

# **MECHANICAL PROPERTIES RESEARCH LABORATORY (MPRL)**

1995-1996 Annual Report

Prepared by:

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Participating Units:

School of Aerospace Engineering  
G.W. Woodruff School of Mechanical Engineering  
School of Materials Science and Engineering

## MPRL STATUS & SUMMARY OF 1995-1996 ACCOMPLISHMENTS

The Mechanical Properties Research Laboratory (MPRL) has been in existence for over a decade. Dr. D.L. McDowell of the Woodruff School of Mechanical Engineering has served as Director of the MPRL since October 1992, and previously served as Associate Director since 1983. He received a joint appointment with the School of Materials Science and Engineering in Spring 1995. Dr. W.S. Johnson of the School of Materials Science and Engineering, formerly of NASA Langley, was named Associate Director of the MPRL in July 1994.

The MPRL is an interdisciplinary laboratory which supports education and research programs in structural materials. Its principal activities are directed towards the measurement and modelling of the mechanical properties of engineering materials, primarily related to deformation, fatigue and fracture. The MPRL impacts very directly on educational and research programs within the academic units of the College of Engineering. In its role as an interdisciplinary umbrella organization for experimental research in mechanical properties of materials, the MPRL provides a degree of coordination of equipment usage, training and maintenance that would be much more costly to the sum of academic units in the conventional university setting of distinctly controlled single investigator equipment.

The MPRL is administered by the Director, with recommendations from a Faculty Governance Board. The Industrial Advisory Board of the School of Materials Science and Engineering also serves as the Industrial Advisory Board of the MPRL, and meets with the Director and selected MPRL faculty each fall.

Principal activities of the MPRL include:

- ! Fatigue and fracture studies of structural materials, structures and joints
- ! Development of constitutive equations for deformation and damage
- ! Characterization and quantitative analysis of microstructure and damage in engineering materials
- ! Development of life prediction methodologies
- ! Development of improved constitutive models and simulation capability for processing
- ! Durability and degradation of aging materials and structures
- ! Durability of materials used in biomedical applications

Participation includes faculty and students from ME, MSE and AE (Appendix A). New faculty in the MPRL include Drs. Min Zhou and Chris Lynch, Assistant Professors in the GWW School of Mechanical Engineering.

MPRL staff nominally includes:

- ! MPRL Director (10% time)
- ! MPRL Associate Director (5% time)
- ! Technician (40% time)
- ! Secretary (25% time)

! Administrative Assistant (5% time)

The following Table provides data regarding the activities of the MPRL during the past year.

No. Faculty	Published Papers	Presentations	Students Graduated		Major Faculty & Student Awards
			M.S.	Ph.D.	
17	97	61	8	6	18

Approximately \$1.76M was expended during the past year by MPRL faculty in externally sponsored research. This represents the highest annual funding level in the last decade. Appendices B and C list the publications and presentations of participating MPRL faculty from July 1, 1995 to May 15, 1996. Appendix D lists MPRL-related sponsored funding and Appendix E lists major awards bestowed upon participating MPRL faculty in 1995-96. In addition, 5 undergraduate students were involved in research. A total of eight women and four minority students were involved in MPRL research this past year.

MPRL funding in each of the past two years has held fast at a level of \$1.7M, up from \$1.2M two years ago. Faculty participation has increased from 10 to 17 in the same period, and the number of published papers has increased by 60%. This year the MPRL graduated more M.S. (8 compared to 6) and Ph.D. (6 compared to 1) students than in the previous year. These graduation rates are, of course, subject to a certain range of cyclical variation.

MPRL faculty offer a wide range of courses in fatigue, fracture, deformation and damage of engineering materials, mechanics of solids, quantitative image analysis and nondestructive evaluation, and mechanical behavior of materials. The sequence of introductory and advanced applied fracture mechanics courses, cross-listed between ME and MSE, is among the strongest such sequence offered at any U.S. university. A graduate certificate in the Mechanical Properties of Solids is also offered through the MPRL.

### PROGRAM DEVELOPMENT

Over the past few years, the MPRL has played a leading role, in cooperation with the Composites Education and Research Center (CERC), the Materials Council, and various other faculty, in developing proposals with multiple investigators.

The MPRL continues to be actively involved in developing a program on durability models for the NASA initiative on the High Speed Civil Transport.

A major new research thrust involving MPRL faculty is the development of high cycle fatigue models and integration with real-time inspection techniques for critical rotorcraft components. Sponsored by ONR at an overall exceeding \$1.5M/yr, a 3-5 year M-URI in "Integrated Diagnostics" (PI/PD W.O. Winer) involves four MPRL faculty (McDowell, Johnson, Neu and Saxena) and two other universities

(Northwestern and the University of Minnesota). The MPRL-related component is approximately \$230K/yr.

MPRL faculty were critical in the development of the new AFOSR initiative to address basic mechanics and materials issues in high cycle fatigue of polycrystalline and single crystal Ni-base superalloys used in jet engine components. Drs. McDowell and Johnson were invited to attend an AFOSR workshop held June 7, 1995 in Dayton, Ohio in which basic research issues were discussed in order to formulate Air Force research initiatives in high cycle fatigue. Dr. McDowell was an invited lecturer at the workshop in the area of mechanics issues in high cycle fatigue, and upon AFOSR request led the effort to draft a white paper that served as the basis for the AFOSR MURI RFP in late 1995. A collaborative team of Georgia Tech researchers (D. McDowell (PI/PD), W.S. Johnson (co-PI), A. Saxena, R.W. Neu and G. Kardomateas as well as other satellite faculty) and the University of Illinois submitted a white paper and were invited to submit a full proposal by March 20, 1996. The team is awaiting news of the decision in late May 1996. The MPRL expects to play a leading role among U.S. universities in this area.

With a tremendous increase in faculty involvement since 1992, the MPRL has risen to an unprecedented level of research activity. New faculty in 1995-96 include:

1. C. Lynch - Dr. Lynch received his doctorate from the University of California at Santa Barbara and joined the Mechanical Engineering faculty in August 1995. He is focusing on the mechanics of coupled electromagnetic-mechanical effects in fracture of ferroelectric materials, and has a strong background in dynamic testing of materials. He is a recipient of the prestigious ONR Young Investigator Award, and has been requested by the U.S. Air Force to assist in developing their basic research program in ferroelectrics. Dr. Lynch is setting up an experimental research facility to process and study the behavior of ferroelectric materials.
2. M. Zhou - Dr. Zhou received his doctorate from Brown University and conducted post-doctoral work at Cal Tech before joining the Mechanical Engineering faculty in Fall 1995. He has made fundamental contributions to the understanding of dynamic inelastic behavior of single and multiphase materials, including fracture and shear localization, from both experimental and computational modelling perspectives. Dr. Zhou is developing an instrumented gas gun facility, in collaboration with N. Thadhani of MSE, and is also developing several Hopkinson bar test beds.

It is expected that both of these new faculty members will make significant contributions to development of new MPRL facilities in these critical research areas.

## PROGRESS TOWARDS LONG RANGE PLAN GOALS

### Development of a Leading Position in Mechanical Properties Research

The major Center weaknesses which were identified in the 1994 MPRL strategic plan included, in order of priority, lack of equipment and electronic upgrades in the last five years, the lack of block funding, a high percentage of external funding from DoD sources (50%), and lack of breadth of faculty participation. These weaknesses have been addressed on a systematic basis, as discussed next.

