S. THOMAS PICRAUX

Chief Scientist, Center for Integrated Nanotechnologies, Los Alamos National Laboratory, Los Alamos, NM 87545

EDUCATION, EMPLOYMENT, AFFILIATIONS

1965	B.S. (Electrical Engineering) **University of Missouri, Columbia, MO**
1966	Fulbright Fellow (Physics) **Cambridge University, UK**
1967	M.S. (Engineering Science) **California Institute of Technology, Pasadena, CA**
1969	Ph.D. (Engineering Science & Physics) **California Institute of Technology, Pasadena, CA**
1969-2001	**Sandia National Laboratories, Albuquerque, NM**
69-72	Member, Technical Staff
72-85	Supervisor, Ion-Solid Interactions Division
85-86	Manager, Ion Implantation and Radiation Physics Research Department
86-88	Manager, Ion Implantation and Microsensor Research Department
89-90	Manager, Ion-Solid Interactions and Surface Sciences Research Department
90-92	Manager, Surface, Interface and Ion Beam Research Department
92-94	Manager, Semiconductor Physics, Nanoelectronics & Nanophotonics Dept. & Defense Programs, Center 1100
95-96	Manager, Nanostructure & Semiconductor Phys. Dept.; and Program Manager, Center 1100
96-01	Director, Physical and Chemical Sciences Center 1100
2001-2005	**Arizona State University, Tempe, AZ**
	Executive Director for Materials Research, Office of the Vice Provost for Research
	Professor, Department of Chemical and Materials Engineering
	Co-Director, Center for Solid-State Science; Co-Director, Center for Solid-State Electronics Research
2005-2010	Research Professor and Adjunct Professor
2005-pres	**Los Alamos National Laboratory, Los Alamos, NM**
05-pres	Chief Scientist, DOE Center for Integrated Nanotechnologies
09-pres	Thrust Leader, DOE Energy Frontier Research Center for Nanostructures for Electrical Energy Storage
1968-1999	**Visiting scientist** at **Catania Univ., Aarhus Univ., Bell Labs, Chalk River Nuclear Labs, HRL**

AWARDS AND HONORS

1965-66	Fulbright Fellow
1978-pres	Fellow: Amer. Physical Society (78); Amer. Assoc. for the Adv. Science (99); Materials Research Society (08)
1985	DOE/BES Materials Science Award for Significant Implication for Energy Technology
1990	E.O. Lawrence Award for Materials Research
1992	DOE/BES Materials Science Award for Sustained Outstanding Research: Ion Beam Analysis
1994	DOE/BES Materials Science Award for Sustained Outstanding Research: Growth Science
2000	Outstanding Intellectuals of 21st Century
2001	DOE Energy 100 and Energy at 23 Awards: Strained-Layer Semiconductors (team award)
2006	Missouri Honor Award for Distinguished Service in Engineering (Univ. of MO's highest eng. alumni award)
2008	Nanotech Briefs Nano 50 Award, Technologies category: Directed Assembly of Nanowire-Metal Contacts
2009	Los Alamos National Laboratory Fellow
2011	Los Alamos National Laboratory Postdoc Distinguished Mentor Award
1990-pres	Who's Who in Science & Engineering; Who's Who in America; Who's Who in the World

PUBLIC AND PROFESSIONAL SERVICE

Professional Society Offices:

1978-pres	**Materials Research Society**
	President (93), Vice President (91-92), Past President (94), Board of Directors (88-90), Chair Public Affairs Comm. (95-96), Chair Awards Comm. (04), Program Comm. (95-96), Chair Nominations Comm. (94), Member: Outstanding Young Investigator Comm. (03), Fellows Comm. (11-pres)
1965-pres	**American Physical Society**
90-91	Chairman, Division of Materials Physics

96-98 Member, Panel on Public Affairs

1990-pres **American Association for the Advancement of Science**

09-10 Chairman, Section P (Industrial Science & Technology)

01-04 Member, Section P (Industrial Science & Technology), Electorate Nominating Committee

04-07 Member, Section B (Physics), Electorate Nominating Committee

Conference, Symposia and Workshop Organization:

