References

1. Andreottola, M. A. Inkjet Ink Technology. In Daimond, A. S. (eds.), Handbook of Imaging Material; Marcel Dekker: New York. 1991; pp. 527-544.
2. Leach, R. H., and Pierce, R. J. Inkjet inks. In Leach, R. S. and Tierce, R. I. (eds.), The Printing Ink Manual. 5 th ed.; Blueprint: London. 1993; pp. 678-698.
3. Lavery, A. Photomedia for Inkjet Printing. *Proceedings of IS&T NIP 16: International Conference on Digital Printing Technologies*: 216-220 (2000).
4. Henk, J. W. Design of pigment dispersants : Methodology for Selection of Anchoring Groups. *Journal of Coating of Technology*: **69: 873**: 137-142 (1997).
5. Guidice, C. A., and Benitez, J. C. Pigment Dispersion Degree and Its Evaluation in Storage. *Pigment & Resin Technology*: **27: 3**: 298-303 (1998).
6. Noguchi, H. and Hosoda, T. Fine Particle Dispersion of Pigment for Inkjet Ink. *Journal of the Japan Society of Color Material*: **69: 12**: 855-866 (1996).
7. Clayton, J. Pigment/Dispersant Interactions in Water-based Coating. *Surface Coating International*: **9**: 414-419 (1997).
8. Tsutsumi, T., Sawada, M. and Nakano, Y. Polymer Emulsion-Based Inkjet Colorant and Ink. *Proceedings of IS&T NIP 15: International Conference on Digital Printing Technologies*: 133-136 (1999).
9. Medina, S. W. and Lee, F. J. Surfactant: A powerful Tool in Formulating Waterborne Inks. *American Ink Maker*: **76: 1**: 49-57(1998).
10. Schofield, J. D. Ink System for the Xaar Inkjet Printhead. *Proceedings of IS&T NIP 13: International Conference on Digital Printing Technologies*: 633-637 (1997).
11. Tanaka, M., Yasui, K. and Seki, Y. Water borne Dispersions of Micro-encapsulated Pigments. *Proceedings of IS&T NIP 15: International Conference on Digital Printing Technologies*: 82-84 (1999).
12. Johnson, J. E., and Bok, G. L. Surface-Modified Black Pigments for Industrial Inkjet Ink Application. *Proceedings of IS&T NIP 13: International Conference on Digital Printing Technologies*: 659-663 (1997).

13. Yu, Y., and Gottberg, F. V. Surface Modified Color Pigments for Inkjet Ink Application. *Proceedings of IS&T NIP 16: International Conference on Digital Printing Technologies*: 512-515 (2000).

14. Gutjahr, H. Direct Print Coloration. In Miles, L. W. C., (eds.), Textile Printing; Dyers Company Publications Trust: London. 1981; pp. 141-194.

15. Geisenberger, J., and Zeller, K. Textile Printing: A Challenge for Inkjet Printing Technology. *Proceedings of IS&T NIP 16: International Conference on Digital Printing Technologies*: 533-535 (2000).

16. Weiser, J., Digital Textile Printing. *Proceedings of IS&T NIP 16: International Conference on Digital Printing Technologies*: 529-532 (2000).

17. Tincher, W. C. Coloration Systems for Inkjet Printing of Textiles. *Proceedings of IS&T NIP 14: International Conference on Digital Printing Technologies*: 243-256 (1998).

18. Corbman, B.P. Introduction to textiles industry, market, and fiber In Textiles Fiber to Fabric; McGraw-Hill: Singapore. 1983; pp. 1-52.

19. Ingamells, W. The attributes of fibres. In Colour for Textiles A User's Handbook; Society of Dyers and Colourists: West Yorkshire.1993; pp. 44-75.

20. Corbman, B.P. Silk another protein fiber. In Textiles Fiber to Fabric; McGraw-Hill: Singapore. 1983; pp. 290-304.

21. Tortora, P. G. Protein Fibers. In Understanding Textiles; Macmillan Publishingin: New York. 1978; pp. 67-95.

22. Hollen, N., Saddler J., and Langford, A. L. Silk. In *Textiles*. New York; Macmillan Publishing; 1979, pp 31-34.

23. Hollen, N., Saddler J., and Langford, A. L. Textile fibers and Their Properties. In *Textiles*. New York; Macmillan Publishing; 1979, pp 4-17.

24. Corbman, B.P. Cotton a natural cellulose fiber. In Textiles Fiber to Fabric; McGraw-Hill: Singapore. 1983; pp. 246-255.

25. Tortora, P. G. Natural Cellulosic Fiber. In Understanding Textiles; Macmillan Publishingin: New York. 1978; pp. 33-52.

26. Corbman, B.P. Polyester the terephthalate fiber. In Textiles Fiber to Fabric; McGraw-Hill: Singapore. 1983; pp. 246-255.

27. Tortora, P. G. Man-made Cellulosic Fiber. In Understanding Textiles; Macmillan Publishingin: New York. 1978; pp. 63-66.

28. Tortora, P. G. Polyester Fibers. In Understanding Textiles; Macmillan Publishingin: New York. 1978; pp. 121-125.

29. Hollen, N., Saddler J., and Langford, A. L. Blend. In *Textiles*. New York; Macmillan Publishing; 1979, pp 142-146.

30. Tortora, P. G. Textile Testing and Standards. In Understanding Textiles; Macmillan Publishingin: New York. 1978; pp. 355-367.

31. Ingamells, W. The mosern approach to coloration. In Colour for Textiles A User's Handbook; Society of Dyers and Colourists: West Yorkshire.1993; pp. 138-157.

32. Tortora, P. G. Fabric Structure: The Sum of Its Parts In Understanding Textiles; Macmillan Publishingin: New York. 1978; pp. 368-376.

33. Work, R. A. Color Pigmented Inkjet Inks: New Developments and New Applications. *Proceedings of IS&T NIP 15: International Conference on Digital Printing Technologies*: 149-150 (1999).

34. Bugner, D. E. and Bermel, A. D. Particle Size Effects in Pigmented Inkjet Inks. *Proceedings of IS&T NIP 13: International Conference on Digital Printing Technologies*: 667-669 (1997).

35. Hauser, H. P. and Buhler, N. E. Fine Particle Pigment Concentrates for Inkjet Printing inks. *Proceedings of IS&T NIP 14: International Conference on Digital Printing Technologies*: 92-94 (1998).

36. Adair, P. C. Inkjet Coating for Pigmented Inks. *Proceedings of IS&T NIP 14: International Conference on Digital Printing Technologies*: 146-151 (1998).

37. Basak, A. K. and Dante, H. M. Investigation of the Physical Properties of Some Pigmented Inks and their Mechanism of dispersion. *Proceedings of IS&T NIP 15: International Conference on Digital Printing Technologies*: 124-128 (1999).

38. Kwan, V. W. Effect of Resin/Binders on Lightfastness of Colorants in Inkjet Inks. *Proceedings of IS&T NIP 15: International Conference on Digital Printing Technologies*: 92-94 (1999).

39. Keller, C. K. The Evolution of Jet Inks to Meet New Application Needs. *Proceedings of IS&T NIP 15: International Conference on Digital Printing Technologies*: 95-97 (1999).

40. Work, R. A. Challenges of Digital Inkjet Pigment Textile Printing. *Proceedings of IS&T NIP 14: International Conference on Digital Printing Technologies*: 247-251 (1998).

41. Tian, O. Y. Pigmented latex System for Inkjet Printing on Textile. *Proceedings of IS&T NIP 15: International Conference on Digital Printing Technologies*: 196-199 (1999).

42. Tincher, W. C. and Yang, R. Inkjet Resin-Pigment Printing of Silk Fabrics. *Proceedings of IS&T NIP 15: International Conference on Digital Printing Technologies*: 200-202 (1999).

