Hiroshi DAIMON

Emeritus Professor, Nara Institute of Science and Technology

[Present Position]

Fellow at Toyota Physical and Chemical Research Institute

[Research Field]

Surface Science, Synchrotron Radiation Photoelectron Spectroscopy

[Date of Birth]

July 22, 1953

[Sex]

Male

[Nationality]

Japan

[Graduation and Degree]

Mar. 1976 Faculty of Science (chemistry). The University of Tokyo
Mar. 1978 Graduate School of Science, Master Course, The University of Tokyo
Mar. 1983 Doctor of Science, The University of Tokyo
(Thesis title: Experimental and Theoretical Studies of Elastic Electron Scattering at Intermediate Energies and Photoemission Studies of Reactions on Semiconductor surfaces Using Synchrotron Radiation)

[Professional Career]

Mar. 1978 - Mar. 1983	Educational Staff, Institute for Solid State Physics (ISSP), The University of Tokyo.
Mar. 1983 - Mar. 1990	Research Associate, Faculty of Science, The University of Tokyo.
Mar. 1990 - Mar. 1997	Associate Professor, Faculty of Engineering Science, Osaka University.
[Apr. 1991 - Mar. 1992	Adjunct Associate Professor, Institute for Solid State Physics (ISSP), The University of Tokyo,] .
[Aug. 1994 - May. 1995	Visiting Scientist at Lawrence Berkeley National Laboratory, (U.S.A.)].
Apr. 1997 - Mar. 2019	Professor, Nara Institute of Science and Technology (NAIST).
Apr. 2019 – Present	Fellow at Toyota Physical and Chemical Research Institute

[Membership]

The Japan Society of Vacuum and Surface Science (president), The Physical Society of Japan, The Japan Society of Applied Physics, The Japanese Society for Synchrotron Radiation Research, American Physical Society

3. Research overview Daimon

1. **1976.4 – 1978.3 Master's thesis** at Prof. Kozo Kuchitsu laboratory, Department of Chemistry, Faculty of Science, The University of Tokyo.

Prof. Kuchitsu

Theme: Measurement and theoretical analysis of differential cross sections of low-energy electrons elastically scattered by gas molecules (O_2, N_2, CCl_4, As_4).

- **Publication list** (2), (4), (9)

Effect of Intramolecular Double Scattering and polarization etc. to elastic differential cross section (EDCS) of low-energy electrons (100 – 500 eV) scattered by gas molecules (O_2, N_2, CCl_4, As_4) were analyzed theoretically and experimentally. The independent atom model considering double scattering and polarization effects was found to be enough to reproduce the experimental data.

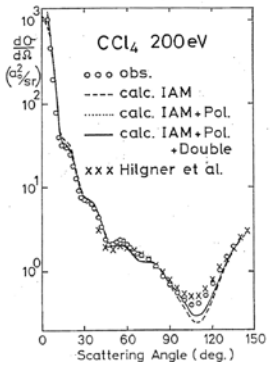

Fig. 1 EDCS from CCl_4

(4) "Measurement of Differential Cross Sections of Low-Energy Electrons Elastically Scattered by Gas Molecules. III. Effects of Intramolecular Double Scattering as Observed inthe Scattering of 70-400 eV Electrons by Carbon Tetrachloride", H. Daimon, T. Kondou and K. Kuchitsu, J. Phys. Soc. Jpn., 52 (1) 84-89 (1983).

2. **1978.3 – 1983.3 PhD thesis** at Prof. Yoshitada Murata laboratory, Institute for Solid State Physics (ISSP), The University of Tokyo.

Prof. Murata

Theme: Photoelectron spectroscopy using synchrotron radiation. Photoelectron diffraction. Resonant photoemission.

- **Publication list** (1), (3), (5), (6), (7), (8), (10), (11), (12), (14), (15), (16), (19)

At that time the world first dedicated synchrotron radiation facility INS-SOR was constructed. Hence we started photoelectron spectroscopy using synchrotron radiation especially photoelectron diffraction.

