

LABORATORY OF POWDER AND CRYSTAL CHEMISTRY

Head: Dr. Natsu Uyeda

The Laboratory established by Prof. E. Suito in 1952 has been succeeded to Prof. N. Uyeda in 1976 in order to develop the new field of science concerning the physical chemistry of powders and micro-crystals by the collaboration of staff members, Dr. M. Arakawa, Dr. T. Kobayashi, Dr. M. Nishino, and Mr. T. Yoshida. The scopes of major researches are outlined hereunder together with the lists of papers published during the last decade.

I. Transformation and Growth of Microcrystals in Suspensions

It was found by X-ray diffraction and electron microscopy that metastable powders of organic compounds are transformed to stable forms, being accompanied by considerable crystal growth in organic suspensions. This phenomenon is common to various metal derivatives of phthalocyanine. Remarkable solvent effects were also observed giving rise to intermediate states during the transformation, including preliminary growth, formations of complexes with solvent molecules and different polymorphs. These effects were interpreted in terms of electron affinities and donating properties of dispersed powders and suspension media.

The crystal structures of some adducts complexes of Zn and Fe-phthalocyanines were determined by X-ray diffraction analysis.

II. Epitaxial Growth and Topotactic Formation of Thin Films of Organic Semi-Conductors and Charge Transfer Complexes

Electron microscopy was applied to the studies of thin crystalline films formed on cleaved surfaces of ionic crystals by epitaxial growth from the vapor phase. The orientation and structures were analysed by the combined use of selected area diffraction to find that there are certain evidences for the crystal orientation being mostly controlled by the oriented adsorption of molecules which form the epitactic nucleation on the substrate surfaces.

LEED and AES were also applied to confirm the state of oriented adsorption with systematic combinations of alkali halides as substrates and cyano- and halogeno-derivatives of ethylene as adsorbates.

Topotactic formation of charge transfer complexes was also studied with TCNQ as electron acceptor and counterpart donors such as metal ions and anthracene.

III. High Resolution Electron Microscopy of Fine Structures of Microcrystals

Various lattice defects, such as multiple twins, spiral steps, dislocations, and stacking faults were investigated by high resolution electron microscopy with respect to colloidal particles of gold and silver, and various clay minerals. The fine structures were analysed by the observation of diffraction contrasts, moiré fringes and lattice images which directly reveal the arrangements in crystals.

IV. Direct Observation of Molecular Images for the Structure Determination

Since the first success in the direct observation of molecular images of hexadeca-chloro-Cu-Phthalocyanine arrayed in thin epitaxial films, high resolution electron microscopy of atomic order has been explored from both experimental and theoretical phases. The qualification of molecular images and the reconstruction of correct structures have been undertaken by means of computer simulation.

Joint exploration on the attainment of atomic resolution with Prof. K. Kobayashi, is also proceeded in regard to the construction and application of new 500 kV electron microscope.

V. Characteristics of Powder

Systematic investigations have been carried out concerning the physical properties of various industrial powders in view of the characteristic behavior unexpectable from bulk properties. The mechanical properties such as fluidity, packing property and mixing of powders have been investigated in relation to the shape, size, surface state, and interaction of component particles. The methods to estimate these properties are also explored with model powders, practical application to the analysis, and the classification of results.

Publications

(* indicates an article published in Japanese)

I. Transformation and Growth of Microcrystals in Suspensions

1. T. Kobayashi, N. Uyeda, and E. Suito: The n-Donor Complex Formation and Polymorphic Transformation of Zinc Phthalocyanine in Organic Suspension Media., *J. Phys. Chem.*, **72**, 2446 (1968).
2. T. Kobayashi: The Far-Infrared Spectra of Phthalocyanine and Its Metal Derivatives., *Spectrochim. Acta*, **26A**, 1305 (1969).
3. T. Kobayashi, N. Uyeda, and E. Suito: Infrared Spectra of Charge Transfer Complexes between Zinc-Phthalocyanine and Various Amines., *Bull. Inst. Chem. Res., Kyoto Univ.*, **47**, 401 (1969).
4. T. Kobayashi, F. Kurokawa, N. Uyeda, and E. Suito: The Metal-Ligand Vibrations in the Infrared Spectra of Various Metal Phthalocyanines., *Spectrochim. Acta*, **26A**, 1305 (1970).
5. T. Kobayashi: The Far infrared Spectra of Phthalocyanine and Its Metal Derivatives., *ibid.*, **26A**, 1313 (1970).
6. T. Kobayashi, T. Ashida, N. Uyeda, E. Suito, and M. Kakudo: The Crystal Structure of the 2 : 3 Complex of Zinc Phthalocyanine and n-Hexylamine., *Bull. Chem. Soc. Japan*, **44**, 2095 (1971).