43. Nogichi, H. Private communications. 17 January 2001.

44. Sanders, J. D. Pigments for Ink Makers; SITA Technology: London. 1989; pp. 39-46.

45. Oliver, J. F. Wetting and Penetration of Paper. In Hair, M. and Croucher, M. D., Colloids and Surfaces in Reprographic Technology; American Chemical Society: Washinton, D.C. 1992; pp. 435-453.

46. Kulube, H. M., and Hawkyard, C. J. Fabric pretreatments and inks for textile inkjet printing. *ITB Dyeing Printing Finishing*: 3: 5-10 (1996).

APPENDICES

APPENDIX A

THE PARTICLE SIZE OF VARIOUS PIGMENT DISPERSION TECHNIQUES EVALUATED BY ZETASIZER AND LIGHT SCATERRING

fuji b
File data from Live size Record 1
S4700

Size(nm)	Intensity	Volume	Number
28.8	0.0	0.0	0.4
32.2	0.0	0.1	0.9
35.9	0.0	0.2	1.9
40.1	0.0	0.6	3.6
44.8	0.1	1.3	6.1
50.0	0.4	2.6	9.1
55.9	1.0	4.7	11.9
62.4	2.2	7.4	13.7
69.6	4.2	10.3	14.0
77.7	7.1	12.6	12.5
86.8	10.4	13.6	9.9
96.9	13.3	13.0	7.0
108.2	14.8	11.1	4.4
120.8	14.3	8.5	2.4
134.8	12.1	5.8	1.2
150.5	8.9	3.6	0.6
168.1	5.7	2.1	0.2
187.7	3.1	1.1	0.1
209.5	1.5	0.6	0.0
233.9	0.6	0.3	0.0
261.2	0.2	0.2	0.0
291.6	0.1	0.1	0.0
325.5	0.0	0.1	0.0
363.4	0.0	0.0	0.0

Peak Analysis by intensity

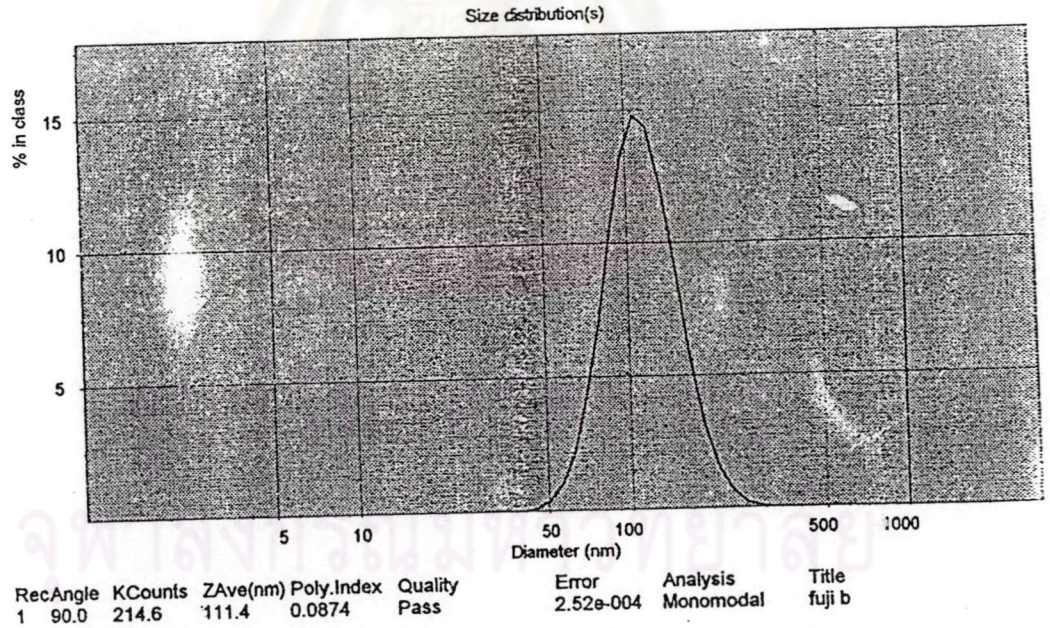
Peak	Area	Mean	Width
1	100.0	116.4	79.9

Peak Analysis by volume

Peak	Area	Mean	Width
1	100.0	95.4	68.9

Peak Analysis by number

Peak	Area	Mean	Width
1	100.0	70.8	50.6



RecAngle	KCounts	ZAve(nm)	Poly.Index	Quality	Error	Analysis	Title
1 90.0	214.6	111.4	0.0874	Pass	2.52e-004	Monomodal	fuji b

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fuji9345 nondis
File data from Live size Record 1
ZetaSizer

Size(nm)	Intensity	Volume	Number
11.7	0.0	0.2	6.5
14.2	0.0	0.6	9.0
17.2	0.0	1.3	12.2
20.9	0.0	2.7	14.5
25.3	0.1	4.8	15.1
30.7	0.4	7.6	13.8
37.3	1.1	10.5	11.1
45.2	2.4	12.8	7.9
54.8	4.5	13.8	4.9
66.5	7.5	13.0	2.7
80.7	10.8	10.9	1.3
97.9	13.6	8.1	0.6
118.7	14.8	5.4	0.2
144.0	14.1	3.2	0.1
174.7	11.7	1.8	0.0
211.9	8.5	1.0	0.0
257.1	5.3	0.6	0.0
311.8	2.9	0.5	0.0
378.3	1.4	0.5	0.0
458.9	0.6	0.4	0.0
556.7	0.2	0.1	0.0
675.3	0.1	0.0	0.0
819.2	0.0	0.0	0.0
993.8	0.0	0.0	0.0

Peak Analysis by intensity

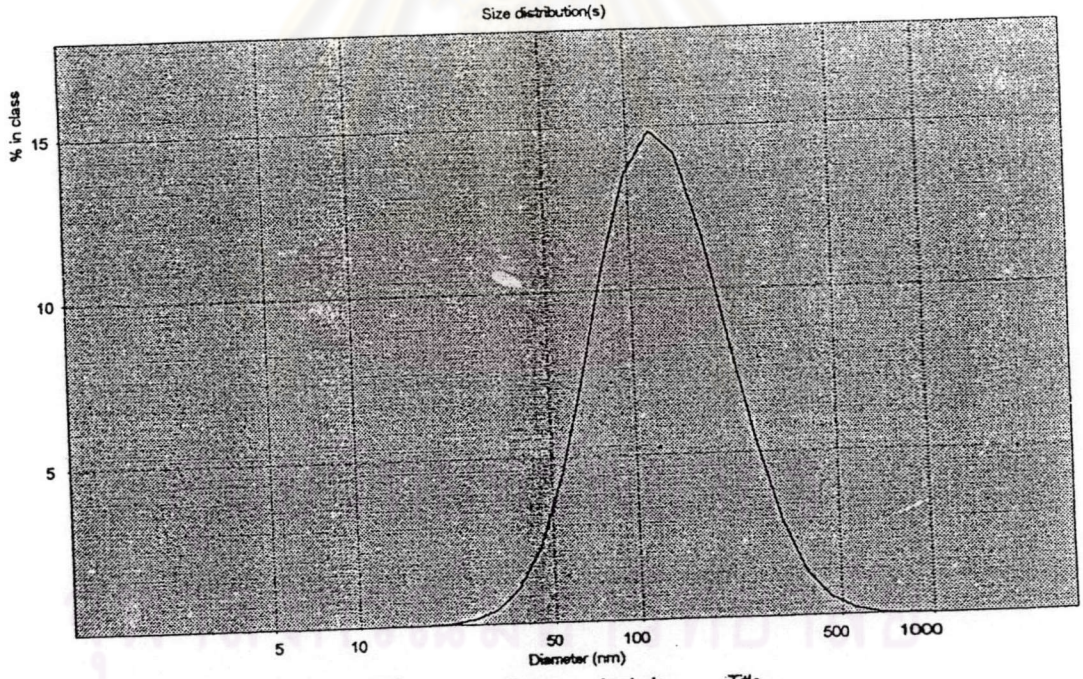
Peak	Area	Mean	Width
1	100.0	139.8	160.6