#### *Lack of equipment/electronic upgrades:*

MPRL faculty have been responding aggressively to proposal development opportunities for sponsored funding of new equipment. Drs. McDowell and Johnson have co-authored two proposals for major external funding to the AFOSR and the NSF in 1995. Through discussions with the AFOSR, it was felt that prospects were excellent for \$500K in new funds to enhance the MPRL's high temperature environment testing capability; regrettably, the proposal received the wrong zip code from OCA and reached the AFOSR five hours late for consideration. The NSF funded the second proposal, resulting in \$205K of NSF money for electronic and supporting equipment upgrades with an additional \$138K in GT matching funds. In addition, the ONR M-URI and new faculty start-up funds are providing some funding for acquisition of electronic upgrades and small equipment items.

It would appear that with the equipment proposal development efforts, program development by new faculty, and the block-funded ONR MURI program, the MPRL is well on its way to achieving state-of-the-art status in control and instrumentation, a dramatic improvement relative to the situation two years ago.

#### *Lack of block funding:*

The MPRL has taken strong steps towards block funded program development to supplement its solid base of single investigator grants. As previously mentioned, four MPRL faculty (McDowell, Johnson, Neu and Saxena) are involved in the 3-5 year ONR M-URI in "Integrated Diagnostics" (PI/PD W.O. Winer). This program provides on the order of \$230K/yr to the MPRL in support of basic research.

The MPRL expects to play a leading role among U.S. universities in this area in the coming years. A current AFOSR initiative will address basic mechanics and materials issues in high cycle fatigue of polycrystalline and single crystal Ni-base superalloys used in jet engine components. Drs. McDowell and Johnson were invited to attend an AFOSR workshop held June 7, 1995 in Dayton, Ohio in which basic research issues were discussed. Dr. McDowell led the effort to draft a white paper based on this workshop that served as input for the AFOSR MURI RFP. Georgia Tech collaborated with the University of Illinois to develop an invited proposal on this topic to the AFOSR.

In conjunction with an internally funded Focused Research Program in Mechanics and Processing of High Temperature Composites, MPRL faculty are also involved in preliminary discussions with faculty at the Virginia Polytechnic Institute and State University and Clark Atlanta University to collaborate on a possible proposal for an NSF Engineering Research Center (ERC) or similar program in long term durability of composite materials. This effort, led by MPRL faculty Drs. W.S. Johnson and R. Talreja, is in very early stages of development (i.e. feasibility). The combined potential of these three universities in this subject is considered to be outstanding, following exploratory meetings at VPI in early July 1995 and at Georgia Tech

in April 1996.

*High percentage of external funding from DoD sources (50%):*

In our view, this earlier perceived weakness has not materialized as such. The MPRL continues to enjoy strong support from both industrial and defense sectors. If anything, its ties to the defense sector have been strengthened with the ONR M-URI program, involvement of MPRL faculty in strategic planning for both the Army and Air Force, and hiring of new faculty with strong research ties to this sector.

This is no longer a concern in the most recent MPRL strategic plan.

*Lack of breadth of faculty participation:*

Through publicity and recruitment of potential faculty, the MPRL is in the midst of its greatest historical expansion of faculty involvement. The number of participating faculty increased by 70% over the past two years. These faculty are drawn from several disciplines and each brings a different set of skills to the MPRL. This is no longer perceived as a weakness, as we must now deal with the pleasant issues of how to accommodate and assist this wide range of research activity.

Diversity

The faculty of the MPRL have worked consistently to ensure that students in the MPRL represent the diversity of the larger student body, including underrepresented groups. Presently, eight female students and four minority students are conducting graduate research in the MPRL. Moreover, the blend of these students with other students from a wide range of European and Asian ethnicity forms the basis for a truly broad experience. For the MPRL, diversity is the norm rather than the exception.

Graduate Degree Productivity

In view of the size of the MPRL faculty, the Ph.D. production is expected to vary somewhat from year to year, and must be viewed in a time-averaged sense. This year, both M.S. and Ph.D. production was up from the previous year. We are nearing our goal of Ph.D. production but still have work to do on M.S. graduation rates. Faculty expansion should naturally address this issue as new faculty become increasingly active in advisement.

Service and Economic Development

Since additional funds necessary to develop topical lectures and short courses in fatigue and fracture were not allocated in this past budget cycle, activities in this area were somewhat limited in scope. Dr. R. Talreja of AE offered a short course in fatigue of composite materials through the Office of Continuing Education. We anticipate that 1-2 more new short courses may be added during 1996-1997, pending availability of support and participant time. With the internationally acknowledged expertise of core MPRL faculty in experimental fracture/fatigue mechanics, Georgia Tech has a unique opportunity to capitalize on development of such short courses for video/satellite presentation.

## APPENDIX A

### List of MPRL Faculty

Name

E.A. Armanios

A. Gokhale

J. Hampikian

W.C. Hutton

W.S. Johnson

K.V. Logan

C. Lynch

D.L. McDowell

R.W. Neu

B. Park

T.H. Sanders

A. Saxena

T.L. Starr

S.R. Stock

R. Talreja

N. Thadhani

M. Zhou

Affiliation

AE

MSE

MSE

EMORY/ME (adjunct)

MSE

MSE

ME

ME/MSE

ME

MSE

MSE

MSE

MSE

MSE

AE

MSE

ME

**APPENDIX B**

**List of Published Papers**



## **A. Gokhale**

1. Pascal Louis and Arun M. Gokhale: "Application of Image Analysis for Characterization of Spatial Arrangements of Features in Microstructure", **Metallurgical and Materials Transactions-A**, Vol. 26A, PP.1449-1455, 1995.
2. Pascal Louis and Arun M. Gokhale: "Can the Average Particle Size in a Metallographic Plane be Larger Than True Average Particle Size in Three-Dimensional Microstructure?", **Metallurgical and Materials Transactions-A**, Vol.26A, PP. 1741-1744, 1995.
3. W.J. Drury, A.M. Gokhale, and S.D. Antolovich: "Effect of Crack Surface Geometry on Fatigue Crack Closure", **Metallurgical and Materials Transactions-A**, Vol. 26A, PP. 2651-2663, 1995.
4. A.M. Gokhale: "Estimation of Bivariate Size and Orientation Distribution of Microcracks", **Acta Metallurgica et Materialia**, Vol. 44, PP. 475-485, 1996.
5. Pascal Louis and A.M. Gokhale: "Computer Simulation of Spatial Arrangement and Connectivity of Particles in Three-Dimensional Microstructure: Application to Model Electrical Conductivity of Polymer Matrix Composite", **Acta Metallurgica et Materialia**, in press.
6. Lars M. Karlsson and A.M. Gokhale: "Estimating Mean Linear Intercept Length Using the Trisector", **Acta Stereologica**, in press.
7. Viktor Benes, Arun M. Gokhale, and Margarita Slamova: "Unfolding the Bivariate Size-Orientation Distribution Function", **Acta Stereologica**, in press.
8. S. Yang, A. Tewari, and A.M. Gokhale: "An Experimental Method for Quantitative Characterization of Spatial Distribution of Fibers in Composites", in **Proceedings of ASM Symposium "Developments in Materials Characterization Technologies"**, ASM, Materials Park, Ohio, in press.
9. Lars M. Karlsson and Arun M. Gokhale: "Stereological Estimation of Mean Linear Intercept Length in Metallography Using Vertical Sections and Trisector", **Journal of Microscopy**, Submitted.

