Curriculum Vitae : ELIAS C. AIFANTIS/ECA

Professor of Mechanics, Department of Civil Engineering, Aristotle University, Thessaloniki, GR-54124, Greece
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http://users.auth.gr/users/0/3/022730/public_html/index3.htm]

■ Personal Data

Date/Place of Birth: 10 October 1950, Greece; *Citizenship:* Hellenic/US

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■ Academic Degrees

- National Technical University of Athens, Mining and Metallurgy (Diploma/BS-MS, 1973)
- University of Minnesota, Chemical Engineering and Materials Science-Mechanics (Ph.D, 1975)

■ Academic Posts

- University of Minnesota (Instructor 1975-76)
- University of Illinois at Urbana-Champaign (Assistant Professor 1976-80)
- University of Minnesota (Visiting Professor 1980-82)
- Michigan Tech Univ (Professor 1982-2000); Distinguished Research Professor 2000-2010; Emeritus 2010-)
- Aristotle University of Thessaloniki (Professor after special honorary invitation/metaklisi, 1990-)
- King Abdulaziz University, Jeddah (Distinguished Adjunct Professor 2011- 2014)
- ITMO Univ/Int Lab of Modern Functional Materials, St. Petersburg (Distinguished Visiting Professor 2014, 2015)
- BUCEA/Beijing Univ. of Civil Engineering and Architecture, Beijing (Distinguished Visiting Professor 2015, 2016)

■ Academic Distinctions

- Fellowship Award for 1 mo Visit to USSR/US Academy of Sciences, 1986
- MTU Research Award, Michigan Tech Univ, Houghton/MI, 1993
- Fellowship Award for 1 mo Visit to Japan/Japanese Government, 1996
- Selected for ASME's Koiter Award, 2000
- ASME/ASCE/SES Symposium honoring his 55th birthday, 1-3 June 2005, Baton Rouge/USA
- Selected for ASM's Author Award
- Acknowledged in G.A. Maugin's Continuum Mechanics Through the 20th Century: A Coincise Historical Perspective, Springer, 2013. [Chapter 10.6.3/Greece: P.S. Theocaris, P.D. Panagiotopoulos, E.C. Aifantis, G.M. Lianis.]
- Listed in ISI Web of most highly cited authors in the world: ENGINEERING (3rd entry. A0086-2010-N out of 262)
- KACST Award/King Abdulaziz University, Jeddah-Saudi Arabia, 2013
- Distinguished Foreign Scientist Fellowship Award/Southwest Jiaotong University, Chengdu-China, 2014
- Aifantis International Symposium honoring his 65th birthday, 4-9 October, 2015, Antalya/Turkey [Appendix II]
- Fray International Sustainability Award (along with Nobel Laureate El-Ichi Negishi)/Flogen Star Outreach, 2015
- ZiF Cooperation Group "Multiscale Modeling of Tumor Initiation, Growth and Progression: From Gene Regulation to Evolutionary Dynamics", September-October 2016.

■ **Teaching and Research**

- *Undergraduate Courses* in Statics and Dynamics; Strength and Mechanics of Materials; Elasticity and Visoelasticity; Plasticity and Damage; Creep and Fracture
- *Graduate Courses* in Continuum Mechanics and Thermodynamics; Mechanical Behavior: Metals – Rocks/Soils – Polymers – Biomaterials; Materials Science: Dislocations – Diffusion – Phase Transformations; Micromechanics and Nanomechanics; Nanosciences and Nanotechnologies
- *Training Seminars/Course Modules* on the above topics in Summer Schools and Multi-University Curricula
- *Interdisciplinary Research on* Macro/Micro/Nano Mechanics of Materials and Structures; Diffusion and Flow through Deformable Porous Media; Stress Corrosion Cracking and Environmental Damage; Phase Transitions and Interfaces; Material Instabilities: Dislocation Patterning/Shear Banding/Damage Localization; Coupled Continuum Mechanics of Structured Natural Materials: Soils/Rocks/Wood/Biomaterials; Thermo-electro-chemo-mechanics of Engineering Materials: Metals/Polymers/Concrete/Composites; Novel Nanostructured Materials/Structures and Devices: Nanoparticles/Nanotubes/Nanowires, Nanofibers/Nanobeams/Nanoplates, MEMS/NEMS, Li-ion Batteries (LiBs), Light Emitting Diodes (LEDs), Medical Implants, Nano-decorated tissues and cells
- *Coined in his publications* the terms Double Diffusivity/Porosity, Chemomechanics, Material Instabilities, Dislocation Patterning, Gradient Plasticity, Nanomechanics, NanoNeuroMechanics

■ **Funding I (Last 5 years)**

- *PI:* Greek National Strategic Reference Framework (NSRF): "Funding of Research Projects Positively Reviewed in the 5th ERC Grant Schemes Call: Internal Length Gradient Mechanics Across Scales and Materials: Theory, Experiments and Applications/*IL-GradMech-ASM*", 2013-2015, 797 kEuros
- *PI:* General Secretariat of Research and Technology (GSRT): "ARISTEIA II: Size Effects in Deformation and Electromechanical Problems/*SEDEMP*", 2014-2015, 283 kEuros
- *Co-PI:* Multi-investigator EU project: ERANET-RUS "STProjects-219/NanoPhase: Shift of the phase equilibria in nanograined materials", 2012-2015, 207 kEuros
- *Co-PI:* Multi-investigator project from the Greek Ministry of Education: "THALES *INTERMONU: Conservation and Restoration of Monuments of Cultural Heritage*", 2012-2015, 600 kEuros
- *Host*: *K.E. Aifantis* – the youngest recipient ever with an ERC Starting Grant (MINATRAN 211166, 2008-2013, 1.130k Euros); *A.E. Romanov* - an international expert on defects in solids with a IIF Marie - Curie Senior Fellowship Grant (PIIF-GA-2008-220419, 2009-2011, 200 kEuros)