7. T. Kobayashi, F. Kurokawa, T. Ashida, N. Uyeda, and E. Suito: X-ray Crystal Structure of a 4 : 1 Amine Complex between Phthalocyanineiron (II) and 4-Methylpyridine., *Chem. Commun.*, 1631 (1971).
8. Y. Saito, T. Kobayashi, N. Uyeda, and E. Suito: A Kinetic Study on the *n*-Donor Complex Formation with Zinc-Phthalocyanine by Means of Quartz Crystal Microbalance and Electron Microscopy., *Bull. Inst. Chem. Res., Kyoto Univ.*, **49**, 256 (1971).
9. T. Kobayashi, N. Uyeda, and E. Suito: Far Infrared Spectra of Amine Complexes of Zinc Phthalocyanine., *ibid.*, **52**, 605 (1974).
10. T. Kobayashi, F. Kurokawa, and N. Uyeda: Formation and Properties of Various Amine Complexes of Iron-Phthalocyanine., *ibid.*, **53**, 186 (1975).

Reviews

1. E. Suito, and T. Kobayashi: Theory of Precipitation. (I) Theory of Nucleation., *Bunseki-Kagaku (Japan Analyst)*, **15**, 1406 (1966).*
2. E. Suito and T. Kobayashi: Theory of Precipitation. (II) Process of Crystal Growth., *ibid.*, **16**, 67 (1967).*
3. E. Suito, N. Uyeda, and M. Ashida: Crystal Structure of Phthalocyanines., *Senryo to Yakuhin (Dye-stuffs and Chemicals)*, **12**, 41 (1967).*
4. N. Uyeda: Solvent Effect on the Transformation of Crystalline Powders in Organic Suspensions., *Kagaku to Kogyo (Chemistry and Industry)*, **22**, 524 (1969).*
5. N. Uyeda: The Solvent Effect on Crystal Transformation of Metal Phthalocyanines in Organic Suspensions., *Progr. Org. Coatings*, **2**, 131 (1974).

II. Epitaxial Growth and Topotactic Formation of Thin Films of Organic Semi-Conductors and Charge Transfer Complexes

1. N. Uyeda, T. Kobayashi, and E. Suito: Electron Microscopy of Epitaxial Reaction of Organic Complex Crystals., *Microscopie Electronique*, **2**, 433 (1970).
2. M. Ashida, N. Uyeda, and E. Suito: Thermal Transformation of Vacuum-Condensed Thin Films of Copper-Phthalocyanine., *J. Cryst. Growth.*, **8**, 45 (1970).
3. T. Takenaka, S. Tadokoro, and N. Uyeda: Infrared Absorption Spectra of Tetracyanoethylene Adsorbed on Evaporated Alkali Halides., *Bull. Inst. Chem. Res., Kyoto Univ.*, **48**, 249 (1970).
4. N. Uyeda, Y. Murata, and E. Suito: Epitaxial Nucleation and Growth of Vacuum-Condensed Organic Semi-Conductor., *8th International Congress on Electron Microscopy, Canberra*, **1**, 692 (1974).
5. Y. Murata, T. Kobayashi, N. Uyeda, and E. Suito: Topotaxial Formation of an Anthracene-TCNQ (1 : 1) Complex in the Solid Phase, *J. Cryst. Growth*, **26**, 187 (1974).
6. N. Uyeda, Y. Murata, T. Kobayashi, and E. Suito: Epitaxial Growth of an Organic Semiconductor from the Vapor Phase-TCNQ on Potassium Chloride., *ibid.*, **26**, 267 (1974).
7. K. Tanabe and N. Uyeda: Oriented Adsorption of Amino Acids on (001) Nickel Surface., *Bull. Inst. Chem. Res., Kyoto Univ.*, **52**, 616 (1974).

