CHAPTER III

PHYSICAL AND OPTICAL PROPERTIES

3.1 Introduction

Forty five samples of blue sapphires from Ilakaka-Sakaraha deposits were selected for detailed study. Most of them are transparent and vitreous luster. Some samples clearly show crystal habits such as barrel-shape, hexagonal prism and bipyramid (see Figure 3.1). Their sizes vary from 3 to 8 millimeters and weights range from 0.5 to 3.0 carats. Subsequently, they were cut and polished as flat surfaces perpendicular and parallel to the c-axis before further investigation. Then physical properties of the samples were observed, measured and recorded.

These physical properties include refractive index (RI), specific gravity (SG) and fluorescence under long wave (LW) and short wave (SW) of ultraviolet (UV) lamp. The observation and measurement of these properties were carried out before heating experiments. However particular properties (e.g. colors, UV-VIS-NIR, FTIR, EDXRF and Laser Raman Spectroscope) have been observed and measured at every step of heating. In this chapter, only characteristics of sapphire samples before heating are reported in the following sections including color grading, mineral inclusions and internal features.

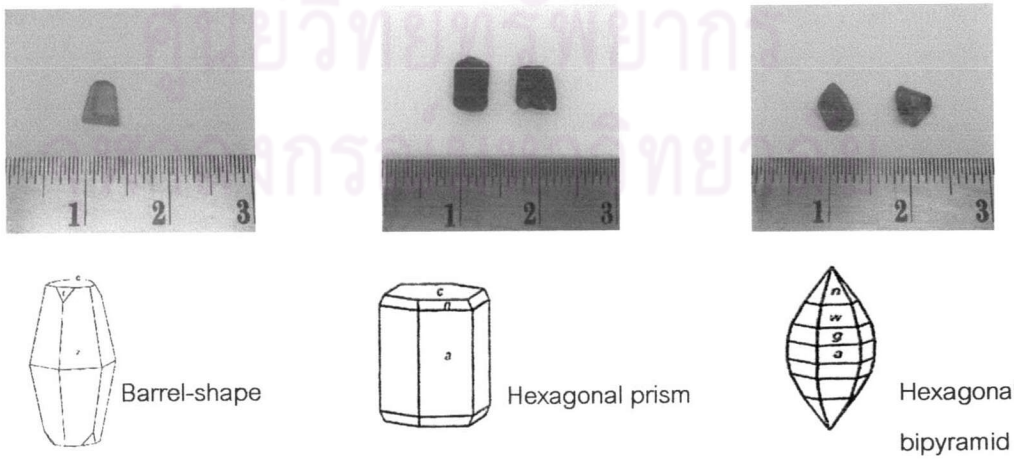

Figure 3.1 Crystal habits in some blue sapphires from Ilakaka-Sakaraha

3.2 Color Grading

The samples were grouped, based on their color shades in comparison with GIA GemSet color specimens (Retail Set) (see Figure 3.2). Observation was done under standard daylight 6500 K. Moreover color-change sapphires were additionally observed under incandescent light. GIA GemSet color specimens (Figure 3.2) were made from plastic; they have 2 different sides (e.g.faceted and flat). Flat side was used during this study because it is more appropriated to the form of samples. Consequently all 45 samples were separated into 7 groups: dark blue, medium blue, very light blue, milky very light blue, dark violet, medium violet and light violet (Figure 3.3). Comparative results of all color groups are summarized in Table 3.1, whereas details of all samples are present in Table I.1 of Appendix I.