Peak Analysis by volume

Peak	Area	Mean	Width
1	98.4	67.2	77.9
2	1.6	404.6	131.3

Peak Analysis by number

Peak	Area	Mean	Width
1	100.0	29.5	33.6



RecAngle	KCounts	ZAve(nm)	Poly.Index	Quality	Error	Analysis	Title
1 90.0	141.0	122.3	0.269	Pass	8.36e-004	Monomodal	fuji9345 nondis

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fuji4254 nondis
File data from A:\zetasize.sz2 Record 2
ZetaSizer

Size(nm)	Intensity	Volume	Number
9.1	0.0	0.2	5.0
10.9	0.0	0.5	7.4
13.1	0.0	1.1	10.6
15.7	0.0	2.4	13.3
18.8	0.1	4.4	14.8
22.5	0.4	7.2	14.4
27.0	1.1	10.2	12.3
32.5	2.3	12.8	9.3
38.9	4.5	14.2	6.2
46.7	7.4	13.7	3.6
56.1	10.7	11.7	1.8
67.3	13.5	8.8	0.8
80.7	14.8	5.9	0.3
96.8	14.2	3.5	0.1
116.2	11.8	1.8	0.0
139.4	8.5	0.9	0.0
167.2	5.3	0.4	0.0
200.6	2.9	0.2	0.0
240.7	1.4	0.1	0.0
288.8	0.6	0.0	0.0
346.6	0.2	0.0	0.0
415.8	0.1	0.0	0.0
498.9	0.0	0.0	0.0
598.6	0.0	0.0	0.0

Peak Analysis by intensity

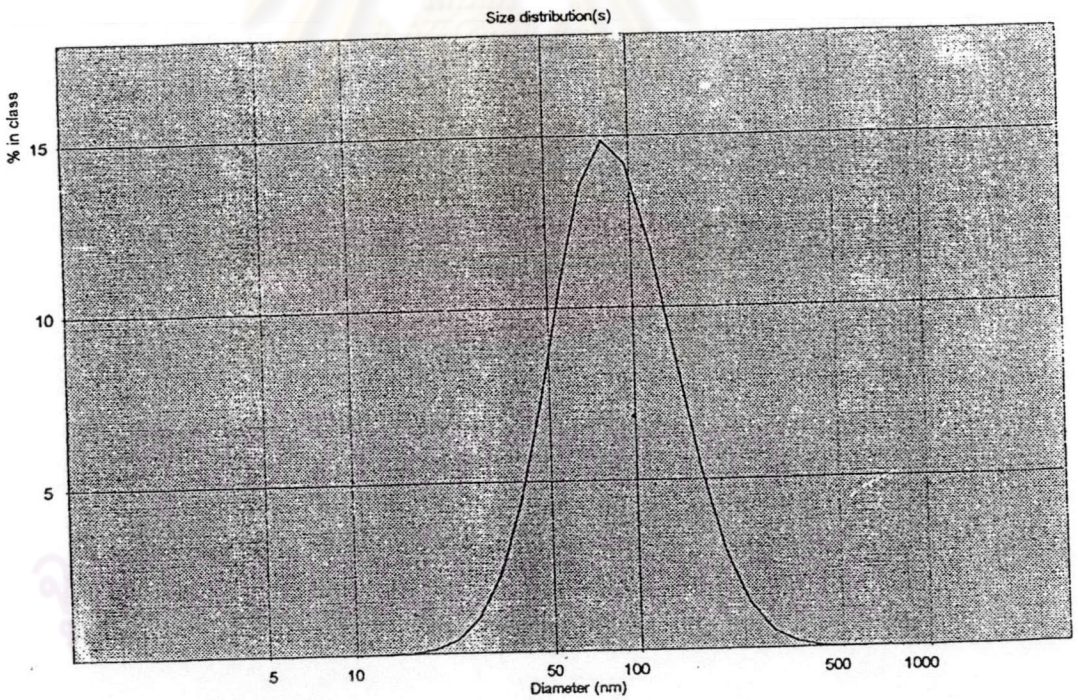
Peak	Area	Mean	Width
1	100.0	93.7	102.2

Peak Analysis by volume

Peak	Area	Mean	Width
1	99.9	47.1	52.8

Peak Analysis by number

Peak	Area	Mean	Width
1	100.0	23.2	25.5



RecAngle	KCounts	ZAve(nm)	Poly.Index	Quality	Error	Analysis	Title
2 90.0	127.1	83.1	0.239	Pass	9.34e-004	Monomodal	fuji4254 nondis

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fuji k
File data from Live size Record 2
S4700

Size(nm)	Intensity	Volume	Number
16.5	0.0	0.1	1.5
19.1	0.0	0.2	2.7
22.0	0.0	0.5	4.8
25.3	0.0	1.1	7.7
29.2	0.1	2.4	10.8
33.7	0.4	4.4	13.2
38.8	1.0	7.1	14.3
44.7	2.3	10.0	13.6
51.6	4.3	12.5	11.4
59.4	7.3	13.8	8.4
68.5	10.6	13.4	5.5
79.0	13.4	11.5	3.2
91.0	14.8	8.8	1.6
104.9	14.2	6.0	0.7
121.0	11.9	3.7	0.3
139.4	8.7	2.1	0.1
160.7	5.5	1.1	0.0
185.2	3.0	0.6	0.0
213.5	1.4	0.3	0.0
246.1	0.6	0.2	0.0
283.7	0.2	0.2	0.0
327.0	0.1	0.2	0.0
376.9	0.0	0.1	0.0
434.5	0.0	0.0	0.0

Peak Analysis by intensity

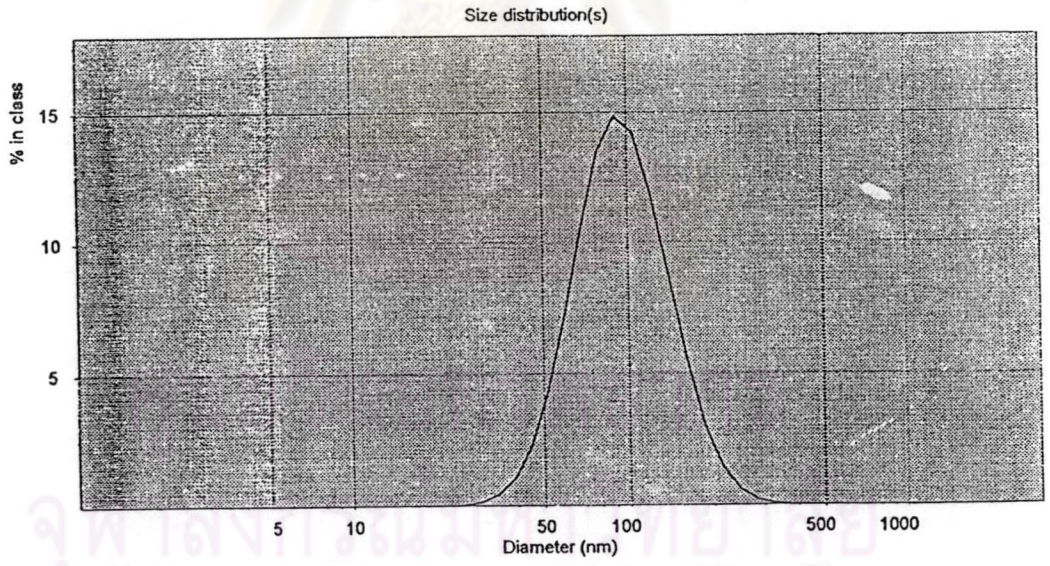
Peak	Area	Mean	Width
1	100.0	100.8	87.9

Peak Analysis by volume

Peak	Area	Mean	Width
1	100.0	69.6	62.1

Peak Analysis by number

Peak	Area	Mean	Width
1	100.0	43.1	38.7



RecAngle	KCounts	ZAve(nm)	Poly.Index	Quality	Error	Analysis	Title
2 90.0	110.9	93.8	0.145	Pass	3.22e-004	Monomodal	fuji k