Reviews

1. N. Uyeda: Epitaxial Growth of Vacuum-Deposited Films of Organic Semiconductors., *Bussei*, **7**, 158 (1966).*
2. N. Uyeda, M. Ashida, K. Yamamoto, and E. Suito: Oriented Adsorption of Organic Molecules as the Epitaxial Nuclei on the Surfaces of Clay Minerals., *U. S.-Japan Seminar on Clay-Organic Complexes*, 110 (1971).
3. E. Suito, N. Uyeda, and T. Kobayashi: World through Electron Microscopy—Structures of Organic Crystals., *Kagaku no Ryoiki*, **26**, A 71-74, pp. 65 (1972).*

III. High Resolution Electron Microscopy on Fine Structures of Microcrystals

1. M. Shiojiri: Crystallization of Amorphous Selenium Films Prepared by Vacuum-Evaporation., *Japan. J. Appl. Phys.*, **6**, 163 (1967).
2. M. Shiojiri, H. Morikawa, and E. Suito: Observation of Dissociated Dislocations in Lead Iodide,

- ibid.*, **6**, 409 (1967).
3. M. Shiojiri, H. Morikawa, and E. Suito: Cinematographic Observation of Crystallization Process of Amorphous Titanium Dioxide Films, *J. Electron Microscopy*, **17**, 1 (1968).
 4. H. Kiho, S. Maruyama, and N. Uyeda: Elastic and Plastic Deformation of Colloidal Gold., *J. Electronmicrosc.*, **17**, 113 (1968).
 5. E. Suito, M. Arakawa, and T. Yoshida: Electron Microscopic Observation of the Layer of Organo-Montmorillonite., *Proc. Int. Clay Conf.*, **1**, 757 (1969).
 6. N. Uyeda: Substructures of Colloidal Silver Particles., *Bull. Inst. Chem. Res., Kyoto Univ.*, **47**, 426 (1969).
 7. M. Shiojiri, H. Morikawa, and E. Suito: Crystal Growth upon Amorphous Phase in Thin Films, *Japan. J. Appl. Phys.*, **8**, 1077 (1969).
 8. H. Morikawa: The Growth of Copper Selenide Crystals Produced by Solid-State Reaction., *J. Appl. Phys.*, **9**, 607 (1970).
 9. E. Suito, Y. Murata, N. Uyeda, and M. Watanabe: High Resolution Electron Microscopy on Very Small Colloidal Particles of Noble Metals, *Microscopie Electronique*, **1**, 25 (1970).
 10. H. Kiho, S. Maruyama, and N. Uyeda: Deformation Elastique et Plastique des Couche de Colloide d'Or., Sept. Congr. Intern'l. Microsc. Electronique, *Grenoble*, **2**, 567 (1970).
 11. H. Morikawa, M. Shiojiri, and E. Suito: Electron Microscopic Observation of Fine Structure of Cu_3Se Crystals., *J. Appl. Phys.*, **42**, 2144 (1971).
 12. E. Suito and T. Yoshida: Lattice Image of Organo-Montmorillonite., *Nature (Phys. Sci.)*, **229**, 22 (1971).
 13. H. Morikawa: Planar Defects of Cu_3Se_2 Crystals Produced by Solid-State Reaction., *Japan. J. Appl. Phys.*, **11**, 431 (1972).
 14. T. Yoshida and E. Suito: Interstratified Layer Structure of the Organo-Montmorillonites as Revealed by Electron Microscopy. *J. Appl. Cryst.*, **5**, 119 (1972).
 15. T. Yoshida: Layer Structures of Clay Minerals as Revealed by Electron Microscopy., *Nendo Kagaku (J. Clay Sci. Soc. Japan)*, **13**, 2 (1973).*
 16. T. Yoshida: Elementary Layers in the Interstratified Clay Minerals as Revealed by Electron Microscopy, *Clays and Clay Minerals*, **21**, 413 (1973).
 17. N. Uyeda, M. Nishino, and E. Suito: Nucleus Interaction and Fine Structures of Colloidal Gold Particles., *J. Colloid Interf. Sci.*, **43**, 264 (1973).
 18. N. Uyeda, P. T. Hang, and G. W. Brindley: The Nature of Garnierites-II, Electron Optical Study., *Clay. Clay Miner.*, **21**, 41 (1973).
 19. E. Suito, N. Uyeda, and T. Yoshida: Microstructures of Interstratified Clay Minerals., *Eighth Inter'l Congr. Electron Microsc.*, *Canberra*, **1**, 498 (1974).
 20. J. R. Günter, N. Uyeda, and E. Suito: Twinning in Low Temperature Silver Selenide., *ibid.*, **1**, 526 (1974).
 21. T. Yoshida and E. Suito: Electron Microscopy of Clay Minerals, Numbers of Stacking Layers Composing Organo-Montmorillonites Flake., Sudo Kyoju Taikankinen Ronbunshu (*Commemoration Issue dedic. to Prof. T. Sudo on his Retirement*), pp. 173 (1975).*
 22. J. R. Günter, N. Uyeda, and E. Suito: Topotactic Reaction of Thin Silver Films with Selenium, *J. Cryst. Growth*, **28**, 209 (1975).
 23. T. Yoshida: Study of Microstructure of Mica and Montmorillonite by High Resolution Electron Microscopy., *Clay Science* **5**, 1 (1976).
 24. T. Yoshida: Direct Observation of the Interstratified Structures in the Clay Minerals by Electron Microscopy, *J. Geo. Soc. Japan*, **12**, 354 (1976).