1973 International Conference on Applications of Ion Beams to Metals

1984 Gordon Research Conference on Particle-Solid Interactions

1985 ASM Annual Materials Science Seminar

1987 Annual MRS Fall Meeting (22 symposia, 3500 attendees)

1981,1986,2010 Materials Research Society Symposia Cochair

1995 DOE Workshop on Center for Microtechnology Science

Selected Study Panels:

1979 Member, Study on Surface Treatments (National Academy of Sciences)

1981,1983 Member, Strategic Materials (Office of Basic Energy Science Studies)

1985-1986 Member, Study on Materials Science (National Academy of Sciences). The resulting report, Advanced Microelectronics Processing in Japan and US, was presented at national NAS/NAE meeting, and, along with a Defense Science Board report, stimulated the formation of SEMATECH.

1987-1988 Member, Study on Photonics (National Academy of Sciences)

1988 Member, Future Interface Research Directions (Office of Basic Energy Science Studies)

1995 Chair, U. S. Dept. of Energy, Council on Matls: New Directions for Ion Beams in Semiconductor Processing

2001-2002 Vice Chair, Implications of Emerging Micro/Nano Technologies (National Academy of Sciences)

Advisory Boards:

National & International

2009-pres International Scientific Advisory Board, Waterloo Institute for Nanotechnology, Canada

2008, 2011 National Science Foundation, Division of Materials Research Visiting Committee

2009-pres Solid-State Lighting Energy Frontier Research Center, Sandia National Laboratories

1995-1998 Solid State Sciences Committee, National Research Council, National Academy of Sciences

1993-1996 Gordon Research Conferences Selection & Scheduling Committee

1975-2000 Intl. Conf. Ion Beam Modification of Materials (Honorary Member, 2000-pres.)

1973-1989 Intl. Conf. on Ion Beam Analysis

1972-1986 Intl. Conf. on Surface Modification of Metals

2011-pres Lawrence Symposium on Epitaxy

2010-pres SPIE Conf. on Nanoepitaxy

National Laboratory Advisory Boards

1987-1990 Advisory Board, Argonne National Laboratory Electron Microscopy Center for Materials Science

1991 Electronic Materials Advisory Committee, Lawrence Berkeley Laboratory Center for Advanced Materials

1999-2001 Member, Lawrence Livermore National Laboratory Chemistry and Materials Committee

1994-1995 Chair, Lawrence Livermore National Laboratory Environmental Programs Committee

1991-1996 Member, Lawrence Livermore National Laboratory Physics Scientific Advisory Committee

1996 Advisory Board, Los Alamos National Laboratory Center for Materials Science

2002-2004 Advisory Board, Los Alamos National Laboratory Materials Science & Technology Division

2003-2004 Chair, Scientific Advisory Committee, DOE Center for Integrated Nanotechnologies

University Advisory Boards

2009-pres University of Missouri, MU Research & Development Advisory Board

2002 Stanford University Materials Science & Engineering Dept. Visiting Committee

1988-2000 University of Texas (Austin), NSF S&T Center for Electronic Matls

1998-2001 University of New Mexico/Sandia Natl. Labs Cooperative Council Co-chair

1998-2001 University of Texas (Austin), Physics Department Visiting Committee

1999-2001 New Mexico State University, Physics Department Visiting Committee

2003-2005 Arizona State University, National Scholarships & Fellowships Committee

2006-2009 University of Wisconsin, NSF MRSEC External Advisory Comm.

Community Leadership

1993-1998 New Mexico Museum Natural History & Science, New Mexico Governor's Board of Trustees

Member (93-98), Secretary (95),Vice President (95-96)

PUBLICATIONS, JOURNAL EDITORSHIPS & ADVISORY BOARDS, BOOKS & REVIEWS, LECTURES

Publications:

>310 peer-reviewed publications (with >6,500 cumulative citations and an H-Index = 42).