■ **Funding II (15 years; 1992-2007)**

- *Director/Co-Director* of Human Capital and Research Training Network projects (HCM/TMR/RTN), INTAS projects, Euratom projects (REVISA, LISSAC), as well as the General Secretariat of Research and Technology (GSRT) projects (PENED, PYTHAGORAS), as follows: *Coordinator* of 3 European Research Training Networks: HCM *Fellowships in Mechanics of Materials* /ERBCHBGCT 920041, 1992-1996, 240 kEuros; TMR Network on *Spatiotemporal Instabilities in Deformation and Fracture*/ERBFMRXCT 960062, 1996-2002, 1760 kEuros; RTN Network on *Deformation and Fracture Instabilities in Novel Materials and Processes*/HPRNCT-2002-00198, 2002-2007, 1500 kEuros; *Partner* of RTN Network on *Degradation and Instabilities in Geomaterials with Application to Hazard Mitigation*/HPRNCT-2002-00220, 2002-2006, 1600 kEuros. *Coordinator* of 3 INTAS Projects (INTAS-93-3213; INTAS-93-3213 – extension; INTAS-94-4380) in addition to PENED and PYTHAGORAS Grants from the Greek Government. *Partner* of 2 European projects on Nuclear Reactor Safety (REVISA/FI4S-CT96-0024, 1997-2000, and LISSAC/FIKS-CT1999-00012, 2000-2002, coordinated by J. Devos/France and R. Krieg/Germany respectively) by focusing on size effects and component failure using ECA's theory of gradient thermoplasticity and damage. The total amount of the INTAS/PENED/PYTHAGORAS and REVISA/LISSAC projects for ECA's Lab was about 1 million Euros.
- *PI/Co-PI* of a number of US projects supported by NSF, ARMY, ARO/NATO and other International Organizations (China, Japan, Saudi Arabia) totalling ~12 million USD. The most recent grant from US/NSF (*Novel Experiments*

and Models for the Nanomechanics of Polymeric and Biological Nanofibers, NSF NIRT Grant DMI #0532320, 2004-2008, 1.3M USD) was carried out in collaboration with Michigan Tech, U. of Illinois (I. Chasiotis), U. of Virginia (L. Zhigilei), U. of Minnesota (R. Ballarini), and Case Western (S. Eppel).

- *Co-Founder* of a Degree Awarding Graduate Program on *Nanosciences and Technologies*, at Aristotle University in Greece (http://nn.physics.auth.gr/) and of similar programs in US: NUE – *Undergraduate Exploration of Nano-Science, Applications, and Societal Implications*; Enterprise/Minor in Nanoscale Science and Engineering at Michigan Tech (http://nano.mtu.edu/nueindex.htm; http://nano.mtu.edu/nanominor.htm).

■ **PhD Students/Postdocs**

- *Advisor/Co-advisor* of ~20 PhDs and supervisor of ~30 postdocs. Many of these hold university positions in the US, EU, Russia and China. Examples include former PhDs *Doug Bammann* (Professor at Mississippi State), *Hussein Zbib* (Professor and former Chair at Washington State) and *David Unger* (Professor, Univ of Evansville); former postdocs/visiting scholars *Andrzej Neimitz* (Professor at Kielce University of Technology), *Oleg Naimark* (Professor at Perm State Univ), *Chongqing Ru* (Professor at University of Alberta), *Alexey Romanov* (Professor and Director at ITMO University), *Harm Askes* (Professor and Head at Univ of Sheffield), *Michael Zaiser* (Professor at the Univ of Erlangen-Nürnberg) and *Kaiyu Xu* (Professor at Shanghai Univ). Four of his more recent PhD students at Aristotle Univ - *A. Konstantinidis*/ *M. Avlonitis*/*G. Efremidis* and *I. Mastorakos* - are assistant professors at greek universities (Thessaloniki/Corfu/Volos) and at Clarkson/US, respectively. Two of his recent postdocs *K. Moutsopoulos* and *A. Kalampakas* are associate professor (Democritus Univ of Thrace) and assistant professor (American Univ of the Middle East), respectively. Former PhD students in the US (*R. Wilson, P. Taylor, T. Webb, X. Zhu, J. Huang*) hold key positions in National Labs and Research Government Organizations.

■ **Diploma/Masters Students and Visiting Scientists**

- *Supervisor* of ~15 Diploma/Master theses and of ~20 young researchers/visiting scientists in joint university projects. Examples of those holding academic positions in US include *I. Chasiotis* (Professor at Univ of Illinois at Urbana-Champaign) and *K. Kalaitzidou* (associate professor at Georgia Tech). Other examples of former postdocs and short-term (3-9 mo) visitors supported by the TMR/RTN/INTAS programs, and currently holding academic positions, include *M. Gutkin*/St. Petersburg, *M. Seefeldt*/Leuven, *M. Lazar*/Darmstadt, *X. Zhang*/Chengdu, *G. Ferro*/Torino, *P. Cornetti*/Torino, *C. di Prisco*/Milano, *N. Pugno*/Trento, *G. Ribarik*/Budapest, *J.V. Andersen*/Paris.
- *Other young scientists/short-term visitors* who spent time in his Lab and currently hold academic positions include *A. Nikitas* (Univ of Huddersfield), *N. Nikitas* (Univ of Leeds), *N.-H. Zhang* (Univ of Shanghai), *H. Xu* (Shanghai Jiaotong Univ), *Y. Chen/R. Yang* (CAS/LNM – Beijing), *A. Chattopadhyay* (Aston Univ), *M. Mousavi* (Aalto Univ).