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polymer cyan
File data from Live size Record 1
S4700

Size(nm)	Intensity	Volume	Number
18.5	0.0	0.1	1.8
21.4	0.0	0.2	3.1
24.8	0.0	0.5	5.5
28.8	0.0	1.2	8.5
33.4	0.1	2.4	11.4
38.7	0.4	4.4	13.6
44.9	1.0	7.0	14.3
52.0	2.3	9.8	13.2
60.3	4.4	12.0	10.7
69.9	7.3	13.1	7.7
81.1	10.6	12.7	4.9
94.0	13.5	10.9	2.8
109.0	14.8	8.4	1.4
126.4	14.2	5.9	0.6
146.5	11.9	3.8	0.3
169.9	8.6	2.4	0.1
197.0	5.5	1.5	0.0
228.4	3.0	1.0	0.0
264.9	1.4	1.0	0.0
307.1	0.6	1.0	0.0
356.1	0.2	0.6	0.0
412.9	0.1	0.1	0.0
478.8	0.0	0.0	0.0
555.1	0.0	0.0	0.0

Peak Analysis by intensity

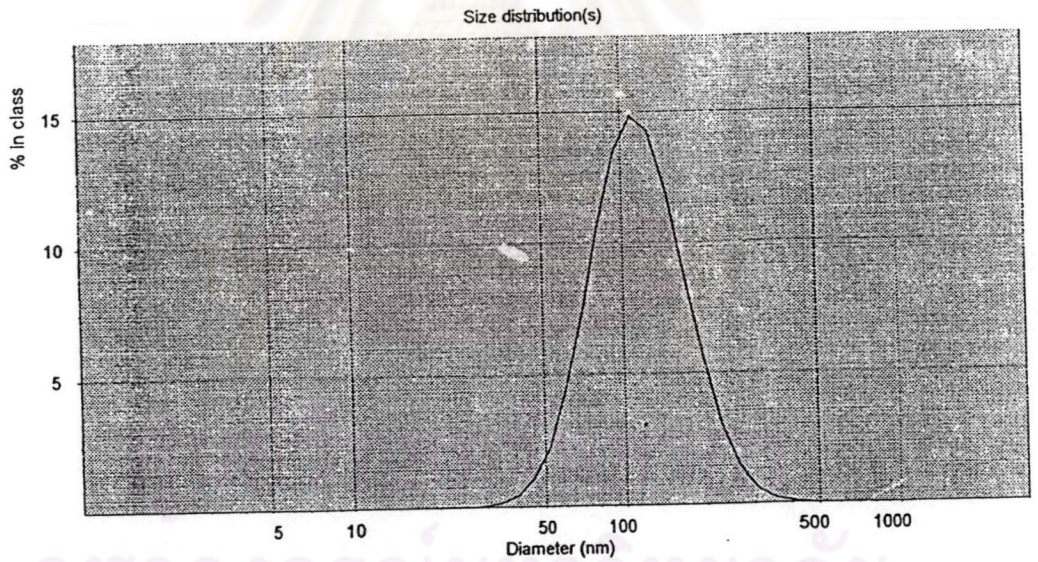
Peak	Area	Mean	Width
1	100.0	121.5	110.0

Peak Analysis by volume

Peak	Area	Mean	Width
1	97.3	83.7	78.0
2	2.7	309.7	57.0

Peak Analysis by number

Peak	Area	Mean	Width
1	100.0	48.7	45.2



RecAngle	KCounts	ZAve(nm)	Poly.Index	Quality	Error	Analysis	Title
1 90.0	120.9	112.3	0.158	Pass	2.55e-004	Monomodal	polymer cyan

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Dainichi M-12
File data from Live size Record 4
ZetaSizer

Size(nm)	Intensity	Volume	Number
8.0	0.0	0.4	11.0
10.0	0.0	0.9	13.4
12.4	0.0	2.0	15.7
15.4	0.0	3.9	16.1
19.2	0.2	6.4	14.5
23.9	0.4	9.4	11.5
29.7	1.1	12.1	8.0
37.0	2.4	13.7	4.9
46.0	4.5	13.6	2.7
57.2	7.5	12.0	1.3
71.1	10.8	9.3	0.5
88.5	13.5	6.4	0.2
110.1	14.6	3.9	0.1
137.0	14.1	2.2	0.0
170.4	11.7	1.1	0.0
212.0	8.4	0.6	0.0
263.8	5.3	0.4	0.0
328.2	2.9	0.5	0.0
408.3	1.4	0.7	0.0
508.0	0.6	0.3	0.0
632.0	0.2	0.0	0.0
786.2	0.1	0.0	0.0
978.1	0.0	0.0	0.0
1216.9	0.0	0.0	0.0

Peak Analysis by intensity

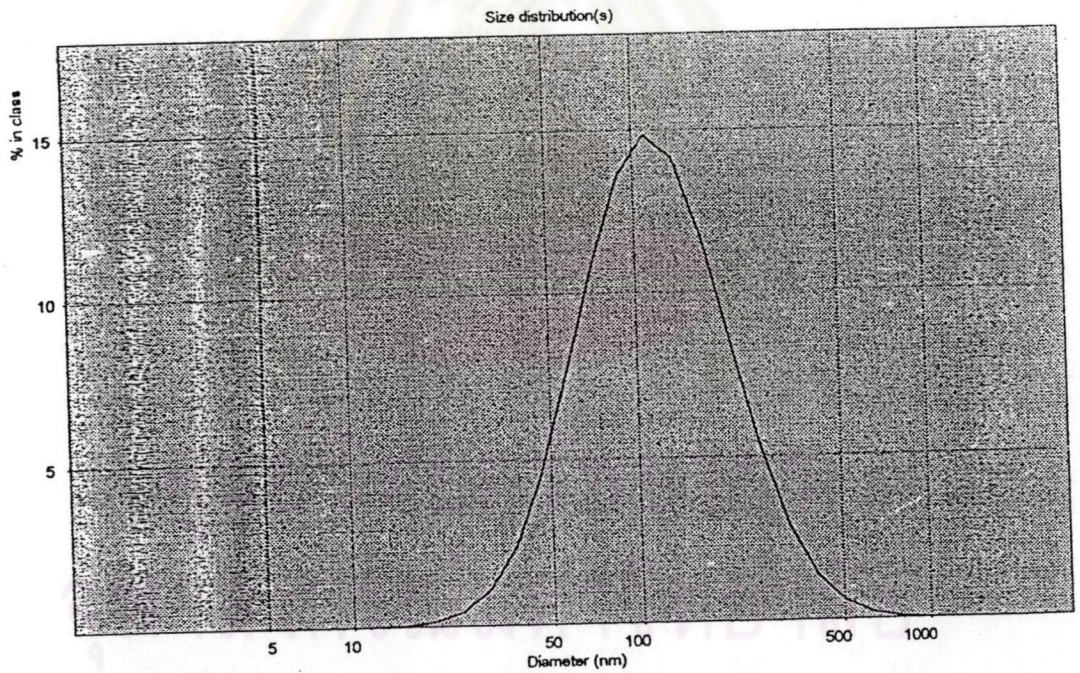
Peak	Area	Mean	Width
1	100.0	134.7	171.4