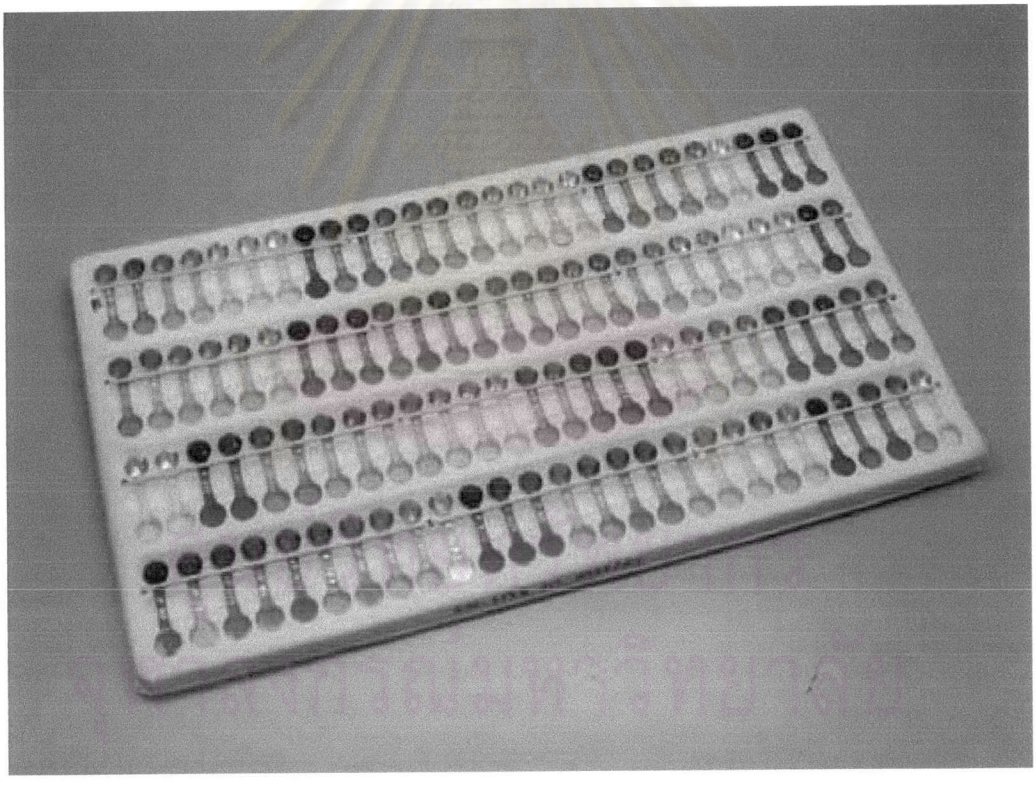

Figure 3.2 GIA GemSet Color Specimens

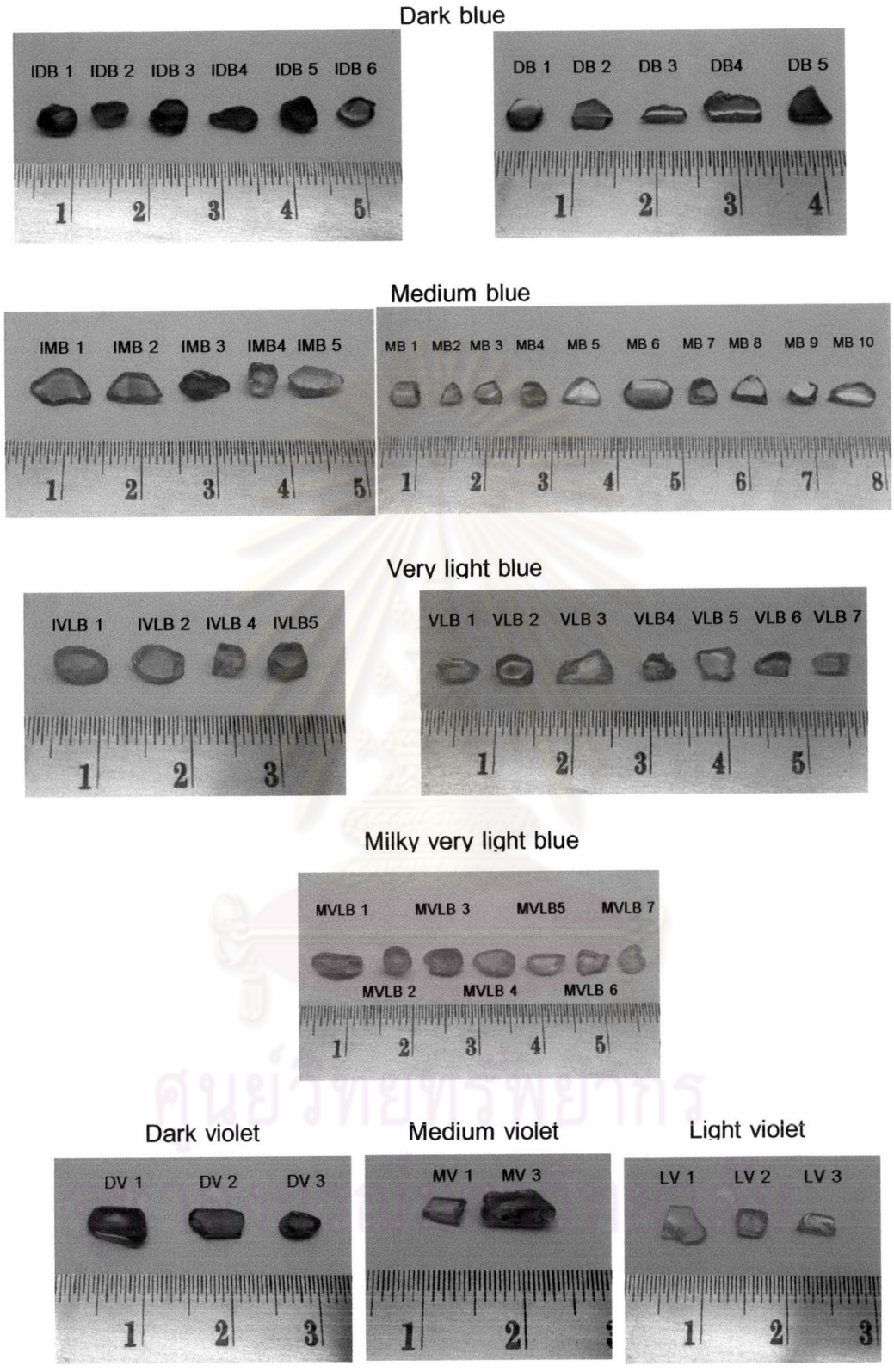

Figure 3.3 Showing 7 color groups of blue sapphire samples: Dark blue (IDB 1-6, DB 1-5); Medium blue (IMB 1 –5, MB 1 – 10); Very light blue (IVLB 1 – 4, VLB 1 – 7); Milky very light blue (MVLB 1 – 7); Dark violet (DV 1 – 3); Medium violet (MV 1, 3); Light violet (LV 1 – 3) from Ilakaka-Sakaraha deposits.

Table 3.1 Representative color codes, based on comparison with GIA GemSet, of each color group before heating experiment.

Sample Groups	GIA GemSet color specimens	
	Code	Tone, Saturation Hue
Dark blue (IDB 1-6, DB 1-5)	bV 6/5 to V 6/4 + rP 5/3	medium dark, strong bluish violet - medium dark, moderately strong violet + medium, very slightly grayish reddish purple
Medium blue (IMB 1-5, MB 1-10)	bV 2/3 to bV 5/4	very light, very slightly grayish bluish violet - medium, moderately strong bluish violet
Very light blue (IVLB 1-4, VLB 1-7)	B 2/2 to bV 3/4	very light, slightly grayish blue - light, moderately strong bluish violet
Milky very light blue (MVLB 1-7)	B 2/2 to B 3/1 + V 2/2	very light, slightly grayish blue - light, grayish blue with very light, slightly grayish blue
Dark violet (DV 1-3)	bP 5/5 + P 6/4 to V 6/4 + rP 4/4	medium, strong bluish purple + medium dark, moderately strong purple - medium dark, moderately strong violet with medium light, moderately strong reddish purple
Medium violet (MV 1, 3)	V 4/3 to V 4/4	medium light, very slightly grayish violet - medium light, moderately strong violet
Light violet (LV 1-3)	V 2/2	very light, slightly grayish violet

3.3 Physical Properties

Physical properties, particularly gemological properties, of samples were collected using the basic instruments. Refractometer was used to measure refractive indices (RI) of both ordinary ray (n_o) and extraordinary ray (n_e); the different values of both rays are then reported as birefringences. Fluorescence under ultraviolet lamps either long wave (LW) or short wave (SW) were also observed. Specific gravity (SG)