Reviews

1. N. Uyeda: The Superstructures of Gold Sol Particles and Their Regularities-, *Hyomen (Surface)*, **8**, 79 (1970).*
2. E. Suito and T. Yoshida: Electron Microscopy on Bentonite., *Bentonite*, **22**(1970).*
3. E. Suito and T. Yoshida: Interstratified Layer Structure of the Organo-Montmorillonite as Revealed by Electron Microscopy., *U. S.-Japan Seminar on Clay-Organic Complexes*, 53 (1971).

IV. Direct Observation of Molecular Images for the Structure Determination

1. N. Uyeda, T. Kobayashi, E. Suito, Y. Harada, and M. Watanabe: Direct Observation of Phthalocyanine Molecules in Epitaxial Films., *Microscopie Electronique*, **1**, 23 (1970).
2. N. Uyeda, T. Kobayashi, E. Suito, Y. Harada, and M. Watanabe: Direct Observation of Cu-Hexadecachlorophthalocyanine Molecules in Epitaxial Films, *Proc. E. M. Society of America 28th Annual Meetings*, 524 (1970).
3. Y. Harada, T. Taoka, M. Watanabe, M. Ohara, T. Kobayashi, and N. Uyeda: Effect of Accelerating Voltage and Specimen Temperature on Radiation Damage of Hexadecachloro-Cu-Phthalocyanine., *30th Ann. Proc. Electron Microsc. Soc. Amer., Los Angeles*, (1972), p. 686.
4. N. Uyeda, T. Kobayashi, M. Ohara, M. Watanabe, T. Taoka, and Y. Harada: Reduced Radiation Damage of Halogenated Copper-Phthalocyanine., *Proc. Fifth Euro. Congr. Electron Microsc., Manchester*, **1972**, p. 566.
5. N. Uyeda, T. Kobayashi, E. Suito, Y. Harada, and M. Watanabe: Molecular Image Resolution in Electron Microscopy., *J. Appl. Phys.*, **43**, 5181 (1972).
6. N. Uyeda and K. Ishizuka: Effect of Spherical Aberration and Accelerating Voltage on Atomic Resolution in Molecular Images., *J. Electron Microscopy*, **23**, 79 (1974).
7. N. Uyeda and K. Ishizuka: Correct Molecular Image Seeking in the Arbitrary Defocus Series., *8th International Congress on Electron Microscopy, Canberra*, **1**, 322 (1974).
8. K. Kobayashi, E. Suito, N. Uyeda, M. Watanabe, T. Yanaka, T. Etoh, H. Watanabe, and M. Moriguchi: A New High Resolution Electron Microscope for Molecular Structure Observation., *Eighth Inter'l Congr. Electron Microsc., Canberra*, **1**, 30 (1974).
9. K. Kobayashi and N. Uyeda: Essential Requirement for the Real Atomic Resolution., *ibid.*, **1**, 264 (1974).
10. T. Kobayashi, L. Reimer, and J. Spruth: Influence of Molecular Composition and Heavy Atoms on the Damage of Organic Crystals., *Proc. 8-th Intern. Cong. Electron Microsc. Canberra*, **1974**, 682.
11. N. Uyeda, K. Ishizuka, Y. Saito, Y. Murata, K. Kobayashi, and M. Ohara: Resolution Limit of Molecular Images Attainable by Transmission Electron Microscopy., *Eighth Inter'l Congr. Electron Microsc., Canberra*, **1**, 266 (1974).
12. T. Kobayashi and L. Reimer: Calculation of Image Contrast of Organic Molecules with Heavy Atoms., *Proc. 8-th Intern. Cong. Electron Microsc. Canberra*, **1974**, 322.
13. N. Uyeda and K. Ishizuka: Molecular Image Reconstruction in High Resolution Electron Microscopy., *J. Electron Microsc.*, **24**, 65 (1975).
14. K. Ishizuka and N. Uyeda: Effect of Through-Focusing on the Bright and Dark Field Molecular Images in High Resolution Electron Microscopy., *Bull. Inst. Chem. Res., Kyoto Univ.*, **53**, 200 (1975).
15. N. Uyeda and K. Ishizuka: Visualization of Molecular Structure., *Nihon-Denshi-Kenbikyo Gakkai-Kaiho (J. Japan Soc. Electron Microsc.)*, **1975**, No. 12, 10.*
16. T. Kobayashi and L. Reimer: Limits in the High Resolution Electron Microscopy of Halogen Substituted Organic Molecule Single Crystals Caused by Radiation Damage., *Bull. Inst. Chem. Res., Kyoto Univ.*, **53**, 105 (1975).
17. T. Kobayashi and L. Reimer: Calculation of Electron Microscopic Images of Single Organic Molecules., *Optik*, **43**, 237 (1975).