Peak Analysis by volume

Peak	Area	Mean	Width
1	98.1	50.7	65.8
2	1.9	389.6	181.2

Peak Analysis by number

Peak	Area	Mean	Width
1	100.0	19.0	19.7



RecAngle	KCounts	ZAve(nm)	Poly.Index	Quality	Error	Analysis	Title
4 90.0	44.1	113.4	0.343	Pass	0.00106	Monomodal	Dainichi M-12

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Dainichi Y-20
File data from Live size Record 2
ZetaSizer

Size(nm)	Intensity	Volume	Number
9.5	0.0	0.2	6.0
11.4	0.0	0.5	8.5
13.8	0.0	1.3	11.~
16.7	0.0	2.6	14.2
20.2	0.1	4.8	15.0
24.4	0.4	7.6	14.1
29.5	1.1	10.6	11.5
35.7	2.3	13.1	8.3
43.1	4.5	14.1	5.3
52.2	7.4	13.4	2.9
63.1	10.8	11.2	1.4
76.2	13.6	8.3	0.6
92.1	14.8	5.5	0.2
111.4	14.2	3.2	0.1
134.6	11.7	1.7	0.0
162.8	8.5	0.8	0.0
196.8	5.3	0.4	0.0
237.9	2.9	0.2	0.0
287.5	1.4	0.1	0.0
347.6	0.6	0.1	0.0
420.2	0.2	0.1	0.0
507.9	0.1	0.1	0.0
614.0	0.0	0.0	0.0
742.2	0.0	0.0	0.0

Peak Analysis by intensity

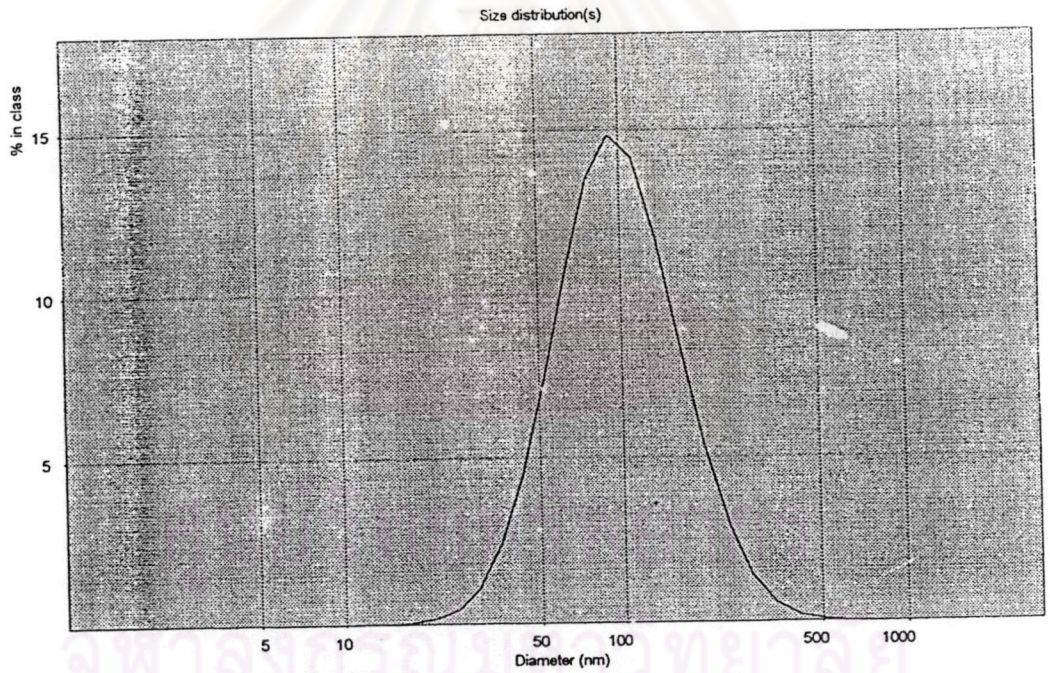
Peak	Area	Mean	Width
1	100.0	108.0	122.1

Peak Analysis by volume

Peak	Area	Mean	Width
1	99.6	51.6	59.7

Peak Analysis by number

Peak	Area	Mean	Width
1	100.0	23.9	27.0



RecAngle	KCounts	ZAve(nm)	Poly.Index	Quality	Error	Analysis	Title
2 90.0	112.4	94.9	0.259	Check Baseline	6.16e-004	Monomodal	Dainichi Y-20

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polymer black
File data from Live size Record 2
S4700

Size(nm)	Intensity	Volume	Number
9.6	0.0	0.1	3.4
11.4	0.0	0.3	5.4
13.4	0.0	0.9	8.4
15.9	0.0	1.9	11.5
18.8	0.1	3.6	13.8
22.2	0.4	6.1	14.6
26.3	1.1	9.1	13.6
31.1	2.3	12.0	11.1
36.8	4.4	13.8	8.0
43.5	7.4	14.0	5.1
51.5	10.7	12.5	2.8
60.9	13.5	9.9	1.4
72.0	14.8	6.9	0.6
85.1	14.2	4.3	0.2
100.7	11.8	2.4	0.1
119.1	8.5	1.2	0.0
140.8	5.4	0.6	0.0
166.6	3.0	0.2	0.0
197.0	1.4	0.1	0.0
233.0	0.6	0.1	0.0
275.5	0.2	0.1	0.0
325.9	0.1	0.1	0.0
385.4	0.0	0.0	0.0
455.8	0.0	0.0	0.0

Peak Analysis by intensity

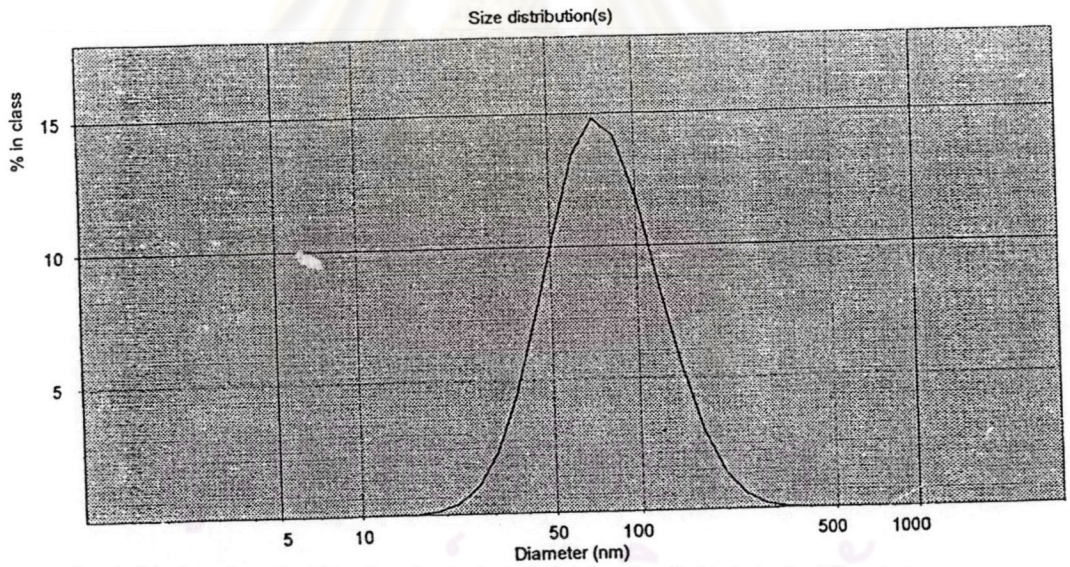
Peak	Area	Mean	Width
1	100.0	82.1	83.2

Peak Analysis by volume

Peak	Area	Mean	Width
1	99.9	46.4	48.2

Peak Analysis by number

Peak	Area	Mean	Width
1	100.0	25.0	25.7



RecAngle	KCounts	ZAve(nm)	Poly.Index	Quality	Error	Analysis	Title
2 90.0	95.1	74.2	0.203	Pass	5.40e-004	Monomodal	polymer black