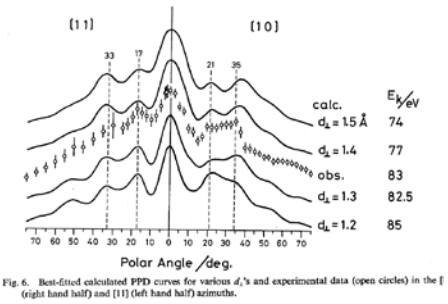

Fig. 6. Best-fitted calculated PPD curves for various $d_\perp$'s and experimental data (open circles) in the [(right hand half) and [11] (left hand half) azimuths.

Fig. 2 Photoelectron diffraction pattern from Ni(001) c(2x2)-S.

(16) "Photoelectron Diffraction from Ni(001)c(2x2)-S(2p)", H. Daimon, H. Ito, S. Shin and Y. Murata, J. Phys. Soc. Jpn., 53 (10) 3488-3497 (1984) .

3. **1983.3 – 1990.3 Research Associate** at Prof. Shozo Ino laboratory, Faculty of Science, The University of Tokyo

Prof. Ino

Theme: RHEED study of surface superstructure, Invension of display-type spherical mirror analyzer.

- **Publication list** (13), (17), (18), (19), (20), (21), (22), (23), (24), (25), (26), (27), (29), (30), (31), (32), (33), (34), (35), (37), (38), (43), (49), (52), (74)

Prof. Ino is an inventor of RHEED. Hence I studied many surface using RHEED. Figure 3 is a new 7×7 structure called δ-7×7 structure.

(18) "Study of the Si(111)7x7 Surface Structure by Alkali-metal Adsorption", H. Daimon and S. Ino, Surf. Sci., 164 (1) 320-326 (1985).

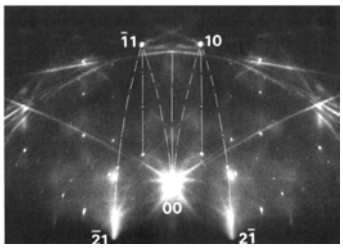

Fig. 3 Si(111) δ-7×7-Li RHEED

I invented a new Two-dimensional photoelectron spectrometer Display-type Spherical Mirror Analyzer (DIANA) (Fig.4), which can display wide angle ±60° cone (≈ 1π sr) angular distribution at once without distortion.

(22) "New display-type analyzer for the energy and the angular distribution of charged particles", H. Daimon, Rev. Sci. Instrum, 59 (4) 545-549 (1988). [Erratum: Rev. Sci. Instrum. 61 (1) 205 (1990).]

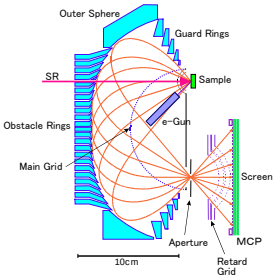

Fig. 4 DIANA

4. **1990.3 – 1997.3 Associate Professor** at Prof. Shigemasa Suga laboratory, Faculty of Engineering Science, Osaka University.

Prof. Sugau

Theme: Photoelectron spectroscopy using synchrotron radiation.

- **Publication list** (28), (36), (39), (40), (41), (42), (44), (45), (46), (47), (48), (50), (51), (53), (54), (55), (56), (57), (58), (59), (60), (61), (62), (63), (64), (65), (66), (67), (69), (70), (71), (72), (73), (79), (81), (82), (83), (84), (85), (86), (87), (88), (91), (94), (95), (96), (97), (115)

Rotation of the forward focusing peaks in a photoelectron diffraction pattern excited by circularly polarized light was found for the first time. The reason was explained by the transfer of angular momentum from the circularly polarized light to the photoelectron. This is the first direct observation of orbital angular momentum.

(42) "Strong circular Dichroism in Photoelectron Diffraction from Non-chiral, Non-magnetic Material--- Direct Observation of Rotational Motion of Electrons", H. Daimon, T. Nakatani, S. Imada, S. Suga, Y. Kagoshima and T. Miyahara, Jpn. J. Appl. Phys., 32 Part 2 (10A) L1480-L1483 (1993).