Reviews

1. E. Suito: From Colloidal Morphology to Molecular Morphology. (An Application of Electron Microscopy by a Chemist), *Denshi-Kenbikyō (J. Electron Microscopy)*, **18**, 341 (1969).*
2. E. Suito: Electron Microscopy of Organic Molecular Crystal. Direct Observation of Organic Molecule., *Kagaku no Ryoiki*, **24**, 84 (1970).*
3. N. Uyeda and E. Suito: Direct Observation of Atoms and Molecules—The Resolution of Electron Microscopy., *Nippon Kessho Gakkaishi (J. Cryst. Soc. Japan)*, **13**, 212 (1971).*
4. N. Uyeda: How to See Molecules by Telescope., *Kagaku (Chemistry)*, **27**, 724 (1973).*
5. N. Uyeda: Can We See An Atom by Electron Microscopy?, *Bussei*, **12**, 347 (1974).*

V. Characteristics of Powders

1. M. Arakawa: The Relation between the Cohesion of Particles and Packing of Powder., *Zairyo (J. Soc. Mater. Sci., Japan)*, **16**, 319 (1967).*
2. M. Arakawa, M. Nishino, and E. Suito: The Flow Property of Powder in Vibrating State., *ibid.*, **17**, 545 (1968).*
3. M. Arakawa and E. Suito: The Porosity Change Based upon Mixing of Fine Powders Having Different Sizes., *Zairyo (J. Soc. Mater. Sci., Japan)*, **17**, 642 (1968).*
4. M. Arakawa: Particle Size and Packing Property of Powder., *Funtai Oyobi Fumatsu Yakin (J. Japan Soc. Powder and Powder Metallurgy)*, **15**, 55 (1968).*
5. E. Suito, M. Arakawa, H. Mishima, S. Yano, H. Shirahase, and S. Ishida: Analysis of Particle Size by Specific Gravity Balance Method in which High Viscosity Liquid is Used for Dispersion Medium., *Zairyo (J. Soc. Mater. Sci., Japan)*, **18**, 531 (1969).*
6. M. Nishino, M. Arakawa, and E. Suito: The Effect of Temperature upon the Adhesive Properties of Powder., *ibid.*, **18**, 535 (1969).*
7. E. Suito, M. Arakawa, H. Mishima, S. Yano, S. Ishida, and K. Hayashida: The Effect of the Particle Shape on the Measurement of Particle Size Distribution., *Zairyo (J. Soc. Mater. Sci., Japan)*, **19**, 548 (1970).*
8. M. Arakawa and M. Nishino: The Effect of Packing Structure of Powder on the Angle of Repose., *ibid.*, **19**, 554 (1970).*
9. M. Nishino and M. Arakawa: The Angle of Repose of Powder in Liquid., *ibid.*, **19**, 560 (1970).*
10. M. Arakawa and M. Nishino: The Fluidity and Structure of Powder Bed in a Vibrating State., *ibid.*, **20**, 776 (1971).*
11. M. Nishino and M. Arakawa: The Effect of Water on the Cohesion of Particles., *ibid.*, **20**, 781 (1971).*
12. M. Arakawa, S. Banerjee, and W. O. Williamson: Extrusion Behavior of Hard Shale., *Amer. Ceram. Soc. Bull.*, **50**, 933 (1971).
13. M. Arakawa and M. Nishino: Percolation of Fine Powder through Packed Bed in Vibrating State., *Zairyo (J. Soc. Mater. Sci., Japan)*, **21**, 562 (1972).*
14. M. Arakawa and M. Nishino: Contact Number and Porosity in Packed Sphere Mixtures of Various Sizes., *ibid.*, **22**, 658 (1973).*
15. M. Nishino and M. Arakawa: The Influence of Humidity on the Cohesion of Powder Particles., *ibid.*, **22**, 663 (1973).*
16. M. Arakawa: Dynamic Properties of Powder and Particle Characteristics., *ibid.*, **23**, 504 (1974).*
17. M. Arakawa and M. Nishino: Flowing Properties of Powder—Measurement and Powder Characteristics—., *ibid.*, **24**, 654 (1975).*
18. T. Nukui, K. Kaida, Y. Furusawa, M. Arakawa, and E. Suito: The Effects of Mechanical Treatment of Kaolinite and Talc upon the Reinforcement of Rubber., *Nihon Gomu Kyokai Shi (J. Soc. Rubber Ind., Japan)*, **49**, 230 (1976).*