## **J. Hampikian**

#### Books or Book Articles

1. Elevated Temperature Coatings: Science and Technology II (proceedings of the Symposium on High Temperature Coatings - II, TMS Annual Meeting, Anaheim, CA, Feb. 4-8, 1996), edited by N.B. Dahotre and J.M. Hampikian, TMS.

#### Journal Papers (refereed)

1. J.M. Hampikian, M. Saqib and D.I. Potter, "Improved Oxidation Resistance of Group VB Refractory Metals by Al<sup>+</sup> Ion Implantation," accepted for publication in **Metallurgical Transactions A**, 24 January, 1996.
2. E.M. Hunt and J.M. Hampikian, "The Effects of Yttrium Ion Implantation and Annealing on Sapphire," to be submitted to **Journal of Materials Science**, 1996.

#### Refereed Conference Proceedings

1. M.R. Hendrick, J.M. Hampikian, and W.B. Carter, "High Temperature Oxidation of an Alumina Coated Ni-Base Alloy," to be published in Elevated Temperature Coatings: Science and Technology II (proceedings of the Symposium on High Temperature Coatings - II, TMS Annual Meeting, Anaheim, CA, Feb. 4-8, 1996), eds. N.B. Dahotre and J.M. Hampikian, TMS.
2. E.M. Hunt, J.M. Hampikian and D.B. Poker, "Nanocrystal Formation via Yttrium Ion Implantation into Sapphire," *Mat. Res. Soc. Symp. Proc.* **396**, pp. 403-410 (1995).

#### Non-refereed Conference Proceedings

1. J.M. Hampikian, W.B. Carter, "Combustion Chemical Vapor Deposited Coatings for Thermal Barrier Coating Systems," presented at the Advanced Turbine Systems Annual Program Review Meeting, held at the Morgantown Energy Technology Center (METC), Morgantown, WV, October 17-18, 1995.
2. W.B. Carter, J.M. Hampikian, G.W. Book, M.R. Hendrick, T.A. Polley and D.W. Stollberg, "Combustion Chemical Vapor Deposited Coatings for Thermal Barrier Coating Systems," presented at the Advanced Turbine Systems Materials Workshop, Charleston, SC, February 13-14, 1996.
3. J.M. Hampikian and D.I. Potter, "The Effects of Aluminum Ion Implantation on the Oxidation of Group VB Metals," *The Electrochemical Society Extended Abstracts of the 186th Meeting*, volume 94-2, pp. 813-814.

### **W.C. Hutton**

1. Matava, M.J. and Hutton, W.C. (1995). "A Biomechanical Comparison Between the Central One-Third Patellar Tendon and the Residual Tendon." *British Journal of Sports Medicine* **29**(3), pp. 178-184.
2. Boden, S.D., Schimandle, J.H. and Hutton, W.C. (1995). "An Experimental Lumbar Intertransverse Process Spinal Fusion Model: Radiographic, Histologic and Biomechanic Healing Characteristics." *Spine* **20**(4), pp. 412-420.
3. Silcox, D.H. III, Daftari, T., Boden, S.D., Schimandle, J.H., Hutton, W.C. and Whitesides, T.E., Jr. (1995). "The Effect of Nicotine on Spinal Fusion." *Spine* **20**(14), pp. 1549-1553.
4. Schimandle, J.H., Boden, S.D. and Hutton, W.C. (1995). "Experimental Spinal Fusion with Recombinant Human Bone Morphogenetic Protein-2 (rhBMP-2)." *Spine* **20**, pp. 1326-1337.
5. Riebel, G.D., Boden, S.D., Whitesides, T.E. and Hutton, W.C. (1995). "The Effect of Nicotine on Incorporation of Cancellous Bone Graft in an Animal Model." *Spine* **20**(20), pp. 2198-2202.
6. Horton, W.C., Blackstock, S.F., Norman, J.T., Hill, C.S., Feiertag, M.A. and Hutton, W.C. (1995). "The Strength of Fixation of Anterior Vertebral Screws." *Spine* (in press).
7. Fleming, S.S., Moore, T.J. and Hutton, W.C. (1995). "Biomechanical Analysis of Hindfoot Fusion Using an Intramedullary Rod." (submitted for publication)
8. Waggoner, S.M., Albert, M.J., Bailey, E.J. and Hutton, W.C. (1995). "Intra-articular Calcaneus Fractures: A Biomechanical Comparison of Two Fixation Methods." *Journal of Orthopaedic Trauma* . (in press)
9. Volkman, T., Horton, W.C. and Hutton, W.C. (1995). "Transfacet Screws with Lumbar Interbody Reconstruction - A Biomechanical Study of Motion Segment Stiffness." (submitted for publication)

### **W.S. Johnson**

1. Miller, M.A. Portanova and W.S. Johnson, "Impact Damage Resistance and Residual Property Assessment of [0/±45/90]<sub>s</sub> SCS-6/Timetal 21S" NASA Technical Memorandum 110178, May 1995.
2. Mirdamadi, M. and Johnson, W. S., "Experimental Investigation of [0/90]<sub>2s</sub> SCS-6/Timetal 21S Subjected to Hypersonic Flight Profile Simulation," NASP Contractor Report 1183, April 1995,

pgs. 30.

3. Miller, J. L., Progar, D. J., Johnson, W. S. and St. Clair, T. L., "Preliminary Evaluation of Hybrid Titanium Laminates," *J. Adhesion*, 1995, Vol 54, pp. 223-240
4. Mirdamadi, M. and Johnson, W. S., "Experimental Techniques for Hypersonic Flight Simulation Testing of Titanium Matrix Composites," *Proceeding of the 1994 SEM Spring Conference and Exhibits*, June 6-8, 1994, Baltimore, MD, pp. 679-684.(submitted to *Experimental Mechanics*, *accepted*)
5. Johnson, W.S., Mirdamadi, M., Bakuckas, J. G., Jr, "Damage Accumulation in Titanium Matrix Composites Under Generic Hypersonic Vehicle Flight Simulation and Sustained Loads," *Thermo-Mechanical Fatigue of Materials*, Second Volume, Eds. Verrilli and Castelli, ASTM STP1263, 1996.
6. Johnson, W.S., Miller, J. L., Mirdamadi, M., "Fractographic Interpretation of Failure Mechanisms in Titanium Matrix Composites", *Journal of Materials Science and Engineering*, A200, 1995., pp. 78-88.
7. Bakuckas, J.G. and Johnson, W.S., "Thermal residual Stresses in the Analysis of Fiber-Bridged Matrix Crack Growth in Titanium Matrix Composites," *Journal of Composites Technology and Research*, Vol 18, No 2, April 1996, pp.67-79.
8. Johnson, W. S. "Characterization of Titanium Matrix Composites, Volume VIII - Material Characterization of Titanium Matrix Composites", NASP Technical Memorandum 1199, Vol. VIII, June 1995, pps. 464.

Edited Proceedings:

1. Johnson, W. S., Edward Li, and Miller J.L., "High Temperature Hybrid Titanium Composite Laminates: An Early Analytical Assessment", *Proceedings of the Tenth International Conference on Composite Materials*, Ed. A. Poursartip and K. Street, Woodhead Pub., 1995, V-227 thru 234.
2. Calcaterra, J. R., and Johnson, W.S., "A Comparison of Damage Mechanisms for SCS-6/Timetal 21-S Subjected to Various Thermomechanical Fatigue Cycles", *Proceedings of the Tenth Technical Conference of the American Society of Composites*, Ed Ravi Deo, pp 205-214.