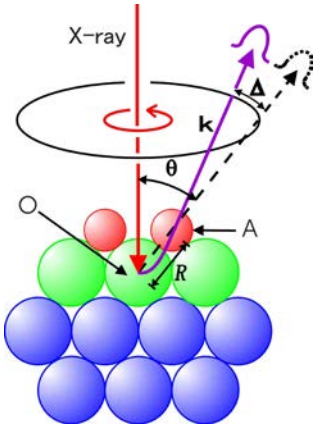

Fig. 5 Rotation of forward focusing peak

When we observed valence band of Graphite by DIANA using linearly polarized light, the equi-energy cross section of π band (Fig. 6) showed two-fold symmetry although graphite is six-fold. This lowered symmetry was explained by ADAO (angular distribution from atomic orbital). The observed pattern exists only in the first Brillouin zone. This effect was explained by the structure factor in photoemission. Using these effect the atomic orbital in the initial state became to be studied.

(55) "Structure factor in photoemission from valence band", H. Daimon, S. Imada, H. Nishimoto, and S. Suga, J. Electron Spectrosc. Relat. Phenom. 76 487-492 (1995).

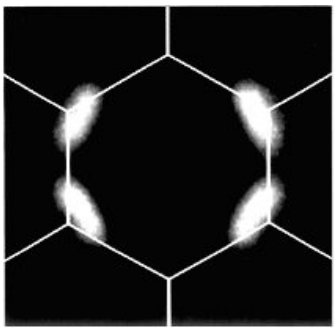

Fig. 6 π band of graphite observed by DIANA and horizontally linearly polarized light

The technique of photoelectron holography started in 1988. Fig. 7 shows our study of photoelectron holography analysis of Si crystal. The holograms in upper panel of Fig. 7 were taken by using DIANA. The reconstructed atomic image is in good agreement with actual structure of Si crystal.

(67) "Photoelectron holography of the Si(001) surface", T. Nakatani, H. Nishimoto, H. Daimon, S. Suga, H. Namba, T. Ohta, Y. Kagoshima, T. Miyahara, J. Synchrotron Rad. 3 239-244 (1996).

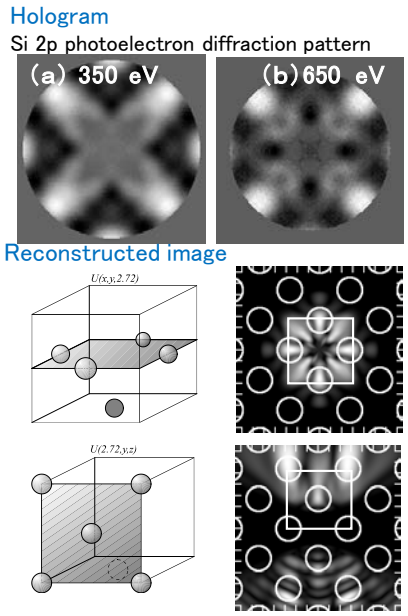

Fig. 7 Photoelectron holography analysis of Si crystal.

5. **1994.8 – 1995.5 Visiting Scientist** at Prof. Charles S, Fadley laboratory, Lawrence Berkeley National Laboratory, Berkeley, California, U.S.A.

Theme: Photoelectron spectroscopy using synchrotron radiation.

Prof. Fadley

- **Publication list** (68), (75), (76), (77), (78), (80), (92), (93)

  At that time the world first third generation synchrotron facility ALS (Advanced Light Source) was constructed in Lawrence Berkeley National Laboratory in Carifornia, USA. I stayed at Chuck Fadley's laboratory for 10 months. Rotation of FFP in Fig. 5 was confirmed in single scattering system of W(110)-O surface.

  (80) "Circular Dichroism in Core-Level Emission from O/W(110): Experiment and theory", H. Daimon, R.X. Ynzunza, F.J. Palomares, E.D. Tober, Z.X. Wang, A.P. Kaduwela, M.A. Van Hove, and C.S. Fadley, Phys. Rev. B, 58, 9662-9665 (1998).

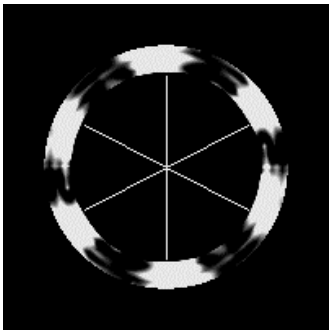

Fig. 6 Rotation of FFP by Circularly Polarized Light.

6. **1997.4 – 2019.3 Professor,** Nara Institute of Science and Technology (NAIST)..

Theme: Photoelectron spectroscopy using synchrotron radiation.