measurements were carried out using electronic balance. All of the physical properties are summarized in Table 3.2 and more details are reported in Table I.2 in Appendix I.

Table 3.2 Showing summarized physical properties of some blue sapphires from Ilakaka-Sakaraha area, Madagascar.

Color	RI		Birefringence	SG	Fluorescence	
	n_o	n_e			LW	SW
Dark blue (IDB 1-6, DB 1-5)	1.769-1.770	1.760-1.761	0.008–0.009	3.92 - 4.04	Inert - moderate red	inert
Medium blue (IMB 1-5, MB 1-10)	1.769–1.770	1.760-1.761	0.008–0.009	3.92 – 4.04	Inert - moderate red	inert
Very light blue (IVLB 1-4, VLB 1-7)	1.769–1.770	1.760-1.761	0.008–0.009	3.91 – 4.02	weak orangy yellow – moderate orangy yellow	inert
Milky very light blue (MVLB 1-7)	1.768-1.769	1.760-1.761	0.008–0.009	3.94 - 3.96	Inert - weak orangy red	inert
Dark violet (DV 1-3)	1.769-1.770	1.760-1.761	0.008–0.009	3.95 – 3.99	moderate orangy red	inert
Medium violet (MV 1, 3)	1.769–1.770	1.760	0.009–0.010	3.94 – 3.95	Inert–moderate orangy red	inert
Light violet (LV 1-3)	1.769–1.771	1.760-1.761	0.009–0.010	3.91–3.96	weak orangy red– moderate orangy red	inert

As shown in Table 3.2, the physical properties of all samples fall within typical range of corundum. The refractive indices (RI) are 1.771 – 1.769 for ordinary ray (n_o) and 1.761 – 1.760 for extraordinary ray (n_e), consequently birefringences range between 0.008 and 0.010. Specific gravity (SG) are approximately 4.0 – 3.9.

3.4 Internal Characteristics

Internal characteristics of 45 samples were observed under gemological microscope and photos of important internal characteristics were taken. Alteration of internal features were again observed during heat treatment, therefore photos of these

features must be shot in every step of heating for comparison. Some mineral inclusions were additionally identified using Laser Raman spectroscope (Model 1000, Ranishaw) based at the Gem and Jewelry Institute of Thailand (GIT) (Figure 3.4). However, the equipment cannot distinguish clearly some mineral inclusions that set deep into sapphire samples. The best result is obtained from mineral inclusions that are exposed or very close to the samples' surfaces.