## **D.L. McDowell**

### Refereed Journal articles:

1. McDowell, D.L., "Stress State Dependence of the Cyclic Ratchetting Behavior of Two Rail Steels," *International Journal of Plasticity*, Vol. 11, No. 4, 1995, pp. 397-421.
2. McDowell, D.L., Miller, M.P. and Brooks, D.C., "A Unified Creep-Plasticity Theory for Pb-Sn Solder," *Fatigue of Electronic Materials*, ASTM STP 1153, S.A. Schroeder and M.R. Mitchell, Eds., ASTM, Philadelphia, 1994, pp. 42-59.
3. Miller, M.P. and McDowell, D.L., "The Effect of Stress-State on the Large Strain Inelastic Deformation Behavior of 304L Stainless Steel," *ASME J. Engng. Mater. Techn.*, Vol. 188, No. 1, 1996, pp. 28-36.
4. Adefris, N., Saxena, A. and McDowell, D.L., "Creep-Fatigue Crack Growth Behavior in 1 Cr-1Mo-0.25V Steel I - Finite Element Analysis," *International Journal of Fatigue and Fracture of Engineering Materials and Structures*, accepted for publication, 1995.
5. Adefris, N., Saxena, A. and McDowell, D.L., "Creep-Fatigue Crack Growth Behavior in 1 Cr-1Mo-0.25V Steel II - Crack Growth Behavior and Models," *International Journal of Fatigue and Fracture of Engineering Materials and Structures*, accepted for publication, 1995.
6. Howell, M., Hahn, G.T., Rubin, C.A. and McDowell, D.L., "Finite Element Analysis of Rolling Contact for Nonlinear Kinematic Hardening Bearing Steel," *ASME Journal of Tribology*, Vol. 117, 1995, pp. 729-736.
7. McDowell, D.L., "An Engineering Model for Propagation of Small Cracks in Fatigue," submitted for publication in *Engineering Fracture Mechanics*, May 1995, accepted February, 1996.
8. Lim, T.J. and McDowell, D.L., "Path Dependence of Shape Memory Alloys During Cyclic Loading," *J. Intelligent Mater. Systems and Struct.*, Vol. 6, 1995, pp. 817-830.
9. McDowell, D.L. and Bennett, V.P., "A Microcrack Growth Law for Multiaxial Fatigue," submitted for publication to *Fat. Fract. Engng. Mater. Struct.*, to appear in 1996.
10. Marin, E.B., McDowell, D.L. and Bertonecelli, C., "Models for Compressible Elasto-Plasticity Based on Internal State Variables," to appear in the *International Journal of Damage Mechanics*, 1996.

11. Marin, E.B. and McDowell, D.L., "Associative Versus Non-Associative Porous Viscoplasticity Based on Internal State Variable Concepts," to appear in the International Journal of Plasticity, 1996.
12. Miller, M.P. and McDowell, D.L., "Biaxial Deformation Experiments Over Multiple Strain Regimes," to appear in ASTM Special Technical Publication 1280, 1996.
13. Hall, D.E., Hamilton, B.C., McDowell, D.L. and Saxena, A., "Creep Crack Growth Behavior of Aluminum Alloy 2519: Part II - Numerical Analysis," to appear in the Twenty Seventh Volume, ASTM STP, 1996.

Books or Chapters of Books:

1. McDowell, D.L., "Multiaxial Fatigue Strength," ASM Handbook, Vol. 19 on Fatigue and Fracture, to appear in 1996.

**R.W. Neu**

1. Neu, R. W., "TMF Life and Damage Mechanism Maps for Titanium Matrix Composites," *proc.Int. Symp. on Fatigue Under Thermal and Mechanical Loading*, Petten (N.H.), The Netherlands, May 22-24, 1995.

**B. Park**

1. B. Park, "The Feasibility of Forming Superhard Nitrides by Ion Implantation," *JOM, The Journal of The Minerals, Metals & Materials Society* **47(11)**, 49 (November 1995).
2. C. Uslu, B. Park and D. B. Poker, "Synthesis of Metastable Carbon-Silicon-Nitrogen Compounds by Ion Implantation," *Journal of Electronic Materials* **25**, 23 (1996).
3. D. H. Lee, B. Park, A. Saxena, and T. P. Serene, "Enhanced Surface Hardness by Boron Implantation in Nitinol Alloy," accepted for publication in *J. Endodontics* (1996).
4. C. Uslu, D. H. Lee, Y. Berta, B. Park, D. B. Poker, and L. Riester, "Enhanced Surface Hardness in Nitrogen-Implanted Silicon Carbide," accepted for publication in *Nucl. Instrum. Methods in Phys. Res. B* (1996).
5. D. H. Lee, B. Park, D. B. Poker, L. Riester, Z. C. Feng, and J. E. E. Baglin, "Surface Hardness Enhancement in Nitrogen-Implanted Amorphous Carbon," submitted to *J. Appl. Phys.* (1996).

6. C. Uslu, B. Park and D. B. Poker, "Synthesis and Characterization of a Metastable (SiC)<sub>3</sub>N<sub>4</sub> Phase," *Mat. Res. Soc. Symp. Proc.* **354**, 195 (1995).
7. B. Park, "Synthesis of Metastable Carbon-Silicon-Nitrogen Compounds," *Proceedings of The Second Pacific Rim International Conference on Advanced Materials and Processing* 1043-1048 (The Korean Institute of Metals and Materials, 1995).

### **T.H. Sanders**

#### Journal Papers (refereed)

1. "The Effect of Iron and Manganese on the Recrystallization Behavior of Hot Rolled and Solution Heat Treated Aluminum Alloy 6013," with Richard A. Jeniski, Jr. and Buncha Thanaboonsombut, Metallurgical and Materials Transactions, Vol 27A, 1996, pp. 19-27.

#### Refereed Conference Proceedings

1. "Mechanisms of Formation of Serrated Grain Boundaries in Nickel Base Superalloys", with H. Loyer Danflou, M. Macia and T. Khan, Proceedings of the Eighth International Symposium on Superalloys, 1996, in press.

#### Non-refereed Conference Proceedings

1. "A Study on the Dendritic Growth of Gamma Prime in Astroloy", with M.L. Macia, Heat - Resistant Materials II, Conference Proceedings of the 2nd International Conference on Heat-Resistant Materials, K. Natesan, P. Ganesan and G. Lai, September 11-14, 1995, Gatlinburg, TN., ASM International, pp. 163-170.
2. "Interaction Between Iron and Cooling Rate from the Melt on the Dispersoid Distribution in AA6013" with A. Conte, to be published in the Proceedings of the Fifth International Conference on Aluminum Alloys (ICAA5), in press.

### **A. Saxena**

#### Books:

1. Completed 5 chapters of 13 chapter book entitled, "Nonlinear Fracture Mechanics", to be published by CRC Press

2. A. Saxena and C. Muhlstein, "Fatigue Crack Growth Testing", ASM Handbook, Vol. 19 on Fatigue and Fracture (invited), (in press).
3. R. H. Norris, P. S. Grover, B. C. Hamilton and A. Saxena, "Elevated Temperature Crack Growth", ASM Handbook, Vol 19 on Fatigue and Fracture (invited), (in press).