Patents:

US20090078326, Issued Jul 26, 2011, Light-Driven Microfluidic Devices and Amplification of Stimulus-Induced Wetting

Journal Editorships & Advisory Boards:

1983-1991 Editor, Journal of Nuclear Instruments and Methods: Section B- Beam Interactions with Materials & Atoms
1990-2002 Advisory Board, Nuclear Science & Techniques
1999-2005 Advisory Board, IEEE Spectrum
1998-2006 Advisory Board, MRS Bulletin
1991-pres Advisory Board, Nuclear Instruments & Methods B
2011-pres Advisory Board, Journal of Nanoscience Letters

Books & Reviews

Books

- Materials Analysis by Ion Channeling: w/L. C. Feldman and J. W. Mayer (Academic Press, 1982).

Edited Books

- Nanomaterials Integration for Electronics, Energy & Sensing, w/D. Perea et al,(MRS Symp. Proc. Vol. 1303, 2011).
- Beam-Solid Interactions and Transient Processes, w/M. Thompson J. Williams, (MRS Symp. Proc. Vol. 74, 1987).
- Surface Alloying by Ion, Electron and Laser Beams (Amer. Soc. for Metals, Metals Park, OH, 1987).
- Ion Mixing and Surface Layer Alloying, w/M. A. Nicolet (Noyes Publications, Park Ridge, NJ, 1984).
- Metastable Materials Formation by Ion Implantation, w/W. J. Choyke, (MRS Symp. Proc. Vol. 100, 1982).
- Applications of Ion Beams to Metals, w/E. P. EerNisse, F. L. Vook (Plenum Press, New York, 1974).

Book Chapters

- *Growth of Ge, Si, and Ge/Si Heterostructure Nanowires*, in Appl. Nanowires of Silicon & Silicides (Elsevier Press, 2012).
- *Semiconductor Nanowires for Solar Cells*, in Semiconductor Nanostructures for Optoelect. Devices, (Springer, Germany, 2011).
- *National Needs Drivers for Nanotechnology*, in Societal Implications of Nanoscience & Nanotechnology, (NSF, Arlington, 2001).
- *Applications: Energy & Chemical Industries*, in Nanotechnology Research Directions, (Kluwer Academic, Boston, 2000).
- *Structure and Characterization of Strained-Layer Superlattices*, in Semiconductors and Semimetals Vol. 33 (Academic Press, 1990).
- *Microstructures of Surface-Melted Alloys*, in Surface Alloying by Ion, Electron & Laser Beams (Amer. Soc. for Metals, 1987).
- *Surface Modification of Materials: Ions, Lasers and Electron Beams*, in Industrial Materials Science & Eng., (Marcel Dekker, 1984).
- *Physics of Ion Implantation*, in Ion Cascade Processes & Physical State of Implanted Solid, (Martinus Nijhoff, Boston, 1984).
- *Characterization of Irradiated Metals by Ion Channeling*, in Adv. Tech. for Characterizing Microstructures, (AIME, 1982).
- *Surface Modification and Alloying: Aluminum*, in Surface Modification & Alloying, NATO Institute Book, (Plenum Press, 1982).
- *Formation of Nonequilibrium Systems by Ion Implantation*, in Site Char. & Aggregation Implanted Atoms in Matls, (Plenum, 1980).
- *Equilibrium Phase Formation by Ion Implantation*, in Site Character. & Aggregation Implanted Atoms in Matls, (Plenum, 1980).
- *Ion Implantation Studies of Hydrogen in Solids*, in Treatise on Materials Science & Technology, (Academic Press, 1980).
- *Lattice Location of Impurities in Metals and Semiconductors*, in New Uses of Low Energy Accelerators (Plenum, 1975).
- *Selected Low Energy Nuclear Reactions*, in Ion Beam Handbook for Materials Analysis, (Academic Press, 1977).

NRC Reports

- *Implications of Emerging Micro and Nanotechnologies*, S.R.J. Brueck, S. T. Picraux, et al. (National Academies Press, 2002).
- *Photonics: Maintaining Competitiveness in the Information Era*, J. R. Whinnery, S. T. Picraux, et al. (National Academies Press, 1988).
- *Advanced Processing of Electronic Materials in the United States & Japan*, Appleton, Picraux et al. (National Academies Press 1986).