Reviews

1. E. Suito: Surface Structure of Powder Particles., *Zairyo (J. Soc. Materials Sci. Japan)*, **15**, 120 (1966).*
2. M. Arakawa: The Chemistry of Powder (II)., *Kuki Seijo (J. Air Cleaning Assoc. Japan)*, **3**, no. 5, 21 (1966).*
3. M. Arakawa: Adhesion and Cohesion Phenomena of Powder., *Hyomen (Surface)*, **4**, 443 (1966).*
4. M. Arakawa: Particle Size Measurement., *Funtai oyobi Fumatsu Yakin (J. Japan Soc. Powder and Powder Metallurgy)*, **14**, 47 (1967).*
5. M. Arakawa: Particle Size and Shape of Fine Powder., *Funtaiogaku Kenkyukaiishi (J. Res. Assoc. Powder Tech.)*, **4**, 850 (1967).*
6. M. Arakawa: Particle Size Measurement., *ibid.*, **4**, 921 (1967).*
7. M. Arakawa: Flow Property of Powder., *Chemical Engineering*, No. 5, 1 (1967).*
8. E. Suito: Calcium Carbonate as Powdered Material., *Sekkai to Sekko (Gypsum and Lime)*, No. 9, 87 (1968).*

9. E. Suito: Electron Microscopic Studies on Inorganic Materials., *Seramikkusu (Ceramics)*, **3**, 443 (1968).*
10. M. Arakawa: Measurement of Specific Surface Area of Powder., *Funtaikogaku Kenkyukaiishi (J. Res. Assoc. Powder Tech.)*, **6**, 31 (1969).*
11. M. Arakawa: Specific Surface Area by Gas Permeability Method in the Molecular Flow Region., *ibid.*, **6**, 357 (1969).*
12. M. Arakawa and E. Suito: Packing Structure of Fine Powder., *Bull. Inst. Chem. Res., Kyoto Univ.*, **47**, 412 (1969).
13. M. Arakawa: Particle Size Measurement., *Shikizai Kyokaishi (Color Material)*, **43**, 333 (1970).*
14. M. Arakawa: Introduction to Powder Science., *ibid.*, **43**, 603 (1970).*
15. M. Arakawa: The Structure of Some Organic Bentonite., *Nendo-Kagaku*, **10**, 8 (1970).*
16. M. Arakawa: Particle Size Measurement., *Funtai to Kogyo*, **2**, 24(1970).*
17. M. Arakawa: Measurement of Powder Characteristics. (III) Particle Size Measurement., *Zairyo (J. Soc. Materials Sci. Japan)*, **19**, 612 (1970).*
18. M. Arakawa: Measurement of Powder Characteristics. (IV) Measurement of Specific Surface Area of Powdered Materials., *ibid.*, **19**, 685 (1970).*
19. M. Arakawa: Cohesion of Particles and the Properties of Powders., *Funtaikogaku Kenkyukaiishi (J. Res. Assoc. Powder Tech.)*, **7**, 209 (1970).*
20. E. Suito: Application of Electron Microscope to the Study of Fine Powders—Fine Structure of Particles—., *Zairyo-Kagaku*, **7**, 196 (1970).*
21. M. Arakawa and T. Yoshida: Characteristics of Organic Bentonite., *Bentonite*, **35** (1970).*
22. M. Arakawa: Utilization of Organic Bentonite for Chemical Industry., *ibid.*, **118** (1970).*
23. M. Arakawa: Packing Process of Powder., *Seramikkusu (Ceramics)*, **6**, 17 (1971).*
24. M. Arakawa: Surface Area Measurement of Powder., *Shikizai Kyokaishi (Color Material)*, **44**, 370 (1971).*
25. M. Arakawa and M. Nishino: Relationship between the Structure and the Fluidity of Powder in Vibrating State., *Bull. Inst. Chem. Res., Kyoto Univ.*, **49**, 248 (1971).
26. M. Arakawa: Relation Between the Particle Size and Characteristics of Powder., *Kagaku-Kōjō*, **16**, 25 (1972).*
27. M. Arakawa: Study on Extrusion Process of Hard Shale Mud., *Funtaikogaku Kenkyukaiishi (J. Res. Assoc. Powder Tech.)*, **9**, 476 (1972).*
28. M. Arakawa: Standard Powder., *Bunseki Kagaku (Japan Analyst)*, **22**, 1260 (1973).*
29. M. Arakawa: Surface Characteristics of Powder (I)., *Funtaikogaku Kenkyukaiishi (J. Res. Assoc. Powder Tech.)*, **10**, 400 (1973).*
30. M. Arakawa: Surface Characteristics of Powder (II)., *ibid.*, **11**, 216 (1974).*
31. M. Arakawa: Measurement of Fundamental Characteristics of Powder., *Kagaku Sōchi (Plant and Process)*, **1974**, No. 6, p. 60.*
32. M. Arakawa: Relationship between Dynamic Properties of Powder and Particle Characteristics., *Zairyo (J. Soc. Mater. Sci., Japan)*, **23**, 504 (1974).*
33. M. Arakawa: Effect of the Particle Size on Powder Characteristics., *Shokubai (Catalyst)*, **16**, (3), 51 (1974).*
34. M. Arakawa: Particle Size Measurement., *Kagaku (Chemistry)*, **30**, 28 (1975).*
35. M. Arakawa: Adhesion and Cohesion of Particles., *Shikizai Kyokaishi (Color Material)*, **48**, 165 (1975).*
36. M. Arakawa and M. Nishino: Dynamic Properties of Powder and Particle Characteristics., *Bull. Inst. Chem. Res., Kyoto Univ.*, **53**, 256 (1975).

