
Formula 3(O)															
Al	1.9976	1.9976	1.9977	1.9961	1.9966	1.9965	1.9976	1.9976	1.9973	1.9965	1.9960	1.9963	1.9958	1.9953	1.9952
Ti	0.0003	0.0003	0.0002	0.0005	0.0004	0.0006	0.0001	0.0000	0.0001	0.0004	0.0004	0.0004	0.0002	0.0001	0.0001
V	0.0000	0.0000	0.0000	0.0001	0.0001	0.0000	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
Ga	0.0001	0.0002	0.0001	0.0002	0.0001	0.0001	0.0001	0.0002	0.0002	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000
Fe	0.0012	0.0012	0.0012	0.0017	0.0015	0.0016	0.0015	0.0016	0.0016	0.0023	0.0027	0.0028	0.0033	0.0040	0.0040
Si	0.0004	0.0003	0.0004	0.0006	0.0005	0.0004	0.0004	0.0004	0.0005	0.0003	0.0003	0.0003	0.0003	0.0004	0.0004
Cr	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Mn	0.0001	0.0001	0.0000	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0001	0.0001	0.0001
Mg	0.0003	0.0003	0.0003	0.0007	0.0004	0.0006	0.0000	0.0000	0.0000	0.0003	0.0003	0.0000	0.0003	0.0000	0.0000
Total*	1.9999	1.9999	1.9999	1.9999	1.9999	1.9999	1.9998	1.9999	1.9998	1.9999	1.9999	1.9998	2.0000	1.9999	1.9999
Mg^{2+}	14.589	14.589	15.147	23.413	15.520	21.960	0.000	0.000	0.000	8.736	7.371	0.000	6.860	0.000	0.000
Fe_{total}	69.218	67.746	74.155	58.649	67.702	57.267	91.873	100.000	92.427	78.924	79.614	88.759	88.987	96.886	96.638
Ti^{4+}	16.193	17.665	10.698	17.937	16.778	20.773	8.127	0.000	7.573	12.340	13.015	11.241	4.153	3.114	3.362

Table IV.2 Showing the major and trace elements content of some selected blue and violet sapphires by Electron Probe Micro-Analyzer. The analyzes were performed after step-heating up to 1650 °C. (continued)