- **Publication list** (89), (98) – (249) [except (115), (248)]

Prof. Daimon

Assoc.Prof. Hattori

Assist. Prof. Takeda

Assist. Prof. Matsui

Assist. Prof. Taguchi

Assist. Prof. Matsuda

A technique of stereophotography was invented, with which we can view the 3D atomic arrangement directly with eyes. The angular momentum of the circularly polarized photon (±1) is transferred to the photoelectron. The rotation angle of FFP is inversely proportional to the distance between the emitter and the scatterer atoms. This relation is the same as parallax which is the origin when we recognize three-dimensional arrangement. Hence stereophotograph of atomic arrangement was realized.

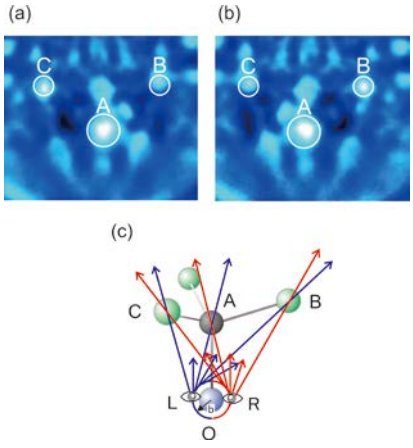

Fig. 7 Stereophotographs of atomic arrangement.

(98) “Stereoscopic microscopy of atomic arrangement by circularly Polarized -Light Photoelectron Diffraction”, H. Daimon, Phys. Rev. Lett., 86 2034-2037 (2001).

A new high-energy-resolution two-dimensional photoelectron energy analyzer DELMA (Display-type ellipsoidal mesh analyzer)[184] (Fig. 8) was invented. DELMA has microscope function with magnification ratio of about 100. DELMA consists of a wide-acceptance-angle electrostatic lens (WAAEL), a transfer lens system, and CHA (VG Scienta R4000). WAAEL is a newly invented objective lens[120] which can accept wide angles of ±50° cone with reducing spherical aberrations to zero. This DELMA system can measure high-energy-resolution 2D angular distribution by a deflector-scanning method. Here the ±50° cone 2D angular distribution formed at the detector plane of DELMA, which is the input plane of the CHA, is scanned using electrostatic deflectors, and many 1D (±12.5°×±0.5°) patterns obtained by the CHA are combined to construct the 2D pattern. Although DELMA solved DIANA’s low-energy-resolution problem, it has some demerit of complicated structure, large size, and relative high cost. Hence we are developing a new analyzer Compact DELMA which can display high-energy-resolved wide-angular-range pattern at once with very simple structure.

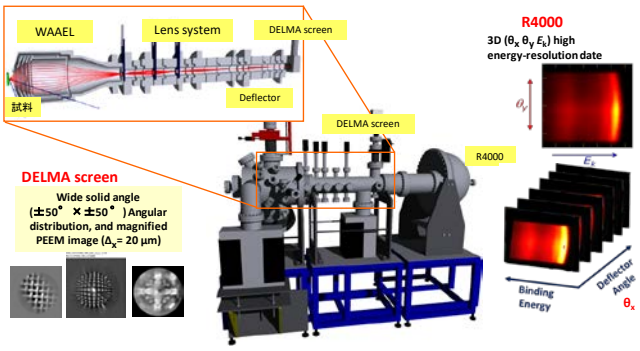

Fig. 8 DELMA (Display-type ellipsoidal mesh analyzer)

(120) “Approach for simultaneous measurement of two-dimensional angular distribution of charged par-ticles: Spherical aberration correction using an ellipsoidal mesh”, H. Matsuda, H. Daimon, M. Kato, M. Kudo, Phys. Rev. E 71, (6) 066503-1-8 (2005)

(184) “Development of Display-Type Ellipsoidal Mesh Analyzer”, K. Goto, H. Matsuda, M. Hashimoto, H. Nojiri, C. Sakai, F. Matsui , H. Daimon, L. Tóth, T. Matsushita, e-J. Surf. Sci. Nanotech. 9, 311-314 (2011)

3D local atomic structure around specific active-site atom plays crucial role in functional materials, but it has not been able to be analyzed by a standard structure analysis method of x-ray diffraction (XRD) because this kind of active site has no translational symmetry. Recently several atomic-resolution holographies have been developed in Japan. We started a new project "3D Active-Site Science" of JSPS Grant-in-Aid for Scientific Research on Innovative Areas for five years

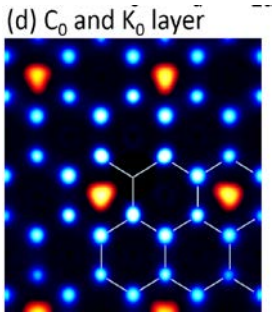

Fig. 9 Photoelectron holography on K in graphite.