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dainippon b
File data from Live size Record 3
S4700

Size(nm)	Intensity	Volume	Number
18.0	0.0	0.1	1.8
20.9	0.0	0.2	3.2
24.3	0.0	0.5	5.6
28.2	0.0	1.2	8.6
32.7	0.1	2.5	11.6
38.0	0.4	4.5	13.7
44.1	1.0	7.1	14.3
51.2	2.3	9.9	13.1
59.4	4.4	12.1	10.6
69.0	7.3	13.2	7.5
80.0	10.6	12.7	4.8
92.9	13.5	10.9	2.7
107.9	14.8	8.3	1.3
125.2	14.2	5.8	0.6
145.4	11.9	3.7	0.3
168.8	8.6	2.3	0.1
195.9	5.4	1.4	0.0
227.4	3.0	0.9	0.0
264.0	1.4	0.9	0.0
306.5	0.6	1.0	0.0
355.8	0.2	0.5	0.0
413.0	0.1	0.1	0.0
479.5	0.0	0.0	0.0
556.6	0.0	0.0	0.0

Peak Analysis by Intensity

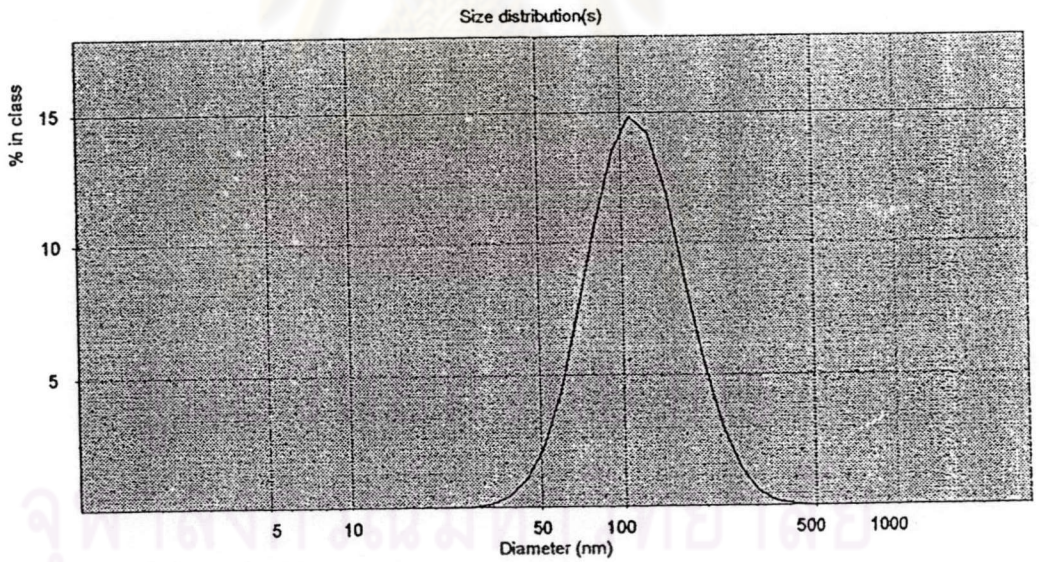
Peak	Area	Mean	Width
1	100.0	120.4	109.8

Peak Analysis by volume

Peak	Area	Mean	Width
1	97.5	82.1	77.0
2	2.5	309.4	58.1

Peak Analysis by number

Peak	Area	Mean	Width
1	100.0	47.5	44.3



RecAngle	KCounts	ZAve(nm)	Poly.Index	Quality	Error	Analysis	Title
3 90.0	110.2	111.1	0.160	Pass	3.52e-004	Monomodal	dainippon b

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daippon mcm-146
File data from Live size Record 3
ZetaSizer

Size(nm)	Intensity	Volume	Number
11.8	0.0	0.3	7.9
14.4	0.0	0.6	10.4
17.6	0.0	1.5	13.4
21.6	0.0	2.9	15.2
26.4	0.1	5.1	15.1
32.3	0.4	7.9	13.2
39.5	1.1	10.6	10.1
48.3	2.4	12.6	6.8
59.1	4.5	13.3	4.1
72.3	7.5	12.3	2.1
88.4	10.8	10.1	1.0
108.2	13.6	7.4	0.4
132.3	14.8	4.9	0.2
161.9	14.1	3.0	0.1
198.0	11.7	1.8	0.0
242.3	8.4	1.1	0.0
296.4	5.3	0.9	0.0
362.6	2.9	1.4	0.0
443.6	1.4	1.6	0.0
542.6	0.6	0.7	0.0
663.8	0.2	0.1	0.0
812.1	0.1	0.0	0.0
993.5	0.0	0.0	0.0
1215.4	0.0	0.0	0.0

Peak Analysis by intensity

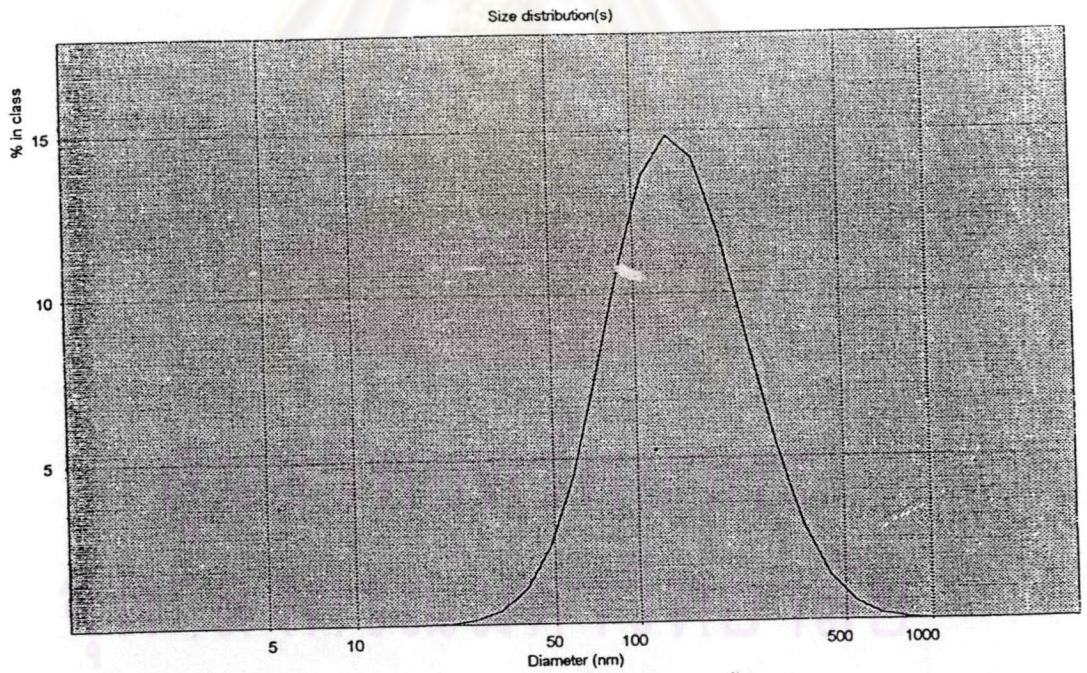
Peak	Area	Mean	Width
1	100.0	157.7	187.8

Peak Analysis by volume

Peak	Area	Mean	Width
1	95.3	71.6	85.8
2	4.7	418.2	173.0

Peak Analysis by number

Peak	Area	Mean	Width
1	100.0	29.2	31.9



RecAngle	KCounts	ZAve(nm)	Poly.Index	Quality	Error	Analysis	Title
3 90.0	65.1	136.3	0.293	Pass	6.63e-004	Monomodal	daippon mcm-146

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MCY-146
File data from Live size Record 1
ZetaSizer