#### Journal Papers (refereed)

1. P. S. Grover and A. Saxena, "Creep Crack Growth in Power Plant Materials" invited article in Sadhana, Journal of the Indian Academy of Sciences, Vol. 20, Feb. 1995, pp 53-86.
2. P. S. Grover and A. Saxena, "Characterization of Creep-fatigue Crack Growth Behavior in 2.25 Cr-1Mo Steel using  $(C_t)_{avg}$ ", International Journal of Fracture, Vol. 73, 1995, pp 273-286.
3. B. C. Hamilton, D. E. Hall, A. Saxena and D. L. McDowell, "Creep Crack Growth Behavior of Al Alloy 2519: Part I - Experimental Analysis", accepted for publication in Fatigue and Fracture: Twenty Seventh Volume, ASTM, STP (in press).
4. D. E. Hall, B. C. Hamilton, D. L. McDowell and A. Saxena, "Creep Crack Growth Behavior of Al Alloy 2519: Part II - Numerical Analysis, Fatigue and Fracture", Twenty Seventh Volume, ASTM STP (in press).
5. J. Cernyar, A. Saxena and Fan Yang, "Fracture Toughness and Fatigue Crack Growth Behavior of  $(sic)_w$  2024 Al Composites", Journal of Composites Technology and Research, Jan 1996, pp 30-37.
6. Fan Yang, A. Saxena and T. L. Starr, "Oxidation Damage in Nicalon Fiber  $Si_3N_4$  Matrix Composite", Fatigue and Fracture: Twenty Seventh Volume, ASTM STP (in press).
7. Yancy Gill, A. Saxena and J. M. Bloom, "Creep Crack Growth Behavior in SA 106 Carbon Steel", submitted to Journal of Pressure Vessel Technology (1995).

#### Refereed Conference Proceedings

1. R. H. Norris and A. Saxena, "Creep Crack Growth Behavior in Cr-Mo Weldments", Materials Aging and Component Life Extension, EMAS, pp 700-713.
2. A. Saxena, "Fatigue Crack Growth in Elevated Temperature Power-Plant Materials and Components", invited keynote paper in the Proceedings of the conference, Fatigue '96, Berlin, May



1996.

Non-refereed Conference Proceedings

1. A. Saxena, "Life Prediction of Weldments in Elevated Temperature Components", International Workshop on Recent Trends in Welding, Bangalore, India (in press).

**T.L. Starr**

1. Fan Yang, A. Saxena and T. L. Starr, "Oxidation Damage in Nicalon Fiber  $\text{Si}_3\text{N}_4$  Matrix Composite", Fatigue and Fracture: Twenty Seventh Volume, ASTM STP (in press).

**R. Talreja**

1. Saha, R. and Talreja, R., "Constrained Transverse Cracking In Composite Laminates", Advanced Composite Letters, Vol. 4, No.2, pp. 35-40, 1995.
2. Sorensen, B. F. and Talreja, R., "Toughness of Damage Tolerant Continuous Fibre Reinforced Ceramic Matrix Composites", Journal of the European Ceramic Society, Vol. 15, pp. 1047-1059, 1995.
3. Corum, J. M., Simpson, W. A., Sun, C. T., Talreja, R. and Weitsman, Y. J., "Durability of Polymer Matrix Composites for Automotive Structural Applications", Report ORNL-6869, Oak Ridge National Lab., 1995, 176 pages.
4. Talreja, R. and Akshantala, N. V., "Inadequacy in Analysis of Damage Evolution in Composites Using a Micromechanics Approach", To appear in Int J Damage Mechanics.
5. Asp, L. E., Berglund, L. A. and Talreja, R., "A Criterion for Crack Initiation in Glassy Polymers Subjected to a Composite-Like Stress State", to appear in Composites Science and Technology.
6. Asp, L. E., Berglund, L. A. and Talreja, R., "Prediction of Matrix Failure in Transversely Loaded Fiber Composites", To appear in Composites Science and Technology.
7. Asp, L. E., Berglund, L. A. and Talreja, R., "Effects of Constituent Properties on Matrix Initiated Transverse Failure in Polymer Composites", to appear in Composites Science and Technology.
8. Lacy, T. E., Willis, P. A., McDowell, D. L. and Talreja, R., "Crack Patterning Effects in Evolution of Damage", To appear in Int Journal of Damage Mechanics.

9. Talreja, R., "A Synergistic Damage Mechanics Approach to Durability of Composite Systems", Invited General Lecture, To appear in Progress in Durability Analysis of Composite Systems, A. Cardon, Ed., Mechanical Engineering Publications.

### **N.N. Thadhani**

1. S.C. Glade and N.N. Thadhani, "Shock Consolidation of Mechanically Alloyed Ti-Si Powders," Metall. and Materials Trans., 26A, 1995, p.2565.
2. J.-H. Lee, N.N. Thadhani, and H.A. Grebe, "Enhanced Solid-State Chemical Reactivity of Shock-Compressed Ti-C Powder Mixtures," Metallurgical and Materials Transactions, accepted December 1995 (in press).
3. T. Royal, S. Namjoshi, and N.N. Thadhani, "Mechanistic Processes Influencing Shock Chemistry in Ti-Al/Si/B System," Metallurgical and Materials Transactions, accepted January 1996 (in press).

### Refereed Proceedings

1. K. Vandersall and N.N. Thadhani, "Shock Compression Synthesis of B1 type Tantalum Nitride," in Shock Compression of Condensed Matter - 1995, eds., S.C. Schmidt, AIP Press, NY, 1996 (in press).
2. V. Subramanian and N.N. Thadhani, "Reaction Behavior of Shock-Compressed Al and Fe-oxide Powder Mixtures," in Shock Compression of Condensed Matter - 1995, eds., S.C. Schmidt, AIP Press, NY, 1996 (in press).
3. N.N. Thadhani, V. Subramanian, R. Russell, D. Savage, and Y.M. Gupta, "The Influence of Pulse Duration on Shock-Induced Chemical Reaction in Ti-Si Powder Mixtures," in Shock Compression of Condensed Matter - 1995, eds., S.C. Schmidt, AIP Press, NY, 1996 (in press).

### Non-refereed proceedings

1. T.E. Royal and N.N. Thadhani, "Shock-Induced Reaction Behavior of Ti-Si and Ti-B powder Mixtures," in Metallurgical and Materials Applications of Shock Wave and High-Strain-Rate Phenomena, eds., L.E. Murr, K.P. Staudhammer, and M.A. Meyers, Elsevier Science, 1995, pp. 629-636.
2. J.H. Lee and N.N. Thadhani, "Synthesis of TiC Ceramics by "Shock-Assisted Reaction Sintering,"

in Metallurgical and Materials Applications of Shock Wave and High-Strain-Rate Phenomena, eds., L.E. Murr, K.P. Staudhammer, and M.A. Meyers, Elsevier Science, 1995, pp. 637-644.

3. V. Joshi, P.A. Persson, and N.N. Thadhani, "Effect of impurities on transient Heat Conduction in Shock Compaction of Diamond Powders," in Metallurgical and Materials Applications of Shock Wave and High-Strain-Rate Phenomena, eds., L.E. Murr, K.P. Staudhammer, and M.A. Meyers, Elsevier Science, 1995, pp. 37-44.
4. K. Vandersall and N.N. Thadhani, "Synthesis of B1 type Tantalum Nitride by Shock-Compression of Hexagonal Phase Precursors," in Tantalum and its Compounds, TMS Publ. eds. P. Kumar, E. Chen, and E. Lavernia, 1996, (in press).