■ **Collaborators/Distinguished Visitors**

- *Senior long-term collaborators* who conducted joint projects or research visits in his Lab include *J. Kratochvil* (Prague), *P. Perzyna* (Warsaw), *Z. Mroz* (Warsaw), *D. Beskos* (Minnesota/Patras), *N. Triantafyllidis* (Ann Arbor/Paris), *E. Gdoutos* (Xanthi/Northwestern), *I. Vardoulakis* (Minnesota/Athens), *Y. Dafalias* (Davis), *N. Aravas* (Pennsylvania/Volos), *H. Mühlhaus* (CSIRO/Queensland), *G. Frantziskonis* (Arizona), *G. Voyiadjis* (Louisiana), *A. Varias* (Malmö), *I. Groma* (Budapest), *J. Willis/N. Fleck* (Cambridge), *G. Maugin* (Paris), *A. Carpinteri* (Torino), *R. de Borst* (Delft/Glasgow/Sheffield), *R. Ballarini* (Case Western/Minnesota/Houston), *S. Forest* (Paris), *P. Steinmann* (Kaizerslautern/Erlangen-Nürnberg).
- *World*-known contributors who were hosted in his Lab in US include *Clifford Truesdell*, *Dan Drucker*, *Cemal Eringen*, *Jerry Ericksen*, *Jim Serrin*, *Frank Nabarro*, as well as the Chemistry Nobel Laureate *Ilya Prigogine*. At Aristotle University he hosted, among others, *A. Ngan* (Hong Kong), *J. Goddard* (San Diego), *Yilong Bai* (Beijing), *Gerard Maugin* (Paris) and *Constantino Tsallis* (Rio).

■ **Seminars/Lectures and Conferences**

- *Invited in ~500 occasions* to speak in conferences, universities, and research laboratories in the US, Europe, Former Soviet Union, Russia, Australia, Japan, South Africa, Brazil, Saudi Arabia, China. The majority of his lectures in conferences and symposia/workshops were invited, keynote and plenary. Examples of plenary lectures in the last 10

years include: *Plenary Lecture* in the *16th European Conference on Fracture/ECF16*, 2-8 July 2006, Alexandroupolis/Greece; *Plenary Lecture* in the 6th *South African Conference on Computational and Applied Mechanics/SACA*-2008, 26-28 March 2008, Cape Town/South Africa; *Plenary Lecture* in the *10th Asia-Pacific Conference on Engineering Plasticity and its Applications/AEPA*-2010, 15-17 November 2010 Wuhan/China; *Plenary Lecture* in the *5th International Conference on Materials Science and Condensed Matter Physics/MSCMP*-2010, 13-17 September 2010, Chisinau/Moldova; *Plenary Lecture* in the *7th WSEAS International Conference on Continuum Mechanics*, 14-17 July 2012, Kos/Greece; *Plenary Lecture* in the *12th International Conference of Numerical Analysis and Applied Mathematics/INCAAM*-2014, 22-28 September 2014, Rhodes/Greece; *Plenary Lecture in the Shechtman International Symposium*, 29 June – 4 July 2014, Cancun/Mexico; *Plenary Lecture* in the *1st Sino-Russian-Belarusian Joint Scientific-Technical Forum*, 15-17 September 2015, Beijing/China; and a forthcoming *Plenary Lecture* in the *XLIV International Conference in Advanced Problems in Mechanics*, June 27-July 2 2016, St. Petersburg.

- *Organizer/Co-organizer* of ~20 International Conferences/Symposia/Workshops and Member of Organizing Committees of ~50 Scientific Meetings. Examples include: E.C. Aifantis and J.P. Hirth, *International Symposium on the Mechanics of Dislocations, 50 years since the Discovery of Dislocations with a Tribute to J.D. Eshelby*, 28-31 August 1983, Houghton, Michigan/USA; E.C. Aifantis, *International Conference on Mechanics, Physics and Structure of Materials: A Celebration of Aristotle's 23 Centuries*, 19-24 August 1990, Thessaloniki/Greece; E.C. Aifantis, *2nd Euroconference and International Symposium on Materials Instabilities in Deformation and Fracture*, 31 August – 4 September 1997, Thessaloniki/Greece; E.C. Aifantis, *5th EuroMech Solid Mechanics Conference (ESMC-5)*, 17-22 August 2003, Thessaloniki/Greece; E.C. Aifantis, *1st World Symposium on Multiscale Material Mechanics and Engineering Sciences, Dedicated to the Memory of Frank Nabarro, Edward Hart and Ronald Rivlin*, 29 April – 3 May 2007, Thessaloniki/Greece; E. Meletis, E.C. Aifantis and E. Kaxiras, *1st International Conference: From Nanoparticles and Nanomaterials to Nanodevices and Nanosystems (1st IC4N-2008)*, 16-18 June 2008, Halkidiki Penninsula/Greece; Y. Dafalias, E.C Aifantis and L. Toth, *Symposium on Generalized Granular Mechanics, 2016 EMI International Conference, 25-27 October 2016*, Metz/France; F. Kongoli, E.C. Aifantis, H. Wang and T. Zhu, *YANG International Symposium on Multiscale Material Mechanics and Multiphysics and Sustainable Applications (in honor of Life-time Achievements of Prof. Wei Yang – President of Natural Science Foundation of China)*, 6-10 November 2016, Hainan Island/China.
- *Symposia Honoring ECA's Contributions: Joint ASME/ASCE/SES Symposium* honoring his 55th birthday, 1-3 June 2005, Baton Rouge, USA [Organizers: D.J. Bammann, H.M. Zbib, P. Sofronis]; *Flogen Star Outreach Symposium* honoring his 65th birthday, 4-9 October 2015, Antalya, Turkey [Organizers: F. Kongoli, S. Bordas, Y. Estrin.]