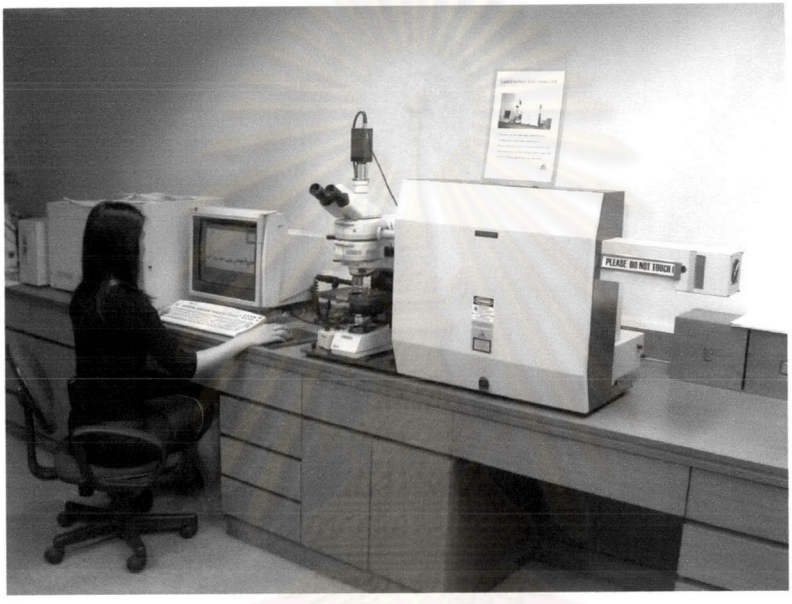

Figure 3.4 Laser Raman spectroscope (Model 1000, Ranishaw) based at the GIT

Types of mineral inclusion and other internal features of each sample group are summarized and revealed in Table 3.3. Investigation of mineral inclusion in 45 blue sapphire samples yielded various types of mineral inclusions. Zircon in sapphires from Ilakaka-Sakaraha is the most common mineral inclusion. Other mineral inclusions are characterized by rutile, apatite and calcite. Zircon inclusions appear to have been formed as single crystals and clusters; they usually formed as rounded and elongate shapes with or without tension disc (Figure 3.5). Raman spectrum of a zircon inclusion is shown in Figure 3.6. Rutile inclusions are usually rounded, dark brown to black crystals (Figure 3.7); a sample of Raman spectrum of rutile inclusion is shown in Figure 3.8. Apatite crystals are characterized by colorless crystal (Figure 3.9) with Raman spectrum as shown in Figure 3.10. Calcite inclusions usually occur as single crystal (Figure 3.11)

Raman spectrum of a calcite inclusion is shown in Figure 3.12. The other internal features in some blue sapphire samples contain fingerprints and minute particles (see Figures 3.13 - 3.15).

Table 3.3 Summary of mineral inclusions and other internal features observed in sapphire samples from Ilakaka-Sakaraha deposits.

Sample Groups	Type of mineral inclusions	Other internal features
Dark blue	Rutile needles, Zircon, Minute particles	Healed fractures, Color zoning
Medium blue	Rutile, Apatite, Minute particles or white dust, Zircon, Rutile needles	Healed fractures, Tubes filled with substance, Color zoning
Very light blue	Calcite, Minute particles or white dust, Rutile needles	Healed fractures
Milky, very light blue	Rutile needles, Zircon, Minute particles or white dust	Healed fractures, Tubes filled with substance, Cloud of minute particles along growth zones
Dark violet	Minute particles or white dust, Zircon, Rutile needles,	Tubes filled with substance, Color zoning, Cloud of minute particles along zones
Medium violet	Zircon, Minute particles or white dust	Healed fractures, Tubes filled with substance, Color zoning, Cloud of minute particles along zones
Light violet	Zircon, Rutile needles, Minute particles or white dust,	Healed fractures, Tubes filled with solid substance

