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Preface

Preface – Ares J. Rosakis

This special issue of JMPS is meant to celebrate the contributions of Professor Ares J. Rosakis to the field of mechanics of solids and structures on the occasion of his 60th birthday. It is a collection of articles contributed by distinguished researchers who have had association with Professor Rosakis as colleagues, students, postdocs or collaborators. Throughout his distinguished career, Professor Rosakis has been a much admired teacher, a mentor and a friend to all who worked with him. This volume complements the symposium held in his honor at Brown University during September 16-17, 2016. We are grateful to the editors of JMPS for making this special issue possible.

Ares J. Rosakis was born in Athens, Greece on September 12, 1956. Ares Rosakis graduated from Athens College, a Greek-American high school in June of 1975. In September of 1975, he moved to the United Kingdom to attend University College Oxford and to read Engineering Science. He received both his bachelor's (B.A.) and Master's of Arts (M.A.) degrees from Oxford University. He went on to obtain his Sc.M. (1980) and Ph.D. (1982) degrees in Engineering (solid mechanics and structures) from Brown University. He joined the California Institute of Technology (Caltech) as an assistant professor in 1982. He was promoted to the ranks of associate and full-professor in 1988 and 1993 respectively. In 2004, he was named the "Theodore von Kármán Professor" of Aeronautics and Professor of Mechanical Engineering.

Between 2009 and 2015, he served as the Chair of the Division of Engineering and Applied Science (EAS) at Caltech. In June 2013, Rosakis was also named the *F. Otis Booth Leadership Chair (2013-2015)* in addition to his academic, *Theodore von Kármán, Chair*. Rosakis was the first holder of the Otis Booth Leadership Chair at the Institute.

Prior to being the Division Chair, of EAS, he served as the fifth Director of the historic Graduate Aerospace Laboratories (GALCIT) formerly known as the Guggenheim Aeronautical Laboratories (Interim Director 2003-2004, Director 2004-2009).

In 2005, Rosakis was a *Distinguished Visiting Professor* in the Dept. of Terre Atmosphére-Océan, École Normale Supérieure Paris, France. In 2008, he held the *Astor Visiting Professorship* at the University of Oxford. In early 2018 he held the *Distinguished Simpson Visiting Professorship* at Northwestern University and a *Distinguished Nanyang Visiting Professorship* at Nanyang Technological University (NTU) in Singapore.

Ares Rosakis' work has always been highly interdisciplinary in nature and sits at the interfaces between Engineering, Technology and Science. It has focused on applying the principles of fundamental solid mechanics and material's reliability to various disciplines within engineering (Aerospace, Mechanical and Civil Engineering) and related sciences such as Materials Science and Earthquake Seismology. As such his work has resulted in both scientific discoveries and practical de-

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velopments that have helped invigorate the field of fracture and failure mechanics and have highlighted its importance in both science and modern engineering practice.

Rosakis' research interests span a multitude of length and time scales ranging from sub-μm (reliability of thin films) to $10^5 m$ (earthquake fault rupture lengths) and from nano-seconds (hypervelocity impact in space) to years (creep fracture and tectonic processes). In particular, Rosakis has contributed to a wide spectrum of research areas including the experimental, theoretical and numerical study of materials reliability, the mechanics of fracture and the dynamics of stain localization in all length and time scales.

Rosakis' earlier work concentrated on the study of dynamic fracture of metals and resulted in the first comprehensive formulation of dynamic crack initiation, crack growth and crack arrest criteria in solids of relevance to engineering practice (metals, metallic glasses, ceramics, polymers bi-materials and composites). From the purely experimental instrumental point of view, Rosakis has invented a number of optical diagnostic techniques and designed multiple diagnostic instruments both in the visible and infra-red wavelength range and has successfully combined them with ultra-high speed photography (100 million frames/s) and high-speed infrared thermography (1 million frames/s) to study previously unexplored dynamic fracture and adiabatic strain localization problems. In parallel to his experimental efforts, he has developed an array of analytical and computational models for analyzing dynamic fracture and localization phenomena, which have resulted in fundamental advances towards understanding highly dynamic failure processes in solids.