■ **Editorships and Editorial Boards**

- *Editor/Co-Editor:* 12 Books/Special Journal Issues and Conference Proceedings. Examples include: E.C. Aifantis and L. Davison, *Media with Microstructures and Wave Propagation*, Special Issue of Int. J. Engng. Science 212, 961-1224, 1984; E.C. Aifantis and J.P. Hirth, *The Mechanics of Dislocations* [248 pages], ASM, Metals Park, 1985; E.C. Aifantis and J. Gittus, *Phase Transformations* [302 pages], Elsevier Appl. Sci. Publ., London-New York, 1986.
- *Editor-in-Chief: J. Mechanical Behavior of Materials* (ISSN 0334-8938)**;** *Honorary Editor* of *Computer and Experimental Simulations in Engineering and Science* (ISSN 1791-3829).
- *Advisory/Editorial Board Member: Reviews on Advanced Materials Science* (ISSN 1605-8127); *Materials Physics and Mechanics* (ISSN 1605-8119); *Acta Mechanica Solida Sinica* (ISSN 0894-9166); *Mechanical Sciences* (ISSN 2191-9151); *J. Control Engineering and Technology* (ISSN 2223-2036)**;** *Open Mechanics Journal* (ISSN 1874-1584), *J. Adv. Microelectronic Engng. (ISSN 2327-7599)*; *Open Conf. Proc. J. (ISSN 2210-2892); Scientific and Technical Journal of Information Technologies, Mechanics and Optics (ISSN 2226-1494)*.
- *Former Editorial Boards: Acta Mechanica* (ISSN 0001-5970), *J. Nano Research* (ISSN 1662-5250)**;** *Mechanics of Cohesive-Frictional Materials* (ISSN 1099-1484); *Numerical and Analytical Methods in Geomechanics* (ISSN 106-222).

■ **Publications/Citations**

- *Published* over *550* articles in scientific journals, book chapters/proceedings, and technical reports
- *Cited*: *~8505* times/*47* h-index (ISI); *~8680* times/*46* h-index (Scopus); *~14030* times/*58* h-index (Google Scholar)
- *3 most Highly Cited single authorship articles*: *E.C. Aifantis*, On the microstructural origin of certain inelastic models, ASME J. Engng. Mat. Tech. 106, 326-330 (1984). [ISI: 595, Scopus: 774; Google Scholar: 1162; 5th most cited article of the Journal]; E.C. Aifantis, The physics of plastic deformation, Int. J. Plasticity 3, 211-247 (1987). [ISI: 524, Scopus: 494; Google Scholar: 823; 7th most cited article of the Journal]; E.C. Aifantis, On the role of gradients in the localization of deformation and fracture, Int. J. Engrg. Sci. 30, 1279-1299 (1992). [ISI: 369, Scopus: 392; Google Scholar: 615; 8th most cited article of the Journal.]
- *12 Most Cited Articles*

1. *E.C. Aifantis*, On the microstructural origin of certain inelastic models, Transactions of ASME, J. Engng. Mat. Tech. 106, 326-330 (1984). [Citations: 758/Scopus, 582/ISI, 1142/Google Scholar]
2. *E.C. Aifantis*, The physics of plastic deformation, Int. J. Plasticity 3, 211-247 (1987). [Citations: 486/Scopus, 521/ISI, 814/Google Scholar]
3. *E.C. Aifantis*, On the role of gradients in the localization of deformation and fracture, Int. J. Engrg. Sci. 30, 1279-1299 (1992). [Citations: 378/Scopus, 359/ISI, 580/Google Scholar]
4. *H.B. Muhlhaus* and *E.C. Aifantis*, A variational principle for gradient plasticity, Int. J. Solids Struct. 28, 845-857 (1991). [Citations: Scopus not listed, 433/ISI, 694/Google Scholar]
5. *E.C. Aifantis*, Update on a class of gradient theories, Mechanics of Materials 35, 259-280 (2003). [Citations: 232/Scopus, 215/ISI, 281/Google Scholar]
6. *E.C. Aifantis*, Strain gradient interpretation of size effects, Int. J. Fract. 95, 299-314 (1999). [Citations: 221/Scopus, 171/ISI, 305/Google Scholar]
7. *H.M. Zbib* and *E.C. Aifantis*, On the localization and postlocalization behavior of plastic deformation - I: On the initiation of shear bands, Res Mechanica 23, 261-277 (1988). [Citations: 188/Scopus, 177/ISI, 274/Google Scholar]
8. *N. Triantafyllidis* and *E.C. Aifantis*, A gradient approach to localization of deformation - I. Hyperelastic materials, J. of Elasticity 16, 225-238 (1986). [Citations: 192/Scopus, 192/ISI, 297/Google Scholar]
9. *M. Ke*, *S.A. Hackney*, *W.W. Milligan*, and *E.C. Aifantis*, Observation and measurement of grain rotation and plastic strain in nanostructured metal thin films, Nanostructured Materials 5, 689-698 (1995). [Citations: 178/Scopus, 183/ISI, 236/Google Scholar]
10. *C.Q. Ru* and *E.C. Aifantis*, A simple approach to solve boundary value problems in gradient elasticity, Acta Mechanica 101, 59-68 (1993). [Citations: 168/Scopus, 165/ISI, 248/Google Scholar]
11. *E.C. Aifantis*, On the problem of diffusion in solids, Acta Mechanica 37, 265-296, 1980. [Citations: 173/Scopus, 168/ISI, 267/Google Scholar]
12. *H. Askes* and *E.C. Aifantis*, Gradient elasticity in statics and dynamics: An overview of formulations, length scale identification procedures, finite element implementations and new results, Int. J. Solids Struct. 48, 1962-1990, 2011. [Citations: 137/Scopus, 124/ISI, 185/Google Scholar]