	Very light blue type						Milky, very light blue								
	ivlb4.1/1	ivlb4.1/2	ivlb4.1/3	ivlb4.2/1	ivlb4.2/2	ivlb4.2/3	mvlb3.1/1	mvlb3.1/2	mvlb3.1/3	mvlb3.2/1	mvlb3.2/2	mvlb3.2/3	mvlb5.1/1	mvlb5.1/2	mvlb5.1/3
Al_2O_3	99.72	100.12	100.23	100.23	100.31	100.13	100.25	100.44	100.30	100.27	100.22	100.23	100.70	100.80	100.95
TiO_2	0.04	0.04	0.05	0.02	0.02	0.02	0.30	0.31	0.34	0.21	0.22	0.18	0.05	0.03	0.04
V_2O_3	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.01
Ga_2O_3	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.00	0.01	0.02	0.01	0.01	0.01
FeO	0.23	0.24	0.21	0.23	0.23	0.22	0.05	0.06	0.05	0.08	0.07	0.06	0.13	0.11	0.12
SiO_2	0.03	0.02	0.02	0.03	0.02	0.03	0.02	0.03	0.02	0.03	0.05	0.02	0.02	0.03	0.02
Cr_2O_3	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.01
MnO	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00
MgO	0.01	0.01	0.01	0.02	0.01	0.01	0.05	0.05	0.04	0.04	0.04	0.03	0.01	0.01	0.01
Total	100.05	100.44	100.55	100.56	100.62	100.43	100.70	100.92	100.78	100.62	100.61	100.55	100.93	101.01	101.17
Formula 3(O)															
Al	1.9953	1.9955	1.9955	1.9954	1.9958	1.9959	1.9927	1.9922	1.9922	1.9943	1.9936	1.9948	1.9966	1.9969	1.9968
Ti	0.0005	0.0005	0.0006	0.0002	0.0002	0.0003	0.0038	0.0040	0.0043	0.0027	0.0027	0.0023	0.0007	0.0004	0.0005
V	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0002	0.0000	0.0001	0.0000	0.0000	0.0000	0.0001	0.0002	0.0001
Ga	0.0001	0.0001	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0000	0.0001	0.0002	0.0001	0.0002	0.0001
Fe	0.0029	0.0030	0.0027	0.0030	0.0029	0.0028	0.0007	0.0008	0.0007	0.0010	0.0009	0.0008	0.0017	0.0014	0.0015
Si	0.0005	0.0004	0.0003	0.0006	0.0004	0.0005	0.0004	0.0005	0.0004	0.0005	0.0008	0.0004	0.0003	0.0004	0.0003
Cr	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0001
Mn	0.0001	0.0000	0.0000	0.0001	0.0001	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000
Mg	0.0003	0.0002	0.0003	0.0005	0.0002	0.0002	0.0011	0.0012	0.0011	0.0009	0.0010	0.0008	0.0003	0.0003	0.0003
Total*	1.9998	1.9998	1.9998	1.9999	1.9999	1.9998	1.9990	1.9990	1.9988	1.9992	1.9992	1.9994	1.9998	1.9998	1.9998
Mg^{2+}	8.951	6.090	7.735	13.087	6.658	6.863	20.308	20.279	17.934	19.465	21.019	19.789	11.444	15.264	12.056
Fe_{total}	78.543	80.256	75.947	81.353	86.251	85.443	11.844	12.794	11.157	21.053	18.705	20.642	63.056	66.373	67.486
Ti^{4+}	13.655	16.318	5.560	7.091	7.694	67.848	66.927	70.909	59.482	60.276	59.569	25.500	18.363	20.458	17.586

Table IV.2 Showing the major and trace elements content of some selected blue and violet sapphires by Electron Probe Micro-Analyzer. The analyzes were performed after step-heating up to 1650 °C. (continued)

	Milky, very light blue type									Dark violet type					
	mvlb5.2/1	mvlb5.2/2	mvlb5.2/3	mvlb6.1/1	mvlb6.1/2	mvlb6.1/3	mvlb6.2/1	mvlb6.2/2	mvlb6.2/3	dv1.1/1	dv1.1/2	dv1.1/3	dv1.2/1	dv1.2/2	dv1.2/3
Al_2O_3	100.66	100.69	100.68	100.81	100.69	100.84	100.37	100.68	100.56	100.99	100.83	99.96	99.19	98.61	99.19
TiO_2	0.03	0.02	0.02	0.04	0.04	0.06	0.03	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00
V_2O_3	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00
Ga_2O_3	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
FeO	0.10	0.12	0.10	0.06	0.06	0.05	0.06	0.06	0.05	0.21	0.23	0.25	0.21	0.22	0.22
SiO_2	0.03	0.02	0.02	0.02	0.03	0.02	0.03	0.02	0.02	0.06	0.04	0.03	0.02	0.02	0.02
Cr_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.11	0.11	0.10	0.10	0.11	0.12
MnO	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.01
MgO	0.01	0.01	0.00	0.02	0.02	0.03	0.02	0.01	0.01	0.02	0.01	0.00	0.00	0.00	0.00
Total	100.85	100.89	100.84	100.96	100.85	101.02	100.53	100.82	100.67	101.41	101.25	100.37	99.53	98.98	99.58
Formula 3(O)															
Al	1.9972	1.9972	1.9978	1.9977	1.9975	1.9971	1.9975	1.9980	1.9983	1.9939	1.9942	1.9944	1.9954	1.9950	1.9948
Ti	0.0003	0.0002	0.0003	0.0005	0.0005	0.0008	0.0004	0.0003	0.0002	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000
V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0001	0.0000
Ga	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0002
Fe	0.0013	0.0015	0.0013	0.0007	0.0007	0.0007	0.0007	0.0007	0.0006	0.0026	0.0029	0.0032	0.0027	0.0028	0.0028
Si	0.0005	0.0004	0.0003	0.0003	0.0005	0.0004	0.0005	0.0004	0.0004	0.0011	0.0007	0.0004	0.0003	0.0003	0.0004
Cr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0014	0.0014	0.0013	0.0013	0.0015	0.0016
Mn	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0000	0.0001	0.0000	0.0000	0.0001
Mg	0.0003	0.0003	0.0000	0.0006	0.0006	0.0006	0.0004	0.0004	0.0003	0.0004	0.0003	0.0000	0.0000	0.0000	0.0000
Total*	1.9999	1.9999	1.9999	1.9999	1.9999	1.9998	1.9999	1.9999	1.9999	1.9998	1.9998	1.9999	1.9999	1.9999	1.9999
Mg^{2+}	14.747	13.990	0.000	32.192	31.744	30.110	26.709	25.989	23.926	11.997	8.231	0.000	0.000	0.000	0.000
Fe_{total}	67.667	73.819	83.339	40.268	39.707	32.218	46.341	52.470	59.174	84.371	87.994	96.155	100.000	100.000	100.000
Ti^{4+}	17.586	12.191	16.661	27.540	28.549	37.672	26.950	21.541	16.899	3.632	3.775	3.845	0.000	0.000	0.000