Size(nm)	Intensity	Volume	Number
9.2	0.0	0.4	10.7
11.4	0.0	0.9	13.2
14.1	0.0	1.9	15.5
17.6	0.0	3.6	16.1
21.8	0.1	6.1	14.6
27.1	0.4	8.9	11.7
33.7	1.1	11.5	8.2
41.9	2.4	13.1	5.1
52.1	4.5	13.1	2.8
64.7	7.5	11.6	1.3
80.4	10.8	9.1	0.6
99.9	13.6	6.4	0.2
124.2	14.8	4.1	0.1
154.3	14.1	2.4	0.0
191.8	11.7	1.3	0.0
238.3	8.4	0.8	0.0
296.1	5.3	0.6	0.0
368.0	2.9	1.3	0.0
457.3	1.4	1.8	0.0
568.3	0.6	0.9	0.0
706.3	0.2	0.1	0.0
877.7	0.1	0.0	0.0
1090.8	0.0	0.0	0.0
1355.5	0.0	0.0	0.0

Peak Analysis by intensity

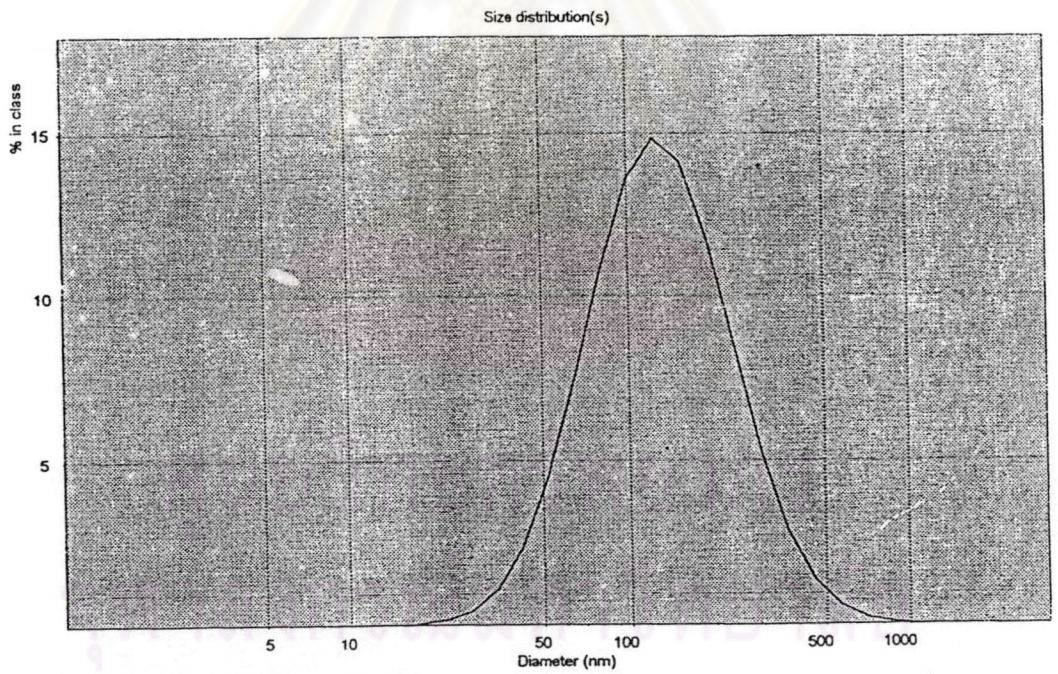
Peak	Area	Mean	Width
1	100.0	151.6	192.2

Peak Analysis by volume

Peak	Area	Mean	Width
1	95.3	59.5	76.0
2	4.7	447.2	235.8

Peak Analysis by number

Peak	Area	Mean	Width
1	100.0	21.8	22.8



RecAngle	KCounts	ZAve(nm)	Poly.Index	Quality	Error	Analysis	Title
1 90.0	64.2	127.9	0.340	Check Baseline	8.09e-004	Monomodal	MCY-146

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dainippon k
File data from Live size Record 4
S4700

Size(nm)	Intensity	Volume	Number
11.2	0.0	0.1	2.7
13.1	0.0	0.3	4.5
15.4	0.0	0.7	7.3
18.1	0.0	1.6	10.4
21.3	0.1	3.2	13.1
25.0	0.4	5.6	14.5
29.3	1.0	8.6	14.0
34.5	2.3	11.5	12.0
40.4	4.4	13.5	9.0
47.5	7.4	14.0	6.0
55.8	10.7	12.8	3.5
65.5	13.5	10.4	1.8
76.9	14.8	7.4	0.8
90.3	14.2	4.7	0.3
106.0	11.8	2.7	0.1
124.4	8.6	1.4	0.0
146.1	5.4	0.7	0.0
171.5	3.0	0.3	0.0
201.4	1.4	0.1	0.0
236.5	0.6	0.1	0.0
277.7	0.2	0.1	0.0
326.0	0.1	0.1	0.0
382.8	0.0	0.0	0.0
449.4	0.0	0.0	0.0

Peak Analysis by Intensity

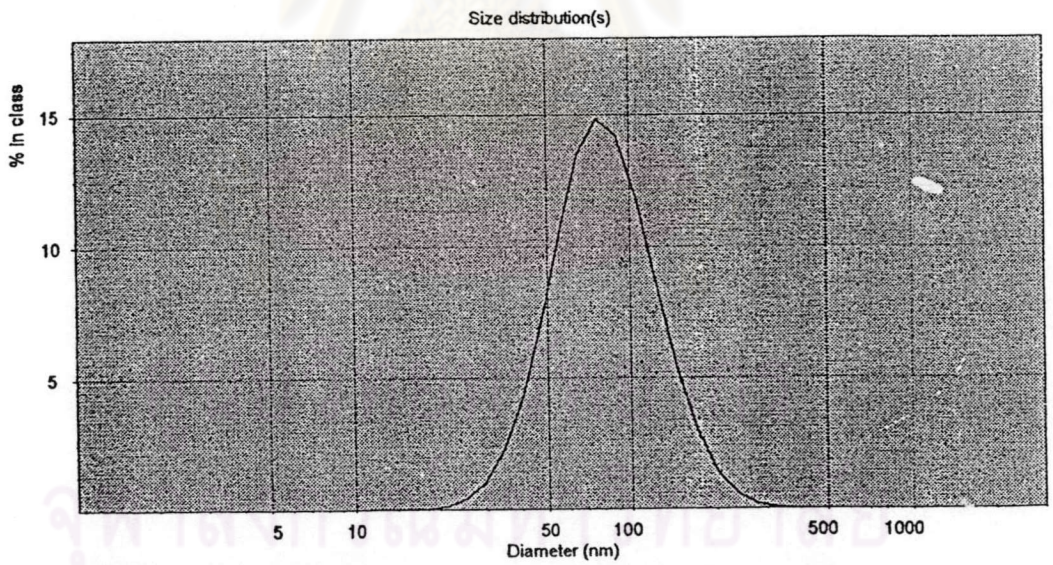
Peak	Area	Mean	Width
1	100.0	86.9	84.7

Peak Analysis by volume

Peak	Area	Mean	Width
1	99.8	51.9	51.8

Peak Analysis by number

Peak	Area	Mean	Width
1	100.0	29.2	29.2



RecAngle	KCounts	ZAve(nm)	Poly.Index	Quality	Error	Analysis	Title
4 90.0	82.5	79.2	0.186	Pass	5.10e-004	Monomodal	dainippon k

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APPENDIX B

THE METHOD OF CALCULATION OF COLOR GAMUT VOLUME

■第４章　画像データの統計量■

SHIPP画像の客観的評価の参考として、次に示す３種類の項目について評価を行った。

（1）画像の統計量(最小・最大値、平均値、分散・共分散、１次元ヒストグラム)

（2）主成分分析(principal component analysis)による色情報量の解析

（3）画像の空間周波数特性(自己相関関数)