- *Research Topics Pioneered by ECA and Discussed in Books Published by Other Distinguished Authors*: Over the past three decades, ECA's research has stimulated the organization of various specialized workshops/conferences and the publication of journal special issues and book chapters. *Chapter 89* of the book *by M. Gurtin/E. Fried/L. Anand* (The Mechanics and Thermodynamics of Continua, Cambridge Univ Press, UK, 2010) is dedicated to his theory of "gradient plasticity" and *Chapter 6* of the book by Nobel Laureate *I. Prigogine and G. Nicolis* (Exploring Complexity, Freeman, New York, 1989) is dedicated to his approach (with D. Walgraef) on "dislocation patterning". A discussion of the Walgraef-Aifantis (W-A) model on PSBs formation is also provided in *Chapter 2.6* of a book by *S. Suresh* (Fatigue of Materials, Cambridge Univ Press, UK, 1991) and in *Chapter 2.7.3* of the 2nd Edition, 2001. His theory on "gradient elasticity" as applied to elimination of singularities from dislocation lines is the subject of *Chapter 3.1.1* of another recent book by *M.Yu. Gutkin* and *I.A. Ovid'ko* (Plastic Deformation in Nanocrystalline Materials, Springer-Verlag, Berlin-Heidelberg-New York, 2004). The W-A model (as well as the role of gradients in plastic instabilities) is also discussed extensively in a recent book by *N. Ghoniem* and *D. Walgraef* (Instabilities and Self-Organization in Materials, Oxford Univ Press, UK, 2008). Finally, a brief discussion of his research contributions was included in Chapter 10.6.3 in a book by *G.A. Maugin* (Continuum Mechanics Through the 20th Century: A Coincise Historical Perspective, Springer, 2013).

■ **Research Interdisciplinarity / Innovation**

- *ECA's broad research background and international collaborations* have led to several world-wide recognized interdisciplinary contributions in the mechanics and physics of materials and structures. His work – combining fundamental theory, mathematical modeling, numerical simulations and experiments – has found numerous applications in various disciplines across engineering sciences and departments, including mining and civil, materials and mechanical, chemical and electrical engineering. This wide spectrum of research activity is partly due to a multifaceted education (first Diploma in mining and metallurgy/NTU-Athens; PhD in mechanics – chemical engineering and materials science/U of Minnesota), as well as to multiple academic posts (first in the Dept of Theoretical and Applied Mechanics/U of Illinois-Urbana; later in the Dept of Chemical Engineering and Materials Science/U of Minnesota and the Dept of Mechanical Engineering – Engineering Mechanics/Michigan Tech; and, finally, in the Dept of Civil Engineering/Aristotle Univ of Thessaloniki). The areas that his theories and models have been applied vary from traditional (flow/diffusion through deformable fissured rocks; damage/failure of geomaterials, asphalts and concrete; deformation and fracture of metals, polymers and composites) to emerging ones (nanopolycrystals and metallic glasses; MEMS/NEMS and optoelectronic films; biomaterials and tissues/bone-collagen-soft tissues-cells).
- *He revised and brought ideas* of *van der Waals* (non-monotone equations of state and higher-order density gradients) and *Maxwell* (diffusive drag and higher-order temperature gradients), as well as of *Landau* (order parameter and non-convex free energy) and *Prigogine* (non-equilibrium thermodynamics and self-organization) into the mechanics of materials and structures within a multiscale/multiphysics setting. This allowed for the development of new approaches to address unresolved issues (spatio-temporal pattern formation, interpretation of size effects, elimination of stress/strain singularities) in this field. The topics/terms of "double diffusivity" and "double porosity", "stress-assisted diffusion", "material instabilities", "dislocation patterning", "chemomechanics", and "nanomechanics" were first introduced/quoted and dealt with in his publications. He pioneered the approach of "gradient plasticity" by providing a method to calculate shear band widths and spacings, and eliminate the mesh-size dependence of finite element calculations in the strain softening regime. He simplified and popularized the approach of "gradient elasticity" by providing the first non-singular solutions for dislocation lines and crack tips. These results, which become increasingly important as the specimen/component dimensions reduce down to micron and nano levels, can now be checked against laboratory and numerical tests which are possible with advanced experimental probes and powerful computers. Variants of his gradient theories in elasticity, plasticity and damage are extensively used today for interpreting size effects across the scale spectrum, as well as for fitting experimental data on the mechanical behavior of micro/nano-objects (micro/nanopillars, nanobeams, nanotubes).
- *More recently, he enriched the aforementioned gradient models with randomness effects,* in order to assess the competition between deterministic gradients and stochastic terms due to internal stress fluctuations. He was among the first to introduce the techniques of bifurcation, stability and self-organization into the field of material mechanics and continues along these lines by introducing new tools recently developed in the field of nonlinear and statistical physics. As examples, reference is made to his recent articles on non-extensive thermodynamics and Tsallis q-statistics, as well as on fractional calculus and fractal media for characterizing deformation, damage and failure of nanocrystalline (NC) and ultrafine grain (UFG) materials, as well as bulk metallic glasses (BMGs). Most recently, he has considered *gradient multiphysics couplings* (gradient thermo-chemo-mechanics and opto-electro-mechanics) for these novel "structural" materials and extended his work to encompass "energetic" materials, including "defect-free" nanolayers for next generation light emitting diodes (LEDs) and "strain relief" nanostructured electrodes for rechargeable Li-ion batteries (LiBs). He is also exploring the applicability of these techniques for addressing the mechano-chemo-electrical response of neural cells/neurons.
- *The above research activity was carried out in collaboration* with former students and postdocs, as well as senior scientists in the US, Europe, Russia and China. Co-authors include profound *mathematicians* (Jim Serrin/Minnesota, James Hill/Australia, Vasily Tarasov/Moscow), mechanicians (Gerard Maugin/Paris, Rene de Borst/Glasgow-Delft, Hans Muhlhaus/Germany), *physicists* (Daniel Walgraef/Brussels, Alexey Romanov/St. Petersburg, Jeff de Hosson/The Netherlands), and *materials scientists* (Bill Gerberich/Minnesota, Ladislas Kubin/France, Yuri Estrin/Australia). A number of leading material mechanics contributors in academia have been his students (Doug