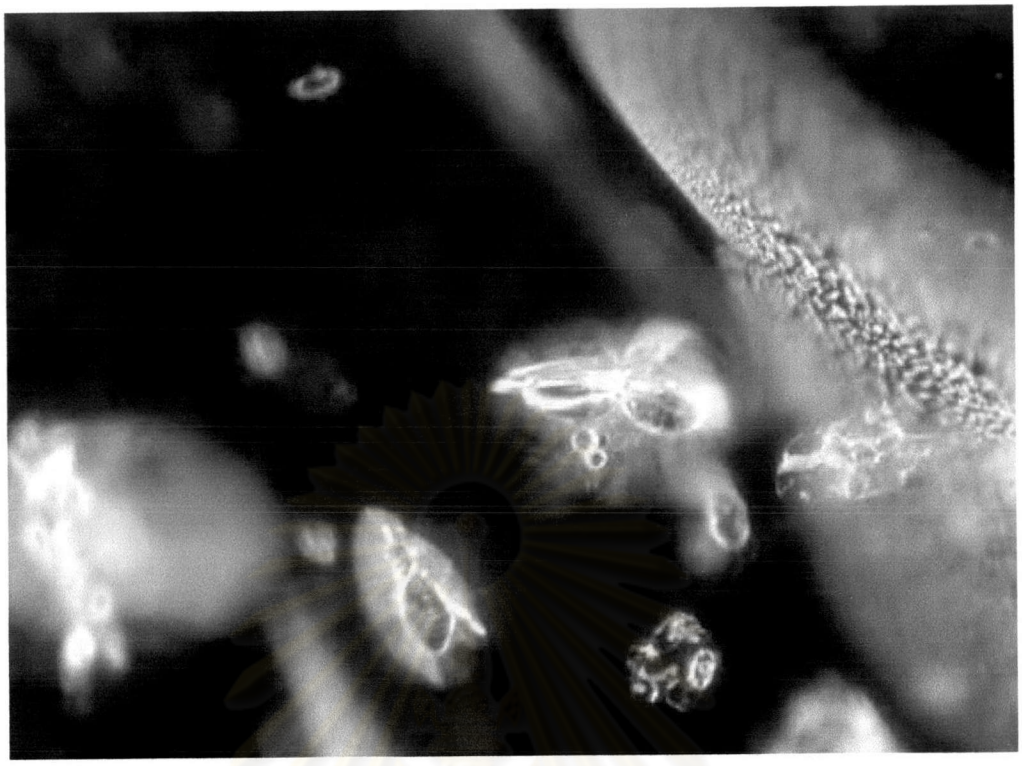

Figure 3.5 Zircon inclusions in a light violet sapphire (sample no. LV 2)

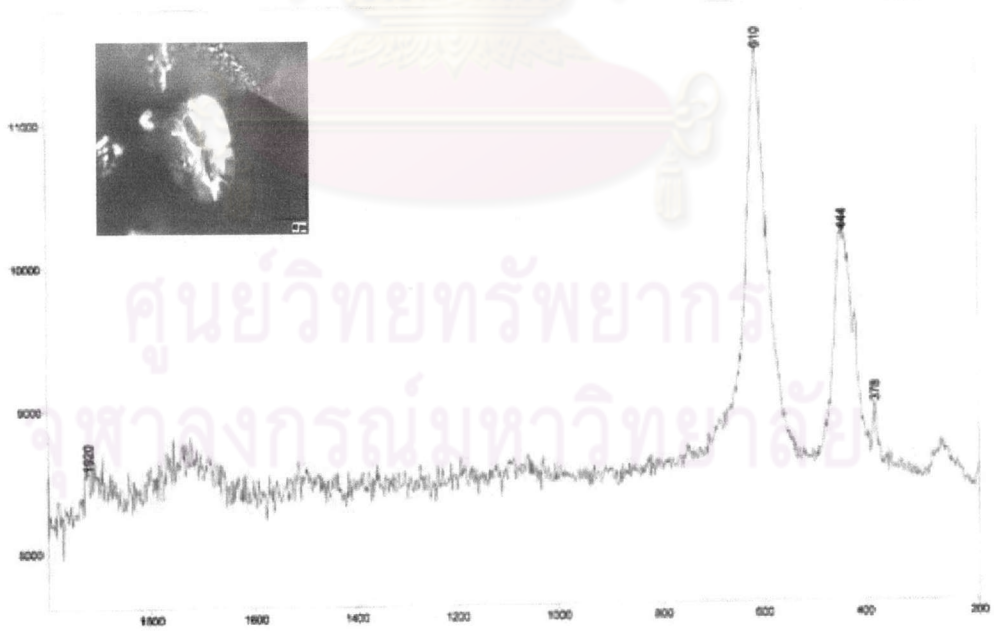

Figure 3.6 Raman spectrum yielded from a zircon inclusion in the light violet sapphire (sample no. LV 2)