VI. Miscellaneous Publications

1. T. Yoshida, M. Arakawa, and E. Suito: The State of Trimethyloctadecylammonium-Steramide Complexes Adsorbed on Bentonite., *Kogyo Kagaku Zasshi (J. Chem. Soc. Japan, Ind. Chem. Sec.)*, **17**, 820 (1968).*
2. N. R. O'Brien and E. Suito: Comparison of the Fabric of a Sensitive Pleistocene Clay with Laboratory Flocculated Clay Using the Scanning Electron Microscope., *Maritime Sediments*, **5**, 58 (1969).

3. N. O'Brien, M. Arakawa, and E. Suito: Freeze Drying Technique in the Study of the Fabric of Moist Clay Sediment., *J. Electron Microscopy*, **19**, 277 (1970).
4. H. E. Ries, Jr.: Effect of a Polar Spreading Solvent on Thin Films, *Nature (Phy. Sci)*, **243**, 14 (1973).
5. A. Onodera, N. Kawai, and T. Kobayashi: Conductive Phthalocyanines under High Pressure., *Solid State Commun.*, **17**, 775 (1975).
6. H. E. Ries, Jr., M. Matsumoto, and N. Uyeda: Electron Micrographs of Lecithin Films., *Bull. Inst. Chem. Res., Kyoto Univ.*, **53**, 77 (1975).
7. H. E. Ries, Jr., M. Matsumoto, N. Uyeda, and E. Suito: Electron Microscope Studies of Monolayers of Lecithin., *Adv. Chem. Series*, No. 144, 286 (1975).
8. A. Baszkin, M. Nishino, and L. Terminassian-Saraga: Solid-Liquid Adhesion of Oxidized Polyethylene Films: Effect of Temperature., *J. Colloid and Interface Sci.*, **54**, 317 (1976).

Reviews

1. E. Suito and M. Shiojiri: Electron Microscopy and Crystal Chemistry., *Kagaku (Chemistry)*, **21**, 35 (1966).*
2. E. Suito: Method of Study on Surface Micro-Structure., *Seminor on the Method of Studies on Surface*, 1 (1968).*
3. N. Uyeda: The Principle of Crystal Growth of Powderly Materials., *Color Material*, **43**, 612 (1970).*
4. E. Suito: Review of Researches on Clay-Organic Complexes in Japan., *U. S.-Japan Seminor on Clay-Organic Complexes*, 5 (1971).*
5. M. Arakawa and E. Suito: Reinforcement of Rubber with Hard Clay., *ibid.*, 63 (1971).
6. G. W. Brindley, E. Suito, and M. Koizumi: Clay Organic Complexes., *Clay & Clay Miner.* **20**, 189 (1972).