Bammann/Mississippi, Hussein Zbib/Washington, Ioannis Chasiotis/Urbana) or postdocs (Harm Askes/Sheffield, Mike Zaiser/Edinburgh-Erlangen, Alexey Romanov/St. Petersburg, Chongqing Ru/Alberta, Michail Gutkin/St. Petersburg).

- *In the last five years* major funding of ~ 3 million Euros has been awarded to his Lab through the European Research Council (ERC) and the Greek General Secretariat of Research and Technology (GSRT) to establish an International Research Center on "Materials and Processes across Scales and Disciplines" at the Aristotle University of Thessaloniki (AUT), even though this effort is currently facing difficulties due to local financial constraints imposed on the country. Nevertheless, nonlocal interactions with US (Civil Engineering and Engineering Mechanics at the University of Arizona), China (State Key Lab of Nonlinear Mechanics of the Chinese Academy of Sciences and Beijing University of Civil Engineering and Architecture), Russia (International Lab of Modern Functional Materials at ITMO University, St. Petersburg), are successfully carried out, in addition to former collaborations with EU Laboratories.

■ **Research Milestones / Impact**

- *In the mid 1970's* – while at the Dept of Theoretical and Applied Mechanics of the Univ of Illinois at Urbana – ECA started with his students the effort of bringing into the field of solid mechanics ideas from diffusion theory, chemical reactions, and nonlinear physics. They developed "stress-assisted diffusion" theories with applications to hydrogen embrittlement and stress corrosion cracking, "double diffusivity and 2-temperature" theories for modeling simultaneous transport in the bulk and grain boundaries of polycrystals, as well as "double porosity" theories for modeling fluid flow in undeformable and deformable fractured rocks with applications to consolidation and subsidence. This initial work on internal mass transport motivated the concept of viewing a stressed solid at the macroscale as an active medium whose deformation is governed by the production/annihilation and transport of defect populations (dislocations, disclinations), which interact with the defect-free material regions according to the laws of microscopic physics. His robust and inspiring models of gradient dislocation dynamics and gradient plasticity that became quite popular later on, were essentially based on the above idea.
- *In the early 1980's* (jointly with Jim Serrin), while at the University of Minnesota, he revisited Maxwell's equal area rule and van der Waals theory of fluid interfaces within a strictly mechanical framework by incorporating higher order density gradients in the non-monotonous constitutive expression for the interfacial stress tensor. Among the results were the relocation of Maxwell's line (i.e. the establishment of non-universality of Maxwell's rule for liquid-vapor transitions) and the derivation of transition, reversal and periodic solutions for fluid/solid microstructures. This work motivated, in part, a number of articles in applied mathematics (Coleman, Gurtin, Slemrod, Truskinovski and others) in the area of non-convex free energy and continuum phase transitions.
- *In the mid 1980's* (jointly with Daniel Walgraef), while at Michigan Tech, he developed the first generation models to interpret self-organization of dislocations and deformation patterning. The Walgraef-Aifantis (W-A) model was the first to predict widths and spacings of the layered dislocation structure of the persistent slip bands observed in fatigued crystals as discussed, for example, in Chapter 6 of the Nobel Laureate's Ilya Prigogine's book "Exploring Complexity", Freeman, New York (1989). This work inspired a steady stream of follow-up efforts on dislocation patterning, including recent papers on discrete and density-based dislocation dynamics simulations (e.g. Kubin, Ghoniem, Zbib, Groma, El-Azab, Zaiser, Ngan and others). Most notably, the W-A model has recently been used by leading geophysicists/geomechanics researchers to interpret crack patterns in granular materials (A. Ord and B. Hobbs, Fracture pattern formation in frictional, cohesive, granular material, Phil. Trans. R. Soc. A 368, 95-118, 2010 [One contribution of 17 to a Theme Issue "Patterns in our Planet: Applications of Multi-scale Non-equilibrium Thermodynamics to Earth-system Science"]).
- *In the mid and late 1980's*, while at Michigan Tech, he proposed the first gradient plasticity model to predict the thickness of shear bands and eliminate the mesh-size dependence of finite element (FE) calculations in the strain softening regime. This was used in FE codes developed by de Borst, Tomita and others to solve large-scale engineering problems for which classical plasticity did not work. Other gradient plasticity models, such as those proposed by Fleck/Hutchinson, Nix/Gao/Huang and co-workers, were developed later in the mid - and late – nineties, and a large number of distinguished researchers (Fleck/Willis, Anand/Gurtin, Geers/Peerlings,

Estrin/Sluys,Voyiadjis, Polizzotto, Forest to mention a few) made seminal contributions in this area for interpreting size effects and other phenomena at the micron scale.