Selected Invited Reviews

- *Integrated Microsystems*, IEEE Spectrum, Vol. 35, 24 (1998).
- *Ion Beams in Silicon Processing and Characterization*, J. Appl. Phys.--Applied Physics Reviews, 81, 6513 (1997).
- *Ion-Assisted Surface Processing of Electronic Materials*, MRS Bulletin Vol. 17, No. 6 (1992).
- *Ion Implantation*, S. T. Picraux and P. S. Peercy, MRS Bulletin, Vol. 12, No. 2, 22 (1987).
- *Ion Implantation of Surfaces*, Scientific American, Vol. 252, No. 3, 101, March (1985).
- *Ion Implantation in Metals*, Annual Reviews Materials Science 14, 335 (1984).
- *Ion Implanted Metallurgy*, Physics Today 37, No. 11, 38, Nov. (1984).
- *Tailored Surface Modification by Ion Implantation and Laser Treatment*, Science, 226, 615 (1984).

- *Analyzing Hydrogen with Nuclear Reactions*, Physics Today 30, No. 10, 42 (1977).

Invited Lectureships (Selected)

NATO Advanced Study Institutes & Summer School Lectures

- Microstructure & Nonequilibrium Aspects of Ion Implanted Systems, in Nonequilibrium Systems, Austin, 1986.
- Physics of Ion Implantation: Ion Cascade Processes & Physical State, Surface Eng. Theory & Application, Les Arcs, 1983.
- Formation of Equilibrium Phases by Implantation, Site Characterization & Aggregation of Implanted Atoms, Corsica, 1978.

Materials Research Society Invited Presentations

- Metastable Materials Formation by Ion Implantation, Boston, 1983.
- Characterization of Defects and Interfaces by the Ion Channeling Technique, Boston, 1984.
- Ion Beam Studies of Strained-Layer Structures, Boston 1985; Ion Beam Assisted MBE, Boston, 1989.
- Energetic Ion Beams in Semiconductor Processing, Boston, 1998.
- Tailored Inorganic/Organic Nanostructured Interfaces Control Surface Hydrophobicity, Boston, 2005
- Synthesis of Si/Ge Nanowire Heterostructures, Boston, 2008.
- Si/Ge Nanowires: Vertical Synthesis and Integration, San Francisco, 2009.

Gordon Research Conference Invited Presentations

- Semiconducting Nanowires: Materials Synthesis and Energy Appl., Nanostructure Fabrication, Biddeford, ME, 2012
- Semiconductor Nanowire Growth, Thin Film and Crystal Growth Mechanisms, Biddeford, ME, 2011
- Ion-Beam Enhanced Epitaxy, Particle-Solid Interactions, Plymouth, NH, 1990
- Effects of P Implantation of Passivity of Fe-Cr Alloys in Acidic Electrolytes, New London, 1986
- Channeling Analysis of Implantation Disorder in Metals, Ion Solid Interactions, Plymouth, NH, 1976
- Nuclear Reaction Analysis of Hydrogen & Helium in Solids, Ion Solid Interactions, Plymouth, NH, 1974

NSF/US Foreign Exchanges

- Ion Implantation Applied to Fusion Research US-USSR Ion Implantation, Moscow, USSR, 1979.
- Application of Ion Channeling to Studies of Extended Defects by Dechanneling, U.S.-Japan, Tokai, 1978.
- Ion Implantation Disorder, US-USSR,(laser annealing first introduced outside Russia), Albany, NY, 1976.
- Nuclear Reaction Analysis of Hydrogen and Helium in Solids, US-Italy, Catania, Italy, 1974.

Others

- Japan Nano 2011 - DOE Nano Research, (Plenary on US DOE nanoscience for BES Director, H. Kung), Tokyo, 2011.
- American Institute of Physics - Ion Implantation Metallurgy, Corporate Associates Annual Meeting, 1982.
- Oregon Distinguished Lecture Series - Surface Modification of Materials, Oregon Graduate Center, 1983
- ASM Annual Materials Science Seminar - Microstructures of Surface Melted Alloys, Toronto, 1985
- American Physical Society Plenary Presentation - Exploring the World of the Teeny Tiny, El Paso, 2008.
- Nanoscience and Technology Forum Keynote- Semiconducting Nanowires-Beauty in 1D, Nashville, 2009.