### **C. Ume**

1. Polsky, Y. and Ume, C., "An Automated System for Temperature Dependent Mechanical Property Measurements," submitted, ASME Journal of Electronic Packaging, 1996.
2. Polsky, Y. and Ume, C., "An Automated System for Temperature Dependent Mechanical Property Measurements," Symposium on Manufacturing for Electronics Industry, ASME International Mechanical Engineering Conference and Exposition, Atlanta, GA, November 17-22, 1996.
3. Fu, C. McDowell, D. and Ume, C., "Tune Integration Procedures for a Cyclic Thermo-visco-plasticity Model for PB-Sn Solder Applications," Symposium on Modeling and Simulation, IEEE 26th ECTC Conference, Orlando, Florida, May 28-31, 1996.

## APPENDIX C

### Presentations

#### A. Gokhale

1. A.M. Gokhale, S. Yang, and A. Tewari: "Characterization of Spatial Arrangements of Features in Microstructures", **Symposium on Developments in Materials Characterization Tech.**, 28th Annual International Metallographic Society Con., Albuquerque, NM, July 23-26, 1995 (*Invited Lecture*).
2. A.M. Gokhale: "Stereological Estimation From Projected Images", **9th International Congress for Stereology**, Copenhagen, Denmark, August 21-25, 1995 (*Keynote Lecture*).
3. A.M. Gokhale: " Estimation of Length From Projected Images", **8<sup>th</sup> International Workshop on Stochastic Geometry, Stereology, and Image Analysis**, Sandbjerg Manor, Denmark, August 27-31, 1995 (*Invited Lecture*).
4. A.M. Gokhale: Three lectures on "Vertical Sections and Vertical Slices" in the short course, **Applications of Unbiased Stereology in Neural Systems**, organized by the School of Medicine, The Johns Hopkins University, at Kent Island, Maryland, October 23-27, 1995 (*Invited Lectures*).
5. A.M. Gokhale and N.U. Deshpande: "Microstructure Based Modelling of Fracture Toughness in Aluminum Alloy 7050", ALCOA Technical Center, ALCOA Center, PA., April 17, 1995 (*Invited Seminar*).
6. A.M. Gokhale: "Applications of Digital Image Analysis for Characterization of Spatial Distance Distributions in Microstructure", **Structural Mechanics Seminar Series**, Georgia Institute of Technology, May, 1995 (*Invited Seminar*).
7. A.M. Gokhale: "Characterization of Microstructure in Composites Using Quantitative Stereology", **ASME AMD-MD Summer Meeting**, Los Angeles, CA, June 28-30, 1995.
8. Lars M. Karlsson and A.M. Gokhale: "Estimating Mean Linear Intercept Using the Trisector", **9<sup>th</sup> International Congress for Stereology**, Copenhagen, Denmark, August 21-25, 1995 (Presented by Lars M. Karlsson)

## **J. Hampikian**

### Invited Presentations

1. J.M. Hampikian, W.B. Carter, "Combustion Chemical Vapor Deposited Coatings for Thermal Barrier Coating Systems," presented at the Advanced Turbine Systems Annual Program Review Meeting, held at the Morgantown Energy Technology Center (METC), Morgantown, WV, October 17-18, 1995.
2. W.B. Carter, J.M. Hampikian, G.W. Book, M.R. Hendrick, T.A. Polley and D.W. Stollberg, "Combustion Chemical Vapor Deposited Coatings for Thermal Barrier Coating Systems," presented at the Advanced Turbine Systems Materials Workshop, Charleston, SC, February 13-14, 1996.
3. J.M. Hampikian, "Ion Beam Modification of Materials," presented in MiRC 102B on May 2, 1995; coordinated by Susan Shows, Economic Development Institute, Georgia Tech.
4. J.M. Hampikian, "Capabilities of MSE in Research and Characterization," presented in Aderhold room, Wardlaw building on June 1, 1995; coordinated by Mike Butler (Semeradak) and Susan Shows (Economic Development Institute, Georgia Tech).
5. E.M. Hunt and J.M. Hampikian, "The Implantation and Annealing Effects of Yttrium Implantation into Alumina," Molecular Design Institute oral presentation, November 9, 1995.
6. E.M. Hunt and J.M. Hampikian, "Yttrium Ion Implantation into Alumina," ASM/SAMPE Atlanta Chapter Student Night, Wardlaw Room, Georgia Institute of Technology.
7. E.M. Hunt and J.M. Hampikian, "The Effects of Yttrium Ion Implantation into Alumina," Molecular Design Presentation, October 16, 1995.
8. J.M. Hampikian, "Oxidation Resistant Coatings," in-house presentation to members of Westinghouse, 3/8/95.

### Contributed Presentations

1. W.B. Carter, J.M. Hampikian, G.W. Book, S.H. Godfrey, and T.A. Polley, "Combustion Chemical Vapor Deposition of Ceramic Coatings," presented at the DoE's Advanced Industrial Materials Program Annual Meeting, Washington, D.C., June 14-16, 1995.
2. M.R. Hendrick, J.M. Hampikian, and W.B. Carter, "Combustion Chemical Vapor Deposition of Alumina," presented at the Gordon Conference on Dry Corrosion, New London, NH, July 17-21,

1995.

3. M.R. Hendrick, J.M. Hampikian, and W.B. Carter, "The High Temperature Oxidation of Alumina Coated Ni-Base Alloys," presented at the Symposium on High Temperature Coatings II, TMS Annual Meeting, Anaheim, CA, Feb. 4-8, 1996.
4. E.M. Hunt and J.M. Hampikian, "Examination of Implantation Induced Damage in Alumina, 1995 Graduate Student Symposium, Student Success Center, poster presentation.
5. J.M. Hampikian, M. Hendrick, S. Murthy and E. Hunt, "Transmission Electron Microscopy of Gold Nanocrystals," Molecular Design Institute poster session, November 8, 1995.
6. E.M. Hunt, J.M. Hampikian and D.B. Poker, "The Effects of Yttrium Implantation into Alumina," Materials Research Society Symposium oral presentation, Boston, MA, November 28, 1995.

### **W.S. Johnson**

1. Butkus, L.M. and Johnson, W.S. "Assessing Structural Integrity of Bonded Joints using Fracture Mechanics" <poster>Air Force 3rd Aging Aircraft Conference, Wright-Patterson AFB, OH, 26-28 September 1995.
2. Butkus, L.M. and Johnson, W.S. "Assessing Structural Integrity of Bonded Joints using Fracture Mechanics" <presentation>1995 USAF Structural Integrity Program Conference, San Antonio, TX, 28-30 November 1995.

### **D.L. McDowell**

Presentations (refereed):

1. Horstemeyer, M.F. and McDowell, D.L., "Stress State and History Effects in Viscoplasticity at Finite Strain," in Finite Deformation Viscoplasticity, eds. R.C. Batra and T.W. Wright, ASME MD-Vol. 69-1, 1995, pp. 519-544.

