

The Minerals, Metals & Materials Series

T. S. Srivatsan · Yuzheng Zhang
W. C. Harrigan, Jr.
Editors

Metal-Matrix Composites Innovations, Advances and Applications

An SMD Symposium in Honor
of William C. Harrigan, Jr.

TMS

 Springer

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Preface

The development, emergence, and proliferation in the use of metal-matrix composites have shown a noticeable increase in recent years, often replacing the heavier monolithic materials for use in a spectrum of performance critical and nonperformance critical applications. The high demand for these composites is also seen in the industries spanning air transportation, ground transportation, defense-related products, and even a plethora of commercial products to include sporting goods. To explore the growth of knowledge on aspects related and relevant to composite materials research, development, emergence, and use in appropriate applications and to concurrently promote communication with specific reference to innovations, advances, and applications of metal-matrix composites, this international symposium was held in honor of Dr. W. C. Harrigan, Jr., to bring to light his outstanding contributions resulting from dedicated, diligent, and dynamic contributions in the domains spanning processing, characterization, property evaluation, failure analysis, applications, and even large-scale commercialization of the family of metal-matrix composites. Appropriately, this symposium was given the title “Metal-Matrix Composites Innovations, Advances and Applications” and was held during the TMS 2018 147th Annual Meeting & Exhibition in Phoenix, Arizona, USA, March 11–15, 2018. This symposium was well represented with abstracts from the United States and international engineers and scientists from academia, research laboratories, and industries. This volume contains many of the papers presented in the five-session symposium, sponsored by the Composite Materials Committee and Structural Materials Division of The Minerals, Metals & Materials Society (TMS). Over 35 abstracts were approved for presentation (both oral and as posters) in the five sessions:

- Session 1: Aluminum and Lightweight Metal Matrix Composites
- Session 2: Synthesis and Developments of Emerging Composites
- Session 3: Basic History and Advances in Metal Matrix Composites
- Session 4: Mechanical Behavior of Metal Matrix Composites
- Session 5: Poster Presentation

In the four oral sessions, recent advances in composite materials processing, characterization, properties, and modeling specifically for aerospace, marine, land applications, and commercial products were presented. Each presenter brought new knowledge and ideas to the symposium, and we, the symposium organizers, extend our warmest thanks and appreciation to the presenters and participants. We also extend our most sincere thanks and appreciation to the elected and governing representatives of the Composite Materials Committee and Structural Materials Division of TMS for their understanding and acknowledgment of our interest, and timely approval of our request to organize this intellectually stimulating symposium.

Unbounded gratitude and valued appreciation and applause, having resonating significance, are also extended to the following individuals:

- (i) **Ms. Trudi Dunlap** (TMS Manager of Events, Education & Exhibitions) for her sustained attention, assistance, interest, involvement, and timely participation stemming from understanding. Ms. Dunlap ensured a timely execution of the numerous intricacies related to both orchestration and layout of this symposium from the moment following its approval through the compilation and publication of this proceedings publication.
- (ii) Special thanks and much deserved appreciation is extended to **Ms. Patricia Warren** (TMS Programming and Proceedings Specialist) for her patience, understanding, and much valued and desired attention to all the specifics and intricacies, far too many to list, from conception to completion by way of compilation and presentation of this volume.
- (iii) The timely publication of this bound volume would not have been possible without the cooperation of the authors and the publishing staff headed by the dedicated TMS Content Senior Manager, **Mr. Matt Baker**.

We hope that this volume will provide all the readers, to include both the experienced and the new entrant, new perspectives and directions in their research efforts in the domain of research on metal-matrix composites. The growth and demand of metal-matrix composites will only show continuing upward trend, and we do hope that by putting together this monumental symposium, we have tried to both aid and assist aerospace, ground transportation, and industries dealing with commercial products in engineering the safe development and eventual use of metal-matrix composites for potentially viable applications.

Dr. T. S. Srivatsan
Dr. Yuzheng Zhang
Dr. W. C. Harrigan, Jr.