(2015 – 2019). One result is shown in Fig. 9, which is a photoelectron holography reconstructed image on K intercalated graphite superconducting material.

(225) “Photoelectron Holographic Atomic Arrangement Imaging of Cleaved Bimetal-intercalated Graphite Superconductor Surface”, Fumihiko Matsui, Ritsuko Eguchi, Saki Nishiyama, Masanari Izumi, Eri Uesugi, Hidenori Goto, Tomohiro Matsushita,, Kenji Sugita, Hiroshi Daimon, Yuji Hamamoto, Ikutaro Hamada, Yoshitada Morikawa, Yoshihiro Kubozono, Scientific Reports 6, 36258 (2016). doi:10.1038/srep36258

Publication list (Refereed papers)

Hiroshi Daimon

(1) "Ni on Si: Interfacial Compound Formation and Electronic Structure", K. L. I. Kobayashi, S. Sugaki, A. Ishizaka, Y. Shiraki, H. Daimon and Y. Murata, *Phys. Rev. B*, **25** (2) 1377-1380 (1982).

(2) "Measurement of Differential Cross Sections of Low-Energy Electrons Elastically Scattered by Gas Molecules. II. Scattering of 200-500 eV Electrons by Molecular Oxygen", H. Daimon, S. Hayashi, T. Kondou and K. Kuchitsu, *J. Phys. Soc. Jpn.*., **51** (8) 2641-2649 (1982).

(3) "Ion Oxidation of Si(111)", H. Daimon and Y. Murata, *Jpn. J. Appl. Phys.*, **21** (11) L718-720 (1982).

(4) "Measurement of Differential Cross Sections of Low-Energy Electrons Elastically Scattered by Gas Molecules. III. Effects of Intramolecular Double Scattering as Observed inthe Scattering of 70-400 eV Electrons by Carbon Tetrachloride", H. Daimon, T. Kondou and K. Kuchitsu, *J. Phys. Soc. Jpn.*, **52** (1) 84-89 (1983).

(5) "Initial Stage of Sputtering in Silicon Oxide", T. Hattori, Y. Hisajima, H. Saito, T. Suzuki, H. Daimon, Y. Murata and M. Tsukada, *Appl. Phys. Lett.*, **42** (3) 244-246 (1983).

(6) "Evidence for Interference Between Direct and Inner-Shell-Deexcitation Photoemission in Semiconductors", K. L. I. Kobayashi, H. Daimon, N. Watanabe, M. Taniguchi, S. Suga, H. Nakashima and Y. Murata, *Physica*, **117B & 118B** 57-59 (1983).

(7) "Systematic Study of 3d Transition Metal-Silicon Interfaces by Photoemission", Y. Shiraki, K. L. I. Kobayashi, H. Daimon, A. Ishizaka, S. Sugaki and Y. Murata, *Physica*, **117B & 118B** 843-845 (1983).

(8) "Resonant Photoemission from Si", K. L. I. Kobayashi, H. Daimon and Y. Murata, *Phys. Rev. Lett.*, **50** (21) 1701-1704 (1983).

(9) "Measurement of Differential Cross Sections of Low-Energy Electrons Elastically Scattered by Gas Molecules: IV. Effect of Intramolecular Double Scattering as Observed in the Scattering of 100 and 500 eV Electrons by As_4", H. Daimon, T. Kondou and K. Kuchitsu , *J. Phys. B: At. Mol. Phys.*, **16** 3453-3464 (1983).

(10) "Valence Band Structure of Hydrogenated Amorphous Silicon-Carbon Alloys", Y. Katayama, T. Shimada, T. Uda, K.L.I. Kobayashi, C. G. Jiang, H. Daimon and Y. Murata, *Journal of Non-crystalline Solids*, **59 & 60** Part I 561-564 (1983).