SELECTED JOURNAL ARTICLES

Selected from more than 310 peer-reviewed journal articles

- Axial Bandgap Engineering in Germanium-Silicon Heterostructured Nanowires, Appl. Phys. Lett.99, 113105 (2011).
- Direct Observation of Nanoscale Size Effects in Ge Semiconductor Nanowire Growth, Nano Lett. 10, 4032 (2010).
- Lotus Effect Amplifies Light-induced Contact Angle Switching, J. Phys. Chem. B108, 12640 (2004). 116 cites
- Metastable SiGeC Formation by Solid Phase Epitaxy, Appl. Phys. Lett. 63, 2786 (1993). 100 cites
- Precipitation and Relaxation in Strained Si1-y Cy/Si Heterostructures, J. Appl. Phys. 76, 3656 (1994). 107 cites
- Critical Stresses for SiGe Strained-Layer Plasticity, Phys. Rev. Let. 59, 2455 (1987). 147 cites
- Epitaxial Growth of Rare Earth Silicides in (111)Si, J Appl. Phys. Letts. 48, 466 (1986). 233 cites
- Depend. of Critical Layer Thickness on Strain for InGaAs/GaAs Strained-Layer Superlattices, APL. 46, 967 (1985). 173 cites
- Formation of SiC in Silicon by Ion Implantation, Appl. Phys. Lett. 18, 509 (1971). 139 cites
- Carbon-Induced Amorphous Surface Layers in Ti-implanted Fe, Appl. Phys. Lett. 37, 330 (1980). 53 cites
- Saturation and Isotopic Replacement of Deuterium in Low-Z Materials, J. Nucl. Mater. 93-4, 551 (1980). 133 cites
- Defect Trapping of Ion-Implanted Deuterium in Fe, J. Appl. Phys. 50, 5710 (1979). 120 cites
- Ion Implantation of Si & Ge at Room Temp., Analysis by 1.0 MeV He Ion Scattering, Can.J.Phys. 46, 663 (1968). 193 cites

KEY TECHNICAL ACCOMPLISHMENTS

Ion Channeling Analysis

• Tom developed the lattice location method for non-substitutional atoms in crystals using ion channeling backscattering and nuclear reactions. He applied this new method to determine for the first time the lattice location of defect-associated near-

substitutional dopants in semiconductors (Bi-vacancy centers in Si; D in Si). Lattice Location by Channeling Angular Distributions – Bi Implanted in Si, Phys. Rev. B6, 1382 (1972) 57cites. Structure of Hydrogen Center in D-Implanted Si, Phys. Rev. B18, 2066 (1978) 82 cites. He also identified the first lattice location of a vacancy-hydrogen center in a metal (D in single-crystal Fe) and determined its trapping kinetics. Defect Trapping of Ion-Implanted Deuterium in Fe, J. Appl. Phys. 50, 5710 (1979) 120 cites.

• Developed for the first time the experimental and analytic formalism to extend ion-channeling to the depth profiling of wide classes of disorder in materials including dislocations, stacking faults, microtwins, strained layer heteroepitaxy and strained layer superlattices, and showed how the dechanneling energy dependence could be used to identify the defect type. These new methodologies for lattice location and disorder profiling by ion channeling were formalized in his book with J.W. Mayer and L.C. Feldman. The channeling analysis was recognized by the 1990 DOE E.O. Lawrence Award and the 2001 DOE Energy 100 and Energy at 23 Awards (Sandia Strained-Layer Semiconductors Team). Materials Analysis by Ion Channeling (Academic Press, 1982) ~1000 citations. Dechanneling by Dislocations in Ion-Implanted Al, Phys. Rev. B18, 2078 (1978) 69 cites. Strain Measurements by Channeling Angular Scans, Appl. Phys. Lett. 43, 1020 (1983) 54 cites. Channeling Analysis of Strain in Superlattices, Nucl. Instrum. Meth. B 15, 306 (1986) 64 cites.