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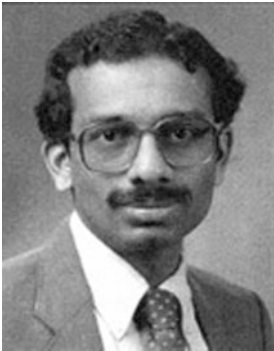
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About the Editors



T. S. Srivatsan is a Professor of Materials Science and Engineering in the Department of Mechanical Engineering at The University of Akron. He received his graduate degrees [Master of Science in Aerospace Engineering (M.S. 1981) from Georgia Institute of Technology and Doctor of Philosophy in Mechanical Engineering (Ph.D. 1984)] from Georgia Institute of Technology. Dr. Srivatsan joined the faculty in The Department of Mechanical Engineering at The University of Akron in August 1987. Since joining, he has instructed undergraduate and graduate courses in the areas of (a) Advanced Materials and Manufacturing Processes, (b) Mechanical Behavior of Materials, (c) Fatigue of Engineering Materials and Structures, (d) Fracture Mechanics, (e) Introduction to Materials Science and Engineering, (f) Mechanical Measurements, (g) Design of Mechanical Systems, and (h) Mechanical Engineering Laboratory. His research areas currently span the fatigue and fracture behavior of advanced materials to include monolithic(s), inter-metallic, nano-materials, and metal-matrix composites; processing techniques for advanced materials and nanostructure materials; the interrelationship between processing and mechanical behavior; electron microscopy; failure analysis; and mechanical design. He has authored/edited/coedited fifty-nine (59) books and four (4) monographs in areas cross-pollinating mechanical

design; processing and fabrication of advanced materials; deformation, fatigue, and fracture of ordered intermetallic materials; machining of composites; failure analysis; and technology of rapid solidification processing of materials. He serves as coeditor of *International Journal on Materials and Manufacturing Processes* and on the editorial advisory board of five journals in the domain of materials science and engineering. His research has enabled him to deliver over two hundred and twenty (220+) technical presentations in national and international meetings and symposia. He has authored and coauthored over seven-hundred (700+) archival publications in international journals, book chapters, proceedings of national and international conferences, book reviews, and technical reports. In recognition of his efforts and contributions and their impact on furthering science, technology, and education, he has been elected

- (a) Fellow of the American Society for Materials, International (ASM International);
- (b) Fellow of American Society of Mechanical Engineers (ASME); and
- (c) Fellow of American Association for the Advancement of Science (AAAS).

He has also been recognized as (i) Outstanding Young Alumnus of Georgia Institute of Technology, (ii) Outstanding Research Faculty of the College of Engineering [The University of Akron], and (iii) Outstanding Research Faculty at The University of Akron. He offers his knowledge in research services to the National Research Laboratories and industries related to aerospace, automotive, power generation, leisure-related products, and applied medical sciences.



Yuzheng Zhang is Lead Materials Scientist at Gamma Alloys, LLC. Other current positions include Visiting Scholar at the USC Composites Center.

Dr. Zhang received his Ph.D. in Materials Science from the University of Southern California (USC) in 2015, M.S. in Materials Science from USC in 2010, and B.S. in Physics from Fudan University (China) in 2008.

Prior to joining Gamma, Dr. Zhang worked as a Research Scientist at Nextgen Aeronautics, developing flexible strain sensor arrays. At Gamma, he continues his interest in processing and characterizing aluminum-based MMCs, and studying fundamental strengthening mechanisms in nanocomposites.



William C. Harrigan, Jr. received a Ph.D. in Materials Science from Stanford University. He received a Master of Science from Stanford University and a Bachelor of Science in Metallurgical Engineering, Cum Laude, from the University of Notre Dame. Dr. Harrigan is the CTO of Gamma Technology which is a commercial manufacturer of metal matrix composites. Dr. Harrigan worked at the Aerospace Corporation where he developed graphite fiber reinforced aluminum and other metal composites. He worked at DWA Aluminum Composites where he helped to develop hardware made from graphite/metal composites and particle reinforced aluminum composites. Dr. Harrigan helped three companies qualify an aluminum matrix composite for use in nuclear spent fuel storage: Alyn Corporation, DWA Technologies, and Ceradyne, Inc. He also managed programs to commercialize metal matrix composite automobile engine components and recreation products. He has also consulted with several companies that are developing new manufacturing methods for aluminum matrix composites. Dr. Harrigan has taught classes in design with composites at the University of California, Irvine, and California State University, Northridge.

In 1985, Dr. Harrigan was the chairman of the International Conference on Composite Materials V, held in San Diego California. He was honored as a Fellow of ASM International in 1999 with the citation for commercialization of metal matrix composites.

While working at The Aerospace Corporation, he was awarded US Patent 4,223,075 for alloy modification for graphite fiber reinforced aluminum composites. At Alyn Corporation, he received two patents for use of metal matrix composites for computer disk drive substrates, 5,948,495 and 5,895,696.