Table IV.2 Showing the major and trace elements content of some selected blue and violet sapphires by Electron Probe Micro-Analyzer. The analyzes were performed after step-heating up to 1650 °C. (continued)

	Dark violet type			Medium violet type		
	dv3.1/1	dv3.1/2	dv3.1/3	mv3.1/1	mv3.1/2	mv3.1/3
Al_2O_3	99.19	99.30	99.59	99.22	99.45	99.31
TiO_2	0.01	0.01	0.01	0.02	0.01	0.02
V_2O_3	0.01	0.00	0.01	0.01	0.01	0.00
Ga_2O_3	0.01	0.01	0.02	0.00	0.01	0.01
FeO	0.26	0.26	0.26	0.18	0.18	0.19
SiO_2	0.04	0.03	0.03	0.03	0.03	0.03
Cr_2O_3	0.10	0.10	0.11	0.03	0.04	0.04
MnO	0.01	0.01	0.01	0.00	0.01	0.00
MgO	0.01	0.00	0.00	0.00	0.01	0.01
Total	99.64	99.72	100.03	99.49	99.74	99.60
Formula 3(O)						
Al	1.9937	1.9943	1.9940	1.9961	1.9959	1.9959
Ti	0.0001	0.0001	0.0001	0.0002	0.0001	0.0002
V	0.0002	0.0000	0.0001	0.0001	0.0001	0.0000
Ga	0.0002	0.0001	0.0002	0.0000	0.0001	0.0001
Fe	0.0033	0.0033	0.0034	0.0024	0.0023	0.0024
Si	0.0006	0.0005	0.0005	0.0005	0.0005	0.0005
Cr	0.0014	0.0014	0.0014	0.0004	0.0005	0.0005
Mn	0.0001	0.0001	0.0001	0.0000	0.0001	0.0000
Mg	0.0003	0.0000	0.0000	0.0000	0.0003	0.0003
Total*	1.9999	1.9998	1.9998	1.9998	1.9999	1.9999
Mg^{2+}	6.860	0.000	0.000	0.000	9.580	8.892
Fe_{total}	89.679	96.242	96.352	92.427	85.587	83.481
Ti^{4+}	3.461	3.758	3.648	7.573	4.833	7.627

BIOGRAPHY

Miss Somruedee Sakkaravej was born in August 17, 1974, at Bangkok. She graduated with a bachelor degree in general science from the Department of General Science, Faculty of Science, Kasetsart University in 1998. At present, she works at Gem Testing Laboratory, The Gem and Jewelry Institute of Thailand and also studies in a Master program in earth science at Chulalongkorn University.