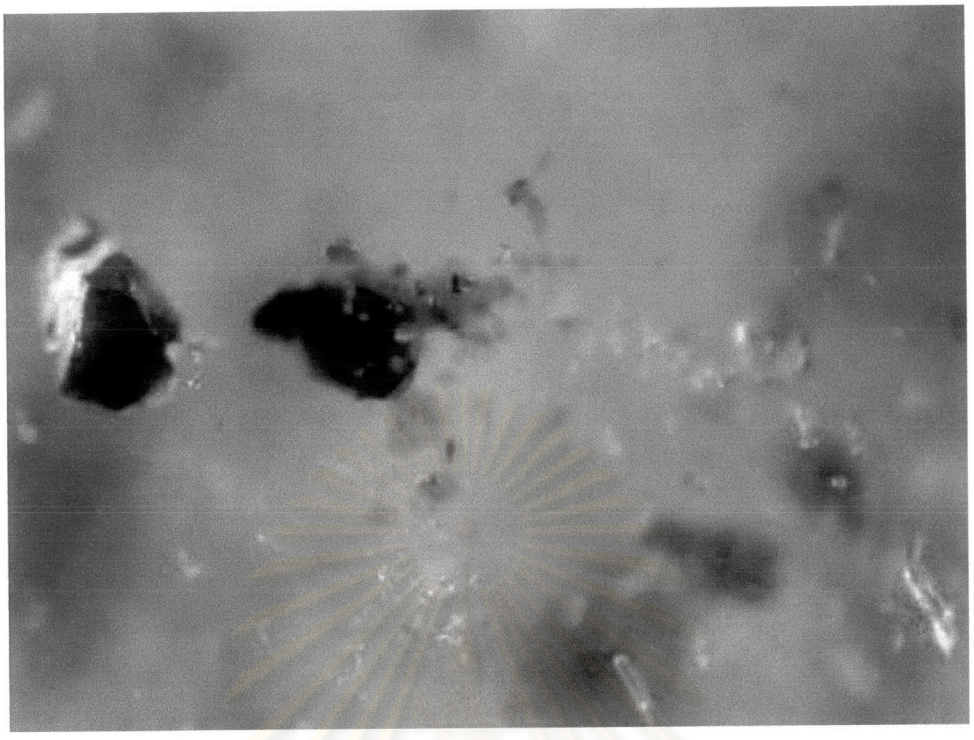

Figure 3.7 Rutile inclusions in a medium blue sapphire group (sample no. MB 8)

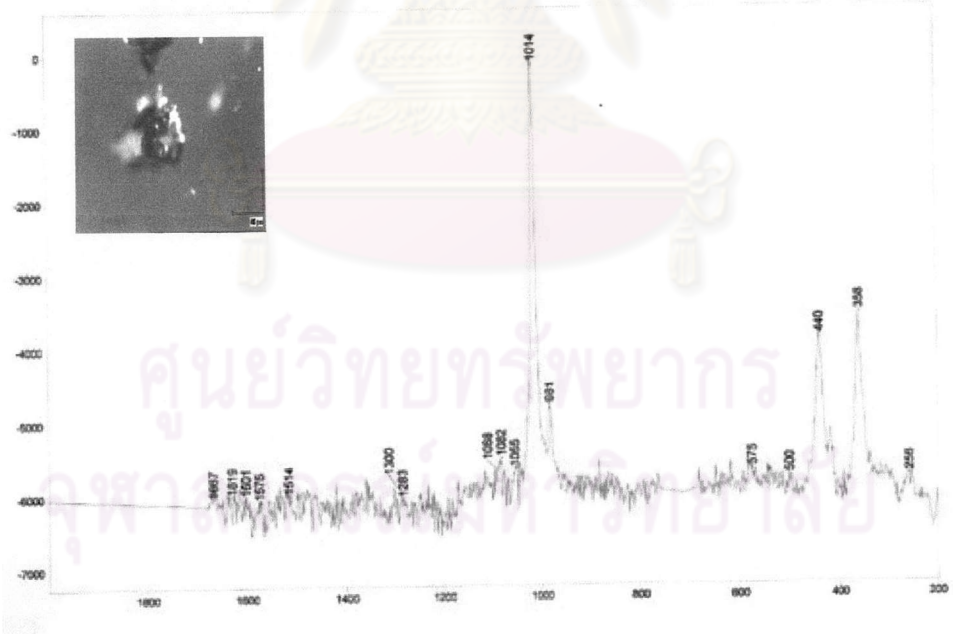

Figure 3.8 Raman spectrum yielded from a rutile inclusion in the medium blue sapphire (sample no. MB 8)