Presentations (non-refereed):

1. Hall, D.E., McDowell, D.L. and Saxena, A., "Some Aspects of Crack Growth in Creep-Brittle Materials," ICES '95, Hawaii, July 30-Aug. 3, 1995.
2. Mazataud, P. and McDowell, D.L., "Effect of Aspect Ratio and Strain Hardening on Void Growth:

- Proportional Loading at Low to Moderate Triaxiality," ICES '95, Hawaii, July 30-Aug. 3, 1995.
3. Le Gall, C., Qu, J. and McDowell, D.L., "Delamination Cracking in Encapsulated Flip Chips," 46th Electronic Components and Technology Conference, Arlington, VA, May 28-31, 1996.
  4. Fu, C., McDowell, D.L. and Ume, C., "Time Integration Procedures for a Cyclic Thermoviscoplasticity Model for Pb-Sn Solder Applications," 46th Electronic Components and Technology Conference, Orlando, FL, 1996.
  5. McDowell, D.L., "Mechanics-Related High Cycle Fatigue Research Issues," invited presentation, AFOSR Workshop on Basic Research Issues in the Materials and Mechanics of HCF, Dayton, OH, June 7, 1995.

### **R.W. Neu**

1. Neu, R.W., "TMF Damage-Mechanism and Life Maps for [0/90] TMCs," ASME Joint Applied Mechanics and Materials Summer Conference, UCLA, Los Angeles, CA, June 28-30, 1995.

### **B. Park**

1. B. Park, "Synthesis of Metastable Carbon-Silicon-Nitrogen Compounds," Materials Science and Metallurgy Seminar, Columbia University, New York, NY, July 1995.
2. D. H. Lee, B. Park and D. B. Poker, "Surface Hardness Enhancement in Nitrogen-Implanted Dense-Amorphous Carbon," Materials Research Society Fall Meeting, Boston, MA, November 1995.
3. B. Park, "Synthesis of Metastable Carbon-Silicon-Nitrogen Compounds," Department of Materials Science and Engineering Seminar, Korea Advanced Institute of Science and Technology (KAIST), Taejon, Korea, December 1995.
4. B. Park, "Synthesis of Metastable Carbon-Silicon-Nitrogen Compounds," Department of Metallurgical Engineering Seminar, Seoul National University, Seoul, Korea, December 1995.
5. B. Park, "Synthesis of Metastable Carbon-Silicon-Nitrogen Compounds," Department of Advanced Materials Engineering Seminar, Korea Advanced Institute of Science and Technology (KAIST) - Seoul Campus, Seoul, Korea, December 1995.
6. B. Park, D. H. Lee, and D. B. Poker, "Surface Hardness Enhancement in Nitrogen-Implanted

Amorphous Carbon," TMS Annual Meeting, Anaheim, CA, February 1996.

### **T.H. Sanders**

#### Contributed Presentations

1. Heat-Resistant Materials II, Second International Conference on Heat-Resistant Materials, 11-14 September, 1995, Gatlinburg, TN, "A Study on the Dendritic Growth of Gamma Prime in Astroloy", with M.L. Macia.
2. TMS Fall Meeting, October 29 - November 2, 1995, Cleveland Convention Center, Cleveland, OH, "Solidification and Ingot Processing", with A. Saxena.

### **A. Saxena**

#### Invited Presentations

1. A. Saxena, "Crack Growth in Creep-Brittle Materials", invited presentation at the TMS Symposium on Behavior of Advanced Structural Materials, Oct. 1995.
2. A. Saxena, "Life Prediction of Weldments in Elevated Temperature Components", invited presentation at the International Workshop on Recent Trends in Welding, Bangalore, India, Oct. 1995.
3. A. Saxena, "Recent Advances in Fracture Mechanics", Seminar at Wayne State University, Detroit, Sept. 1995.
4. A. Saxena, "Recent Advances in Fracture Mechanics", Seminar at University of Tennessee, Knoxville, Aug. 1995.

#### Contributed Presentations

1. B. C. Hamilton, D. E. Hall, A. Saxena, D. L. McDowell, "Creep Crack Growth Behavior in Al Alloy 2519", 27th ASTM Symposium on Fatigue and Fracture, Williamsburg, VA, June 1995.
2. Fan Yang, A. Saxena and T. L. Starr, "Damage Evolution in Nicalon Fiber, Silicon Nitride Matrix Composite", 27th ASTM National Symposium on Fatigue and Fracture, Williamsburg, VA, June 1995.



3. R. H. Norris and A. Saxena, "Creep Crack Growth Behavior in Cr-Mo Weldments", International Conference on Materials Aging and Component Life Extension, Oct. 1995, Milan, Italy.

### **R. Talreja**

1. Talreja, R., "A Synergistic Damage Mechanics Approach to Durability of Composite Systems", Invited General Lecture, International Conference on Progress in Durability Analysis of Composite Systems, Brussels, Belgium, July 16-21, 1995.
2. Saha, R. and Talreja, R. "A Study of The Opening Displacement of Cracks and Their Effect on Stiffness of Composite Laminates", Society of Engineering Science 32nd Annual Technical Meeting, New Orleans, LA, October 29-November 1, 1995.
3. Varna, J., Akshantala, N. and Talreja, R., "An Experimental Study of Crack Opening Displacement in Composite Laminates With Varying Constraints", Society of Engineering Science 32nd Annual Technical Meeting, New Orleans, LA, October 29-November 1, 1995.
4. Talreja, R., "Micromechanics and Continuum Damage Mechanics for Composite Materials", University of Aalborg, Aalborg, Denmark, Sept. 13, 1995.

### **N.N. Thadhani**

#### Contributed Presentations

1. T.E. Royal and N.N. Thadhani, "Shock-Induced Reaction Behavior of Ti-Si and Ti-B powder Mixtures," in Int. Conf. on "Metallurgical and Materials Applications of Shock Wave and High-Strain-Rate Phenomena," El Paso, August 6-10, 1995.
2. J.H. Lee and N.N. Thadhani, "Synthesis of TiC Ceramics by "Shock-Assisted Reaction Sintering," in Int. Conf. on "Metallurgical and Materials Applications of Shock Wave and High-Strain-Rate Phenomena," El Paso, August 6-10, 1995.
3. V. Joshi, P.A. Persson, and N.N. Thadhani, "Effect of impurities on transient Heat Conduction in Shock Compaction of Diamond Powders," in Int. Conf. on "Metallurgical and Materials Applications of Shock Wave and High-Strain-Rate Phenomena," El Paso, August 6-10, 1995.
4. V. Subramanian and N.N. Thadhani, "Reaction Behavior of Shock-Compressed Al and Fe-oxide Powder Mixtures," in APS Topical Conf. on Shock Compression of Condensed Matter, Seattle, August 13-18, 1995.

5. V. Joshi, N.N. Thadhani, R.A. Graham, and G.T. Holman, "Shock Compression Behavior of Quartz and Al Powder Mixtures," in APS Topical Conf. on Shock Compression of Condensed Matter, Seattle, August 13-18, 1995.
6. N.N. Thadhani, V. Subramanian, R. Russell, D. Savage, and Y.M. Gupta, "The Influence of Pulse Duration on Shock-Induced Chemical Reaction in Ti-Si Powder Mixtures," in APS Topical Conf. on Shock Compression of Condensed Matter, Seattle, August 13-18, 1995.
7. N.N. Thadhani, J.-H. Lee, B. Turner, TMS Symposium on "Processing and Fabrication of Advanced Materials - IV, Cleveland, November, 1995.
8. K. Vandersall and N.N. Thadhani, "Synthesis of B1 type Tantalum Nitride by Shock-Compression of Hexagonal Phase Precursors," TMS Symposium on Tantalum and its Compounds, Anaheim, February 1996.
9. N.N. Thadhani, "Evaluation of Materials Issues in Shock Chemistry Based on Time-Resolved Measurements and Shock-Recovery Experiments," at Shock Chemistry Colloquium, North Carolina State University, Raleigh, February 1996.