(11) "Resonant Photoemission from Al-GaAs(110) Interfaces", K. L. I. Kobayashi, N. Watanabe, H. Nakashima, M. Kubota, H. Daimon and Y. Murata, *Phys. Rev. Lett.*, **52** (2) 160-163 (1984).

(12) "Comment on "Resonant Photoemission from Si", K. L. I. Kobayashi, H. Daimon and Y. Murata, *Phys. Rev. Lett.*, **52** (17) 1568-1569 (1984) .

(13) "New Models for the 7x7, 5x5, 2x8 Structures on Si(111) and Ge(111) Surfaces", S. Ino, H. Daimon and T. Hanada, *J. Phys. Soc. Jpn.*, **53** (6) 1911-1914 (1984) .

(14) "Resonant Photoemission in Open and Closed 3d Shell Systems: Ni_xSi(x=3, 2.5, 2, 1.5, 1, and 0.5)", H. Daimon, A. Ishizaka, K. L. I. Kobayashi and Y. Murata, *J. Phys. Soc. Jpn.*, **53** (6) 2130-2136 (1984) .

(15) "Performance of a New Plane-Grating Grazing-Incidence UHV Monochromator", S. Suga, M. Taniguchi, S. Shin. H. Sakamoto, M. Yamamoto, M. Seki,Y. Murata and H. Daimon, *Nucl. Instr. and Meth. (Nuclear Instruments and Methods in Physics Research)* **222** 80-84 (1984).

(16) "Photoelectron Diffraction from Ni(001)c(2x2)-S(2p)", H. Daimon, H. Ito, S. Shin and Y. Murata, *J. Phys. Soc. Jpn.*, **53** (10) 3488-3497 (1984) .

(17) "Chemical Analysis of Surfaces by Total-Reflection-Angle X-ray Spectroscopy in RHEED Experiments (RHEED-TRAXS)", S. Hasegawa, S. Ino, Y. Yamamoto and H. Daimon, *Japn. J. Appl. Phys.*, **24** (6) L387-390 (1985).

(18) "Study of the Si(111)7x7 Surface Structure by Alkali-metal Adsorption", H. Daimon and S. Ino, *Surf. Sci.*, **164** (1) 320-326 (1985).

(19) "Electronic Structures of $CuFeS_2$ and $CuAl_{0.9}Fe_{0.1}S_2$ Studied by Photoelectron Spectroscopy: Role of Fe 3d Electron States", M. Fujisawa, M. Taniguchi, S. Shin, H. Daimon, H. Sakamoto, K. Sato and S. Suga, *Proc. 18th Int.* Conf. on the Physics of Semiconductors (World Scientific, ed. by O. Engstrom 1987, Singapore) 1137-1140.

(20) "A Study of Adsorption and Desorption Processes of Ag on Si(111) Surface by means of RHEED-TRAXS(Total ReflectionAngle X-ray Spectroscopy in RHEED experiments)", S. Hasegawa, H. Daimon and S. Ino, *Surf. Sci,.* **186** 138-162 (1987).

(21) "Si(111)7×7 and Si(111)$\sqrt{3}\times\sqrt{3}$-Al Surface Structure Analysis by Ion-Induced Auger Electron Spectroscopy", T. Aizawa, T. Tsuno, H. Daimon and S. Ino, *Phys. Rev. B*, **36** (17) 9107-9114 (1987).

(22) "New display-type analyzer for the energy and the angular distribution of charged particles", H. Daimon, *Rev. Sci. Instrum*, **59** (4) 545-549 (1988). [Erratum: Rev. Sci. Instrum. **61** (1) 205 (1990).]

(23) "新しい２次元表示型球面鏡分析器の解析", 大門寛、井野正三, 真空, **31** (12) 954-959 (1988).

(24) "Soft x-ray beamline (10-1000 eV) with a plane grating monochromator for surface studies", H. Namba, H. Daimon, Y. Idei, N. Kosugi, H. Kuroda, M. Taniguchi, S. Suga, Y. Murata, K. Ueyama and T. Miyahara, *Rev. Sci. Instrum.*, **60** (7) 1909-1912 (1989).