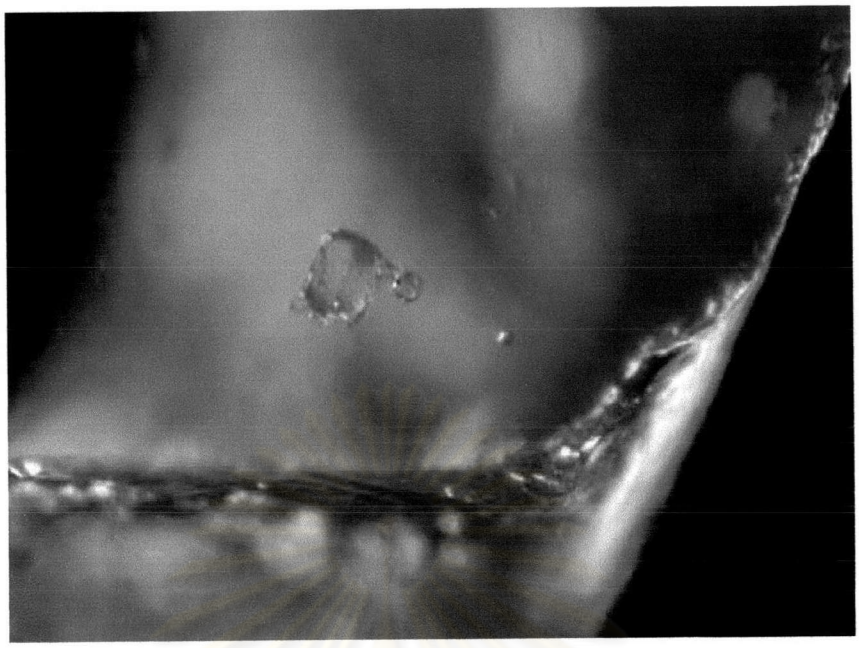

Figure 3.9 Apatite inclusions in medium blue sapphire group (sample no. IMB 4)

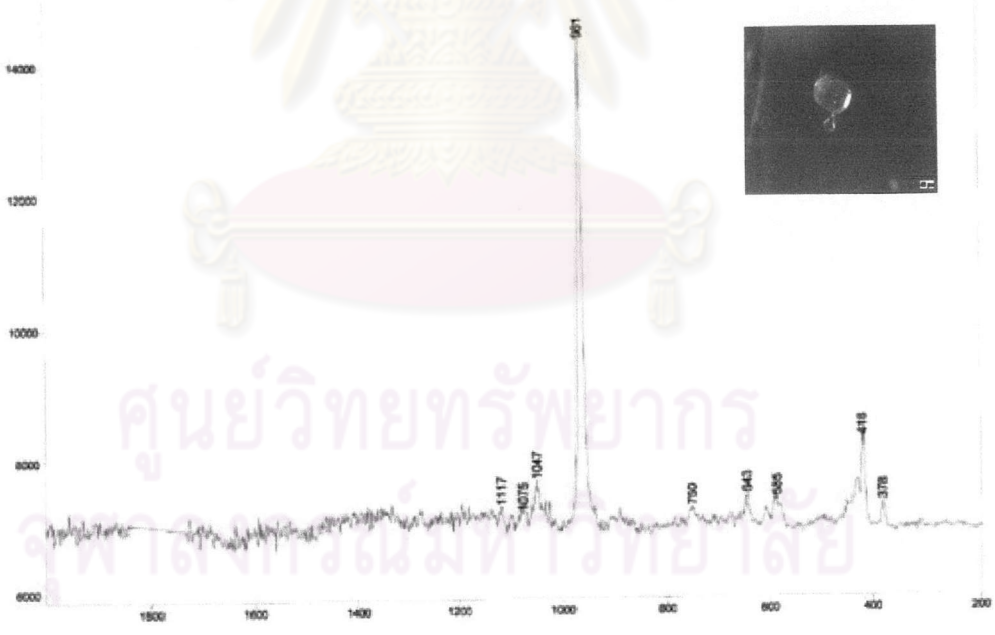

Figure 3.10 Raman spectrum of an apatite inclusion in medium blue sapphire (sample no. IMB 4)

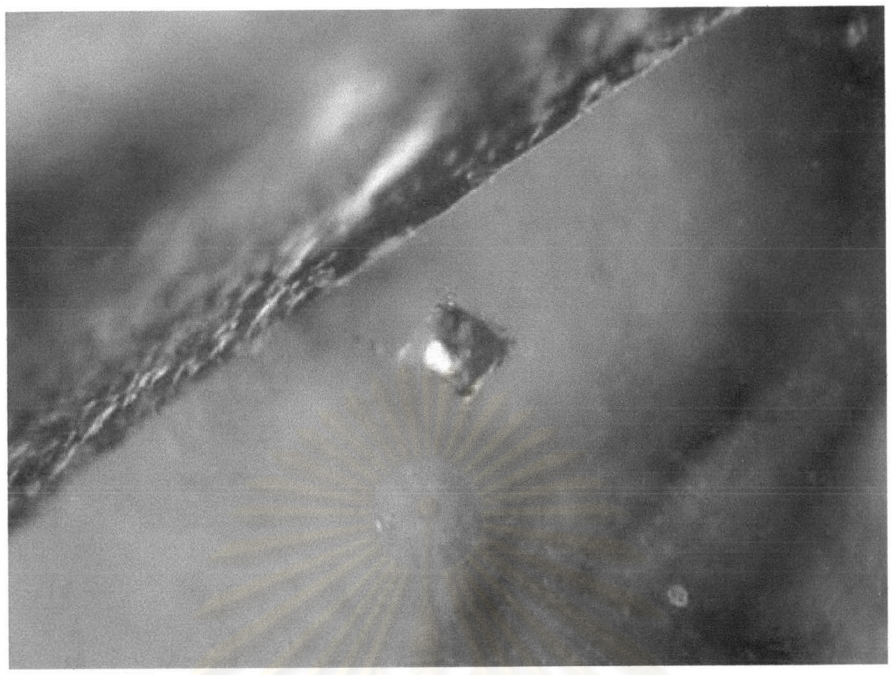

Figure 3.11 Calcite crystal in a very light blue sapphire (sample no. IVLB 2)