- *In the early and mid 1990's* – in collaboration with his experimental colleagues at Michigan Tech (Walter Milligan and Steve Hackney) – he directed a project on nanostructured materials and "coined" the term "nanomechanics" as he did earlier with "dislocation patterning" and "material instabilities". They identified, theoretically and experimentally, the critical grain size regime where plasticity transition occurs from grain rotation/sliding in the absence of dislocation activity to intragranular avalanche-like dislocation motion. This mechanism has also been numerically confirmed by molecular dynamics (MD) simulations later performed by Swygenhoven's group at PSI-Switzerland. For bulk ultrafine and nanograin materials they discovered another plasticity transition mechanism controlled by "multiple" or "massive" shear banding without any hardening, not observed for the conventional grain size counterparts of these materials which are always strain-hardened. These micro/nanoplasticity mechanisms are now routinely observed in nanocrystalline (NC) and ultrafine grain (UFG) materials produced by severe plastic deformation (SPD), as well as in bulk metallic glasses (BMGs).
- *Since 2000*, while at Aristotle University of Thessaloniki, he continued with students and postdocs by employing his earlier work on gradient elasticity and plasticity to address some key-unresolved issues in mechanics. They expanded on dislocation and crack non-singular solutions (previously derived with his co-workers Altan, Gutkin, Ru et al) by deriving new robust and easy-to-use expressions for the local microscopic stresses and strains on the basis of his simple gradient elasticity (GradEla) model – a topic which has recently become popular in Greece (Vardoulakis, Beskos, Exadaktylos, Georgiadis, Aravas, Giannakopoulos) and elsewhere (EU, US, China), since Mindlin's original but complex work which remained dormant for 30 years. Work also focused on dislocations/disclinations and cracks/interfaces, as well as nanomaterials including nanotubes and nanomembranes. Gradient multi-element defect kinetics were used to capture mechanical behavior at the nanoscale and obtain stability and defect patterning results for thin films and small volumes. Wavelet analysis and neural networks were used for bridging the length scale spectrum. Main senior collaborators in this area included A. Romanov / I. Ovid'ko (St. Petersburg, Russia) on defect theory; A. Carpinteri / N. Pugno (Torino, Italy) on fractals and size effects; S. Forest (Ecole des Mines, France) and P. Steinmann (Univ of Erlangen, Germany) on gradient plasticity; H. Askes (Univ of Sheffield) and M. Lazar (Tech Univ of Darmstadt)/G. Maugin (Univ of Paris VI) on gradient elasticity; M. Zaiser (Univ of Edinburgh/Erlangen-Nürnberg) on stochastic dynamics/avalanches and random plasticity; I. Groma (Eotvos Univ Hungary) on discrete dislocation dynamics, and I. Vardoulakis (NTU-Athens, Greece) on soil mechanics and granular media.
- *Since 2005*, with his students and postdocs, he used variants of his earlier gradient elasticity and plasticity models to interpret the deformation/fracture behavior and size effects observed during microtensile, microbending and micro/nanoindentation tests. The results compared very well with corresponding molecular dynamics (MD) and discrete dislocation dynamics (DDD) simulations for such micro/nano-objects (MEMS/NEMS, micro/nanobeams, micro/nanoplates). They provided support of Nobel Laureate's Richard Smalley (*American Scientist 85, 324, 1997*) quotation "The Laws of Continuum Mechanics are amazingly robust for treating even intrinsically discrete objects only a few atoms in diameter" by *replacing* "Continuum Mechanics" with "*Gradient* Continuum Mechanics".
- Since 2008 his Lab activities were expanded to consider advanced energy materials/components, such as light emitting diodes (with A. Romanov) and Li-ion batteries/LiBs (with K.E. Aifantis). This became possible through a Marie-Curie Senior Fellowship (A. Romanov) on *Nanomechanics of Defects in Solids* with applications to thin films, nanoparticles, nanocrystals and biomaterials and an ERC-Starting Grant (K.E. Aifantis) on *Probing the Micro-Nano Transition/MINATRAN*, respectively. The major equipment that was purchased to conduct nanoindentation (NI) and atomic force microscopy (AFM) studies for the above projects, was also used to initiate research on polymeric and hydrophobic/hydrophilic materials for monument protection/cultural heritage preservation, as well as for novel mechano-electro-chemical studies on neural cells.
- Since 2012 collaborations have been extended to include *fractional derivatives and fractal media* (jointly with V. Tarasov at Moscow State University), *zonal disintegration in deep underground tunnels* (jointly with C. Qi at Beijing University of Civil Engineering and Architecture) and, most recently, *neuromechanics and medical imaging* (jointly with neurologists at AUT and Karolinska – work in progress).

2015 :: SUSTAINABLE INDUSTRIAL PROCESSING SUMMIT & EXHIBITION

Prof. E. AIFANTIS

AIFANTIS INTERNATIONAL SYMPOSIUM

Multiscale Mechanics and Multiphysics of Solids Across Materials, Processes and Scales.