• Using hydrogen depth profiling Tom discovered enhanced hydrogen trapping and saturation in C which he used in hydrogen profiles at the plasma edge inside a tokomak (with Princeton Plasma Physics Lab) to determine the plasma edge temperature and flux for the first time. Saturation and Isotopic Replacement of Deuterium in Low-Z Materials, J. Nucl. Mater. 93-4, 551 (1980) 133 cites. This approach was used to correctly predict a safe tritium inventory in TFTR in the first US fusion tokomak demonstration with tritium.

Ion Beam Modification

• In the early 1970's Tom demonstrate the direct synthesis of uniform buried layers of new phases in Si by ion implantation. He demonstrated silicon carbide synthesis, and then buried phases (silicon nitride isolating layers in silicon), culminating in the first publication of electrically active devices on Si layers electrically isolated by implantation-formed dielectric layers. This new approach was subsequently used worldwide in Si-on-insulator wafer fabrication by implantation of oxygen (SIMOX) for advanced electronic circuits. Formation of SiC in Silicon by Ion Implantation, Appl. Phys. Lett. 18, 509 (1971) 139 cites. Epitaxial Silicon Layers Grown on Ion-Implanted Silicon-Nitride Layers, Appl. Phys. Lett. 8, 455 (1973) 58 cites.

• Tom pioneered the development of ion-implantation metallurgy techniques for new metastable and nanoscale equilibrium phase formation. Among the many new systems he and collaborators discovered were new low friction-wear-corrosion resistant amorphous FeTiC alloys. Recognition of this work included articles in Physics Today, Science, edited books, book chapters, and international meetings.

Heteroepitaxy

• Tom pioneered heteroepitaxial growth for bandgap engineering of materials, including: SiGeC strained layer synthesis on Si, Metastable SiGeC Formation by Solid Phase Epitaxy, Appl. Phys. Lett. 63, 2786 (1993) 100 cites, strained layer stability, Dependence of Critical Layer Thickness on Strain for InGaAs/GaAs Strained-Layer Superlattices, Appl. Phys. Lett. 46, 967 (1985) 173 cites; Critical Stresses for SixGe1-x Strained-Layer Plasticity, Phys. Rev. Lett. 59, 2455 (1987) 147 cites; epitaxial silicide formation (Epitaxial Growth of Rare Earth Silicides in (111)Si, Appl. Phys. Letts. 48, 466 (1986) 233 cites); Si and Ge surface vacancy island formation and layer-by-layer removal by low energy ion bombardment, the inverse of adatom clustering and layer-by-layer Si epitaxy, Layer-by-Layer Sputtering and Epitaxy of Si (100), Phys. Rev. Lett. 67, 124 (1991) 63 cites.

Nanoepitaxy

• Tom pioneered the study of nanoscience at Sandia, including forming and leading the Nanoelectronics and Nanophotonics Dept. and then as Director of Physical and Chemical Sciences as one of the national lab leaders in the National Nanotechnology Initiative to bring together a coordinated set of nano-technology programs within DOE weapons labs. This culminated in the DOE Office of Basic Energy Sciences asking Sandia and Los Alamos to jointly form one of the 5 DOE national nanoscience centers.

• Extended heteroepitaxial growth and bandgap engineering studies to Si/Ge nanowire growth, initiating nanowire studies at ASU and then establishing a new program of semiconductor nanowire synthesis, properties and performance at LANL. Tom's group grew the first 100% Ge to Si axial heterostructured nanowires (previously 30% composition change was maximum), Axial Bandgap Engineering in Germanium-Silicon Heterostructured Nanowires, Appl. Phys. Lett.99, 113105 (2011), and demonstrated new applications in wettability, electronics, photonics, photovoltaics, Li ion energy storage, and spin transport, Vapor-liquid-solid Growth of Germanium Nanostructures on Silicon, J. Appl. Phys. 96, 7556 (2004) 64 cites; Lotus Effect Amplifies Light-induced Contact Angle Switching, J. Phys. Chem. B108, 12640 (2004) 116 cites.