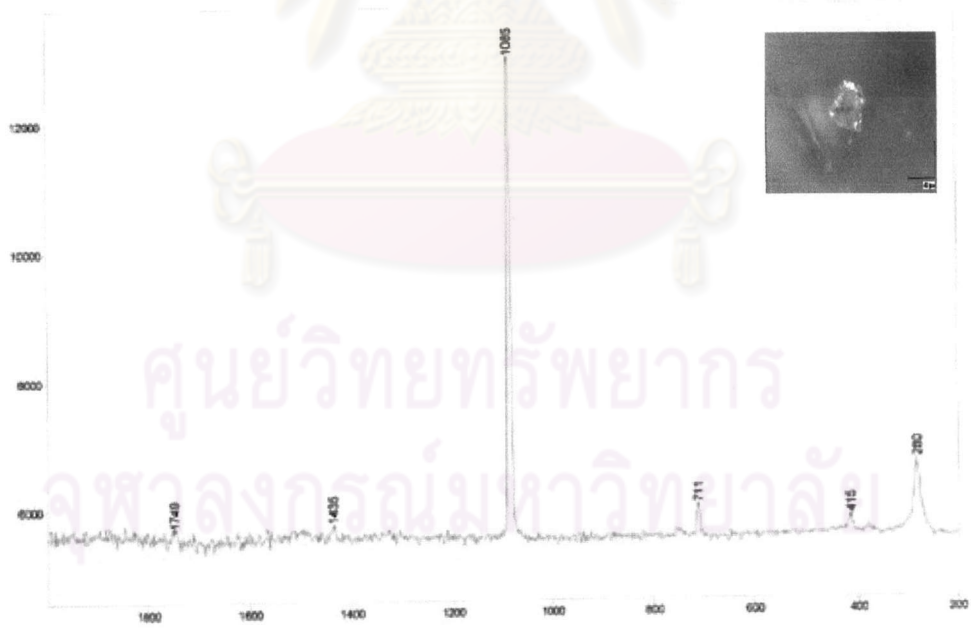

Figure 3.12 Raman spectrum indicating the calcite inclusion in the very light blue sapphire (sample no. IVLB 2)

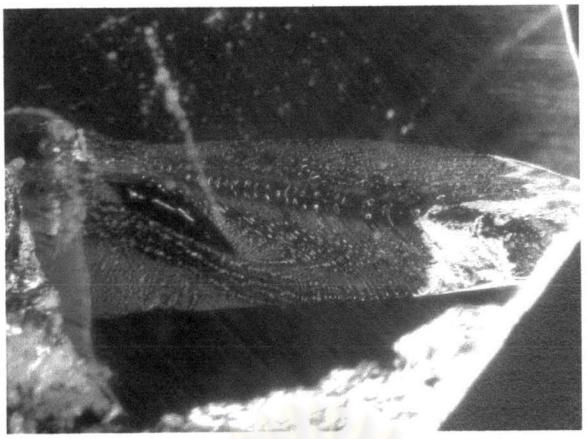

Figure 3.13 Fingerprint or healed fissures in DB 1

Figure 3.14 Minute particles or white dust in MVLB 6

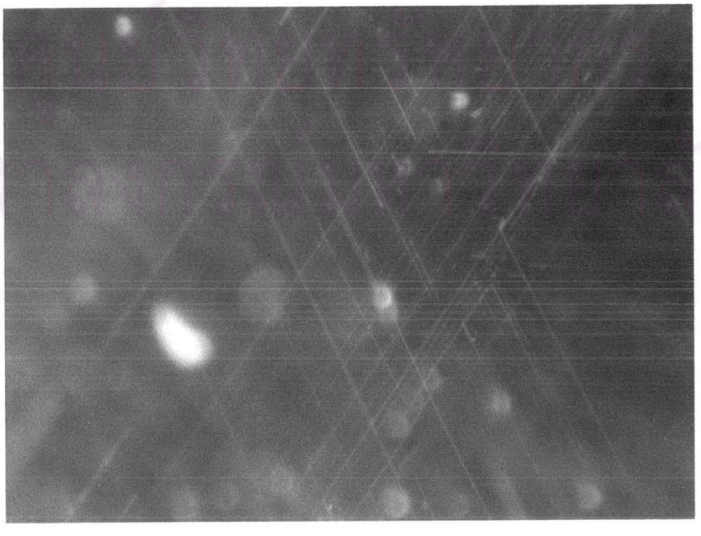

Figure 3.15 Rutile needles crossed in 3-direction in MB 3