In the mid-1980s, he invented a new full-field optical technique, the Coherent Gradient Sensor method, or CGS. CGS is a shearing, laser interferometer sensitive to gradients of surface topography, when used in a reflection mode, and gradients of refractive index, when used in a transmission mode. Rosakis designed and fabricated the first CGS interferometer and applied this method to the study of dynamic interfacial fracture of bonded solids with applications to composite materials and modern sandwich structures. He made singular contributions to this field, including the scientific discovery of shear dominated, *transonic de-bonding* in various layered systems and composites of Engineering significance (*Transonic de-bonding fracture fronts are defined as those propagating at speeds above the lowest of the shear wave speeds of the composite and as fast as the highest of the pressure wave speeds of the layered system*). He also applied CGS and high-speed photography to the study of impact and fragmentation of ceramics and brittle polymers and to the investigation of *hypervelocity impact phenomena* of relevance to the study of micrometeorite impact on space structures and the protection of space assets from space debris.

One of the most notable practical applications of CGS pioneered by Rosakis is the application of this method to the study of the reliability of thin-film structures and thin-film problems. This has included the design of an industrial level CGS instrument for the *in-situ* wafer measurement and the real-time optical monitoring of large, 300 mm, production wafers during processing. This invention has resulted in a venture-capital funded, *Caltech/MIT spin-off company, called "Oraxion Diagnostics"*, which has generated considerable enthusiasm in microelectronics and opto-electronics industry. This Startup was co-founded with Subra Suresh, the new President of NTU Singapore and then Dean of Engineering at MIT. Major industry players such as Intel, Semetech and Applied Materials in addition to various fabrication facilities in Taiwan and Singapore have used the resulting instruments as a tool for yield management. In 2006, Oraxion Diagnostics was acquired by Ultratech, a leader in semiconductor processing and metrology equipment. In addition to developing CGS interferometry for wafer inspection and measurement during various processing steps, Rosakis and Subra Suresh, also developed theoretical micromechanics models to be used in the analysis of the CGS interferograms. The combined use of such models with the CGS measurements allowed for the accurate inference of thin-film stresses in the micron and sub-micron scale, in the presence of film thickness non-uniformities in multiple layers and three-dimensional patterning. It was the combination of these patented Experimental and analytical technologies that enabled the successful commercialization of the CGS based Diagnostics wafer inspection system, now a standard inspection tool in the microelectronics and optoelectronics industry. In the same time period, Rosakis and his co-workers designed and fabricating the fastest existing high speed, full-field, microprobe infrared thermal camera (1 million frames/second), which was applied to the real-time study of dynamically growing shear bands with implications for high speed machining and penetration mechanics. Both these inventions have been granted a total of *13 U.S. patents*.

In the 1990s, Rosakis' work on the dynamic fracture of heterogeneous and layered solids attracted considerable international attention from both the geophysics and the earthquake seismology communities. Of particular interest to these communities was a section of his work related to the *Transonic Rupture* of impact-loaded, frictionally held interfaces, separating similar and dissimilar materials. Extending this work to the study of earthquake source physics, he introduced the concept of "*Laboratory Earthquakes*" and developed a unique, highly instrumented laboratory facility, which reproduces the physics governing rupture dynamics of crustal earthquakes. In this body of work, he designed experiments that closely mimic earthquake rupture in various controlled settings. Through these experiments, he was able to discover that even naturally nucleated earthquake ruptures may propagate with *super-shear speeds* (*speeds in excess of the bulk shear wave speed of the surrounding crustal rock*). He also conclusively proved that certain historically large earthquakes indeed transitioned to *Super-Shear,* and explained the unusual ground–shaking signatures characteristic of such catastrophic events.

Rosakis' experiments and laboratory discoveries have also helped resolve a number of additional cutting-edge problems and paradoxes in earthquake source physics and mechanics, including the "directionality of rupture growth" in heterogeneous faults, the mechanism of creation of "off-fault damage", the selection between "pulse-like" or "crack-like" modes in earthquake slip, and the possibility of "fault opening" at the earth's surface during certain thrust fault earthquakes. These discoveries proved to be of particular interest to the geophysical community and resulted in symposia at professional meetings in both engineering and geophysical societies such as the American Society of Mechanical Engineers (ASME), the

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