Books

1. E. Suito: Application of Clay to Chemical Industry, in Clay Sci. Soc. Japan, Ed., "Nendo Hando Bukku" (Handbook on Clay Minerals), Gihodo, Tokyo (1966), p. 739.*
2. E. Suito and M. Arakawa: Size and Shape of Pigment Particles, in Japan Soc. Colour Material, Ed., "Shikizai Kogaku Handobukku" (Handbook for Technology of Colour Material), Asakura Shoten, Tokyo (1967), p. 49.*
3. M. Arakawa: Introduction to Powder Chemistry; Physical Chemistry of Powder; and Surface Chemistry of Fine Particles, in K. Iinoya, M. Arakawa, G. Jinbo, and S. Miwa, Ed., "Funtai no Bussei to Kogaku" (Physical Chemistry and Technology of Powder), Kagaku-Dojin, Kyoto (1967), p. 11. p. 33, and p. 37.*
4. M. Arakawa: Particle Size Measurement, in Kōjō Sōsa Shirizu, I. Funsai (Industrial Technology Series. I. Crushing), Kagaku-Kogyosha. Tokyo (1969), p. 31.*
5. E. Suito: "The World through the Electron Microscope, Chemistry IV" (Editor), Japan Elec. Opt. Lab. Co. Ltd., Tokyo (1969).*
6. N. Uyeda: X-ray Analysis, in Japan Soc. Anal. Chem., Ed., "Kikibunseki Jikkenho" (Experimental Method of Instrumental Analysis), Kagaku-Dojin, Kyoto (1969), p. 405.*
7. E. Suito: The Shape, Crystal Habit and Microstructure of Fine Particles, in H. Yukawa, Ed., Profiles of Japanese Science and Scientists", Kodansha, Tokyo (1970), p. 245.
8. E. Suito and M. Shiojiri: Microcrystals, in "Kessho Kogaku Handobukku" (Handbook for Crystal Technology), Kyoritsu Shuppan Co. Ltd., Tokyo (1971), p. 610.*
9. E. Suito and K. Takiyama: Denshikenbikyo Bunseki" (Analytical Electron Microscopy), Tokyo Kagaku-Dojin, Tokyo (1971).*
10. E. Suito and M. Nakahira: Micas and Related Minerals, in J. A. Gard, Ed., "The Electron Optical Investigation of Clays", Mineralogical Soc., London (1971), p. 231.
11. E. Suito: "The World through the Electron Microscope, Chemistry V." (Editor), Japan Elec. Optic. Lab. Co. Ltd., Tokyo (1972).
12. N. Uyeda: Application of Electron Microscopy and Diffraction, in Kinzoku no Jotai no Butsuri Bunseki (Physical Analysis of Metallic State), Japan Inst. Metal, Sendai (1972), p. 1.*
13. M. Arakawa: Recent Work on Particle Size Measurement, in Soc. Chem. Engin. Japan, Ed.,

- “Kagaku Kikai Gijutsu” (Chemical Technology), 25, Maruzen Co. Ltd., Tokyo (1973), p. 139.*
14. M. Arakawa: Measurement of Interface Characteristics of Powder, in S. Hayakawa, Ed., “Funtai Bussei Sokutei Hō (Measurement of Powder Characteristics), Asakura Shoten, Tokyo (1973), p. 228.*
 15. E. Suito and H. Yotsumoto: Review of Analytical Electron Microscopy, in Seramicku Deita Bukku 74, Kogyo to Seihin ‘Ceramic Data Book’ 74, (Industry and Products), Kogyo-Seihin-Gijutsu-Kyokai (1974), p. 77.*
 16. M. Arakawa: Instruments for Powder Characteristics Measurement, in “Funryutai Purosesu Gijutsu Syusei” (Collection of Process Engineering on Powder Sangyo-Gijutsu Center, Tokyo) (1974), p. 297.*
 17. M. Arakawa *et al.*: “Ryudo Sokutei Gijutsu” (Particle Size Measurement), Nikkan-Kogyo Shinbunsha, Tokyo (1975).*
 18. M. Arakawa: Introduction; Observation of Particle Shape; Particle Size Measurement, in M. Arakawa, Ed., “Funtai Bussei Zusetsu” (Atlas of Powder Characteristics), Sangyo-Gijutsu Center, Tokyo (1975), p. 1. p. 41, and p. 81.*