Generalized Continuum Mechanics; Gradient Elasticity; Gradient Viscoelasticity; Gradient Plasticity; Gradient Damage; Nanomechanics; Material Instabilities; Defects in Solids; Diffusion in Solids; Phase Transformations in Solids; Dislocation Patterning; Shear bands, Twins, Size Effects; Metals, Polymers, Ceramics; Soils, Rocks, Concrete; Novel Materials, Thin Films; Electronic, Magnetic, Thermoelectric, Photonic Materials; Cellular Materials, Metallic Glasses; Nanomaterials, Nanocomposites; High Density Energy Storage Materials; Biomaterials, Bio-inspired Materials; Material Fabrication / Forming Mechanics; Experimental Mechanics; Fracture Mechanics; Computational Mechanics; Stochastic Mechanics; Geomechanics; Biomechanics; Thermomechanics; Chemomechanics; Electromechanics; Magnetomechanics; Optomechanics; Discrete vs. Continuous Media Modeling; Fractal Media, Fractional Material Mechanics

Nobel Laureates Opening Event

Technological Entreprenership

Metals Helping Life

Dan SHECHTMAN
2011
Nobel Prize in Chemistry

Ei-ichi NEGISHI
2010

4 - 9 October 2015,
Cornelia Diamond
Antalya, Turkey

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STAR OUTREACH

Florian Kongoli
CEO & President
Flogen Technologies
Canada / USA

Stephane Bordas
Professor
Univ. of Luxembourg
Luxembourg

Yuri Estrin
Professor/Director
Monash Univ.
Australia

Check Website for important dates

Summit WebSite: www.flogen.org/sips2015 **Contact**: Dr Florian Kongoli(fkongoli@flogen.org)
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SIPS 2015 tackles key sustainability issues

In early October 2015, the excellent SIPS 2015 (Sustainable Industrial Processing Summit) was held in Antalya, Turkey. *Copper Worldwide* attended the event, which included many key presentations and discussions on state of the art non-ferrous metal processing technologies. The level of awareness of the global climate situation, the detail and length to which speakers at this event had prepared, and the active engagement of the 500 or so delegates, were testament to the ability of organiser Flogen Star Outreach, in particular Dr. Florian Kongoli. The aim of SIPS 2015, as with previous well-attended Flogen Symposia, was to bring together and invigorate a diverse and talented global Scientific Community under a common purpose, that of furthering the technological innovation in resource processing and stewardship.

Dr. Florian Kongoli presenting Lord John Prescott with the 2015 Shechtman International Leadership Award (Photo: Flogen)

The Sustainable Industrial Processing Summit incorporated 23 symposia covering the entire cycle of metals and materials science from mining, extraction, processing, manufacturing, recycling, waste treatment, environmental, health, legal, management, policy, taxation and social issues. Five symposia were dedicated to the lifetime achievements of:

- *Prof. Elias Aifantis* – 2015 honoree with Aifantis International Symposium on Multiscale Material Mechanics and Multiphysics and Sustainable Applications
- *Prof. Heinrich Wilhelm Gudenau* – 2015 honoree with Gudenau International Symposium on Sustainable Iron and Steel Making
- *Prof. John Meech* – 2015 honoree (postmortem) with Meech International Symposium on Sustainable Mining Operations
- *Prof. Cyro Takano* – 2015 honoree with Takano International Symposium on Sustainable Metals & Alloys Processing
- *Prof. Andrey V. Vanyukov* – 2015 honoree (postmortem) with Vanyukov International Symposium on Sustainable Non-ferrous Smelting and Processing

The honorees cover areas of materials sciences that look distinct but are actually related to each other and all have in common sustainability. Plenary sessions included presentations from many scientific personalities and among them a presentation from 2011 Nobel Laureate in Chemistry, Prof. Dan Shechtman about the challenges of materials science and engineering, a presentation of 2010 Nobel Laureate in Chemistry, Ei-ichi Negishi about the help that metals give to organic life, as well as a powerful address from Lord John Prescott, House of Lords UK, about his view of sustainability issues.

Key SIPS 2015 speakers were (l to r) Prof. Aifantis, Lord John Prescott, Ei-ichi Negishi, Prof. Gudenau, Prof. Dan Schechtman, Prof. Takano, with Dr. Florian Kongoli, Organiser

During the event the winners of two FLOGEN AWARDS were announced. The 2015 Fray International Sustainability Award went to: Ei-ichi Negishi, Purdue University, USA, 2010 Nobel prize in Chemistry; Elias Aifantis, Michigan Tech. University USA and Aristotle University, Greece; Cyro Takano, University of Sao Paulo, Brazil; Heinrich W. Gudenau, RWTH Aachen Germany; and Queiroz Galvão Group, Brazil. The 2015 Shechtman International Leadership Award went to Lord John Prescott, House of Lords, UK (Deputy Prime Minister of UK, 1997-2007).

Many previous FLOGEN AWARDS winners have got further subsequent high recognition. They include:

- Stephane Dion, recipient of FLOGEN 2011 Fray International Sustainability Award in the category of politics, who recently became Foreign Minister of Canada.
- Oscar Gonzalez Rocha, CEO of Southern Copper Corporation, recipient of FLOGEN 2014 Fray International Sustainability Award in the category of corporations, was honoured in 2015 as Copper Man of the Year and received the Ankh Award from The Copper Club in New York City.

Supporters of FLOGEN, NASA Astronaut Hon. Marc Garneau and Justin Trudeau became in 2015 Minister of Transport and Prime Minister of Canada respectively.

Many positive comments were received about SIPS 2015, including from Prof. Brajendra Mishra (AIME, TMS) – "One of the most well-organised meetings I have attended", and Julien Rethore, INSA Lyon – "My best conference this year". The SIPS 2016 venue is being decided during November 2015 and will be announced shortly.

www.flogen.org/sips2015/