また、画像データの正当性を検査するためのチェック・サムも求めた。

4.1　画像の統計量

各プレーンの画素の平均値及び分散・共分散行列は、全画素数をＮとすると次の式で与えられる。

[画素の平均値]

$$\begin{pmatrix}\overline{P_1}\\ \overline{P_2}\\ \overline{P_3}\end{pmatrix}=\frac{1}{N}\begin{pmatrix}\sum P_1\\ \sum P_2\\ \sum P_3\end{pmatrix} \tag{4-1}$$

[分散・共分散行列]

$$\begin{pmatrix}V_{P_{11}} & V_{P_{12}} & V_{P_{13}}\\ V_{P_{21}} & V_{P_{22}} & V_{P_{23}}\\ V_{P_{31}} & V_{P_{32}} & V_{P_{33}}\end{pmatrix}=\frac{1}{N}\begin{pmatrix}\sum(P_1-\overline{P_1})^2 & \sum(P_1-\overline{P_1})(P_2-\overline{P_2}) & \sum(P_1-\overline{P_1})(P_3-\overline{P_3})\\ \sum(P_2-\overline{P_2})(P_1-\overline{P_1}) & \sum(P_2-\overline{P_2})^2 & \sum(P_2-\overline{P_2})(P_3-\overline{P_3})\\ \sum(P_3-\overline{P_3})(P_1-\overline{P_1}) & \sum(P_3-\overline{P_3})(P_2-\overline{P_2}) & \sum(P_3-\overline{P_3})^2\end{pmatrix} \tag{4-2}$$

分散・共分散行列の対角要素 V_{11}, V_{22}, V_{33} は各プレーンの画素値の分散であり、非対角要素は対応するプレーン同士の共分散を表している。プレーン同士の相関は、

$$\begin{pmatrix}R_{P_{11}} & R_{P_{12}} & R_{P_{13}}\\ R_{P_{21}} & R_{P_{22}} & R_{P_{23}}\\ R_{P_{31}} & R_{P_{32}} & R_{P_{33}}\end{pmatrix}=\begin{pmatrix}1 & \dfrac{V_{P_{12}}}{\sqrt{V_{P_{11}}}\cdot\sqrt{V_{P_{22}}}} & \dfrac{V_{P_{13}}}{\sqrt{V_{P_{11}}}\cdot\sqrt{V_{P_{33}}}}\\ \dfrac{V_{P_{21}}}{\sqrt{V_{P_{22}}}\cdot\sqrt{V_{P_{11}}}} & 1 & \dfrac{V_{P_{23}}}{\sqrt{V_{P_{22}}}\cdot\sqrt{V_{P_{33}}}}\\ \dfrac{V_{P_{31}}}{\sqrt{V_{P_{33}}}\cdot\sqrt{V_{P_{11}}}} & \dfrac{V_{P_{32}}}{\sqrt{V_{P_{33}}}\cdot\sqrt{V_{P_{22}}}} & 1\end{pmatrix} \tag{4-3}$$

で与えられる。一般的にRGB系の画像では各プレーン間の相関が高いため、各プレーンの分散を調べただけでは色彩分布の広がりを判定することは困難である。そこで主成分分析の手法を用いて画像の色彩分布の広がりを客観的に求めることを考える。

画像に関する統計を取る際に注意しなければならないのは、各自然画像中に、その色空間に応じて

" SHIPP RGB" 、" SHIPP LAB" 、" SHIPP XYZ" の識別文字が含まれていることである。文字の部分は、" SHIPP RGB" と" SHIPP LAB" の場合には0か255、" SHIPP XYZ" の場合には0か基準白色D65に対応するデータを有するので、画像の性質を知るための統計量の計算をこの文字領域を含んで行うのは不都合である。この理由から、文字領域を除いた画像領域のみで計算を行った。文字領域の位置は図4.1に示すA及びBの座標値で表し、表4.1にこの座標値を示す。

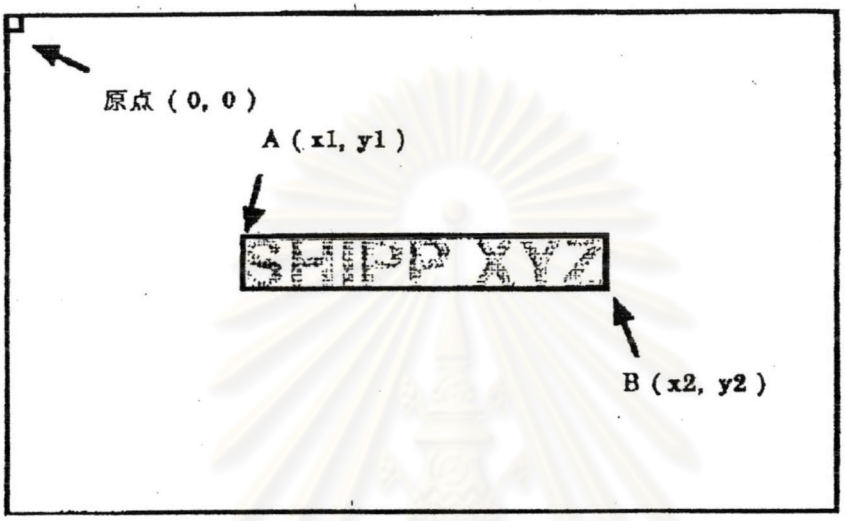

図4.1　文字領域を表す座標

表4.1　文字領域の位置と大きさ

画　像	A (x1, y1)	B (x2, y2)	Size
BrideRGB	(2770, 35)	(3035, 71)	266 × 37
HarborRGB	(34, 35)	(299, 71)	266 × 37
WoolRGB	(3794, 35)	(4059, 71)	266 × 37
BottlesRGB	(2770, 35)	(3035, 71)	266 × 37
BrideLAB	(2770, 36)	(3021, 72)	252 × 37
HarborLAB	(34, 36)	(285, 72)	252 × 37
WoolLAB	(3794, 36)	(4045, 72)	252 × 37
BottlesLAB	(2770, 36)	(3021, 72)	252 × 37
BrideXYZ	(2770, 36)	(3016, 72)	247 × 37
HarborXYZ	(34, 36)	(280, 72)	247 × 37
WoolXYZ	(3794, 36)	(4040, 72)	247 × 37
BottlesXYZ	(2770, 36)	(3016, 72)	247 × 37

4.2 主成分分析

主成分分析は、ある多変量の空間に対して各々の変量の相関が最小となるような直交変換を施すことによって、より少ない変量で元の空間の情報を効果的に表す手法である。この主成分を求めるには分散・共分散行列の固有値問題を解けばよいことが知られている。

Vを3行3列の分散・共分散行列、xを長さ3の列ベクトル、λをスカラーとすると、次の方程式の一般解を求めればよい。

$$V \cdot x = \lambda \cdot x \tag{4-4}$$

この方程式を満たす3つの値λを固有値、xを固有ベクトルと呼ぶ。主成分は分散・共分散行列の固有ベクトルそのものであり、主成分の分散が固有値に等しい。また、各主成分の寄与率は、

$$\text{第n主成分の寄与率} = \text{第n主成分の固有値} \div \text{固有値の合計} \tag{4-5}$$

で与えられ、この値によってその主成分が元の情報をどの程度反映しているかを表している。

このようにして求められた3つの主成分は互いに直交しているので、各々の主成分の標準偏差 (固有値の平方根)を掛け合わせたものは、色彩分布の3次元的な広がり、すなわち体積を表す。そこで、3次元体積V_{3D}を

$$V_{3D} = \sqrt{\lambda_1} \cdot \sqrt{\lambda_2} \cdot \sqrt{\lambda_3} \tag{4-6}$$

として定義する。

各画像の統計量及び主成分分析結果を表4.2から表4.13に、1次元ヒストグラムを図4.2から図4.13に示す。

VITA

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