(25) "Study of the Si(111) $\sqrt{3}\times\sqrt{3}$-Al Surface Structure by Kinetic Energy Dependence of Polar Angle Photoelectron Diffraction", H. Daimon, S. Nagano, T. Hanada, S. Ino, S. Suga and Y. Murata, *Surf. Sci.*, **221** (2/3) 244-252 (1989).

(26) "One Dimensional Circular Diffraction Patterns", H. Daimon and S. Ino, *Surf. Sci.*, **222** (1) 274-282 (1989).

(27) "Improvement of the spherical mirror analyzer", H. Daimon and S. Ino, *Rev. Sci. Instrum.*, **61** (1) 57-60 (1990).

(28) "Vacuum Ultraviolet Reflectance and Photoemission Study of Metal-Insulator Phase Transition in VO_2, V_6O_{13} and V_2O_3", S. Shin, S. Suga, M. Taniguchi. M. Fujisawa, H. Kanzaki, A. Fujimori, H. Daimon, Y.

Ueda, K. Kosuge and S. Kachi, *Phys. Rev. B*, **41** 4993-5009 (1990).

(29) "ESDIAD with a new display-type spherical mirror analyzer", H. Daimon and S. Ino, Proc. the IVC-11/ICSS-7 (Cologne, 1989); *Vacuum*, **41** (1-3) 215-216 (1990).

(30) "A Study of Si(111)5×2-Au Structures by Li Adsorption and Their Co-adsorbed Superstructures", H. Daimon, C. I. Chung, S. Ino and Y. Watanabe, *Surf. Sci.*, **235** (2/3) 142-155 (1990).

(31) "Change of Surface Electronic States Induced by Li and K Adsorption on the Si(111)7×7 Structure", Y. Tezuka, H. Daimon and S. Ino, *Jpn. J. Appl. Phys.*, **29** (9) 1773-1777 (1990).

(32) "Two Dimensional Photoelectron Diffraction Pattern by Display-type Spherical Mirror Analyzer", H. Daimon, Y. Tezuka, A. Otaka, N. Kanada, S. K. Lee, S. Ino, H. Namba and H. Kuroda, Proc. XXVI Yamada Conference on Surface as a New Material (Osaka 1990), *Surf. Sci.*, **242** 288-293 (1991).

(33) "Photoelectron Diffraction Patterns by Display-Type Spherical Mirror Analyzer", H. Daimon, Y. Tezuka, N. Kanada, A. Otaka, S. K. Lee, S. Ino, H. Namba and H. Kuroda, Proc. 3rd Int. Conf. on the Structure of Surfaces, (Milwaukee 1990), Springer Series in Surface Science, **24** "The Structure of Surfaces III" ed. S.Y.Tong et al. 96-101 (Springer, Berlin 1991).

(34) "Direct Observation of Surface Structures by a High Resolution UHV-SEM", S. Ino, A. Endo and H. Daimon, Proc. 3rd Int.Conf. on the Structure of Surfaces, (Milwaukee 1990), Springer Series in *Surf. Sci.*, **24** "The Structure of Surfaces III" ed. S.Y.Tong et al. 168-173 (Springer, Berlin 1991).

(35) "Catalytic Effect of Metals (Sn, Ag, and Pb) on Homoepitaxial Growth of Ge and Si", K. Fukutani, H. Daimon and S. Ino, Proc. 3rd Int.Conf. on the Structure of Surfaces, (Milwaukee 1990), Springer Series in *Surf. Sci.*, **24** "The Structure of Surfaces III" ed. S.Y.Tong et al. 615-622 (Springer, Berlin 1991).

(36) "Electronic Structures of Mn_2Sb and MnAlGe: Photoemission and Inverse Photoemission Spectroscopy", Kimura, S. Suga, H. Matsubara, T. Matsushita, Y. Saitoh, H. Daimon, T. Kaneko and T. Kanomata, Solid State Communications, **81** (8) 707-710 (1992).

(37) "Glancing Angle Dependence of the X-ray Emission Measured at Total Reflection Angle X-ray Spectroscopy (TRAXS) Condition During RHEED Observation", T. Yamanaka, T. Hanada, S. Ino and H. Daimon, *Jpn. J. Appl. Phys. Lett*,. **31** L1503-L1505 (1992).

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