### **C. Ume**

1. Polsky, Y. and Ume, C., "An Automated System for Temperature Dependent Mechanical Property Measurements," Symposium on Manufacturing for Electronics Industry, ASME International Mechanical Engineering Conference and Exposition, Atlanta, GA, November 17-22, 1996.
2. Fu, C. McDowell, D. and Ume, C., "Tune Integration Procedures for a Cyclic Thermovisco-plasticity Model for PB-Sn Solder Applications," Symposium on Modeling and Simulation, IEEE 26th ECTC Conference, Orlando, Florida, May 28-31, 1996.

## APPENDIX D

### Funding

#### **A. Gokhale**

Title: Quantitative Analysis of Fracture Surfaces Using Stereological Methods

Sponsor: National Science Foundation

Funding: \$ 73,856

Title: Evolution of Microstructural Distance Distributions in Normal Gravity and Microgravity Sponsor: Microgravity Science Applications Division, N.A.S.A.

Funding: \$ 49,984 per year

Title: Effect of Gravity on Spatial Arrangement of Features in Microstructure: A Quantitative Approach

Sponsor: Microgravity Science Applications Division, N.A.S.A.

Funding: \$ 80,000 per year

Title: Unrestricted GTF Research Grant for Research in the Area of Quantitative Fractography

Sponsor: Aluminum Company of America (through GTF)

Funding: \$ 33,000 per year

Title: Quantitative Characterization, Modelling, and Simulation of Cast Microstructures in Light Metal Castings

Sponsor: American Foundrymen Society (USCAR project subcontract)

Funding: \$ 74,000 per year

Title: Quantitative Fractography of Fracture Toughness Test Specimens

Sponsor: Aluminum Company of America

Funding: \$ 16,195 per year

Title: Unrestricted Research Grant for Research on Microstructure Properties Correlations in Steels

Sponsor: Southern Saw Services, Inc. (through GTF)

Funding: \$ 20,000 per year

Title: Unrestricted Research Grant for Research on Steels

Sponsor: Inland Steel Company (through GTF)

Funding: \$ 5,000 per year

**J. Hampikian**

Title: Combustion Chemical Vapor Deposition of Thermal Barrier Coatings

Sponsor: DOE

Co-PI: B. Carter

Funding: \$74,101

Title: Yttrium Ion Implantation Implantation of Sapphire

Sponsor: MDI

Funding: \$10,725 per year

Note: Dr. Hampikian is a 1996-2001 recipient of the prestigious NSF CAREER Award at a level of approximately \$80K/yr. The topic is Coatings for High Temperature Alloys.

**W.S. Johnson**

Title: Fatigue Behavior of Hybrid Titanium Composite Laminates

Sponsor: NASA/CAU HiPPAC

P.I.: W. S. Johnson

Annual Funding Level: \$55K

Title: Fracture Mechanics Applications to the Durability of Bonded Composite Joints

Sponsor: FAA/Air Force

P.I.: W. S. Johnson

Annual Funding: \$52K

Title: Creep Bearing Behavior in Highly Loaded Bolted Joints

Sponsor: Lockheed/NASA

P.I.: W. S. Johnson

Annual Funding: \$50K

Title: Crack Initiation, Growth, and Detection under Simulated Rotorcraft Spectrum Loading

Sponsor: ONR

P.I. Ward Winer

Annual Funding: \$50K

Title: Funding for Instrumentation for MPRL

Sponsor: NSF

co-P.I.s: Steve Johnson and Dave McDowell

Funding: \$205K

Title: Thermo-Viscoplastic Characterization of K-3B Resins  
Sponsor: NASA HiPPAC Center and Research Leader Money  
P.I. W. S. Johnson  
Annual Funding Level: \$10K

**D.L. McDowell**

Title: Damage Evolution in High Temperature Composites  
Sponsor: NASA (Graduate Student Researchers Program (Mr. T. Lacy))  
Annual funding: \$22,000

Title: Cyclic Multiaxial Behavior of Shape Memory Alloys  
Sponsor: NSF  
Annual funding: \$51,054

Title: Internal State Variable Models for Rate and Temperature  
History Dependent Behavior at Finite Strain  
Sponsor: ARO  
Annual funding: \$80,000

Title: Equipment for a Laboratory Course on Mechanical Reliability of  
Microelectronic Devices  
Sponsor: NSF (with J. Qu and S. Danyluk, ME)  
Annual funding: \$29,291

Title: Acquisition of Integrated Material Simulation and Test Control  
Capability  
Sponsor: NSF (Co-PI with W.S. Johnson, MSE)  
Annual funding: \$71,000

Title: Damage Coupled Thermal Response of Ceramic Matrix Composites United  
Technologies Fellowship (Mr. S. Graham)  
Sponsor: UTC  
Annual funding: \$25,000

Title: Texture and Substructure Anisotropy in Finite Strain Inelasticity  
Sponsor: ARO AASERT Program (Mr. G.C. Butler)  
Annual funding: \$27,000

Title: Integrated Diagnostics (PI - W.O. Winer, ME)  
Sponsor: ONR  
Annual funding: \$40,000

**R.W. Neu**

Title: Integrated Diagnostics  
PI: W.O. Winer, ME  
Sponsor: ONR  
Annual Funding: \$40,000

Title: Fatigue of Lead-free Solders  
Sponsor: MaRC/Army MICOM  
Annual Funding: \$63,767

**B. Park**

Title: "Synthesis of Metastable Carbon-Silicon Nitride by Non-Equilibrium Processing"  
Sponsor: SURA  
Annual Funding: \$6,000

Title: "Surface Modification by Ion-Beam Techniques"  
Sponsor: Tulsa Dental Company  
Annual Funding: \$2,500

Title: "Path History Dependence and Multiaxial Generalization of Constitutive Equations for Shape Memory Alloys"  
Sponsor: NSF  
P.I.: D. L. McDowell  
Annual Funding: \$3,492

Title: "Evolution of Microstructures in TiC Coatings"  
Sponsor: Southern Saw Products  
P.I.: A. Gokhale  
Annual Funding: \$10,000

**A. Saxena**

Sponsor: MPC  
Annual Funding: \$784

Sponsor: NASA  
Annual Funding: \$18,877

Sponsor: NASA  
Annual Funding: \$54,069

Sponsor: EPRI  
Annual Funding: \$89,548

Sponsor: Lockheed  
Annual Funding: \$38,762

Sponsor: ONR  
Annual Funding: \$40,005  
PI: W.O. Winer, ME

Sponsor: SURA  
Annual Funding: \$6,000

**R. Talreja**

Title: Mathematical Modeling of Damage in Polymer Matrix Composites  
Sponsor: McDonnell Douglas  
Annual funding: \$40,000

Title: Long Term Durability of Polymer Matrix Composites for High Temperature Applications  
Sponsor: NASA Lewis/Clark Atlanta University  
Annual Funding: \$14,605

**N.N. Thadhani**

Title: Dynamic Processing and Synthesis of High-temperature Materials  
Sponsor: NSF  
Annual Funding: nil

Title: An Investigation of Mechanisms and Kinetics of Shock-induced Chemical Reactions in Ti-Al/Si/B

System

Sponsor: ARO

Annual Funding: \$80,000

Title: Mechanisms of Shock-initiated Intermetallic Reactions (Total \$209,000).

Sponsor: ONR

Annual Funding: \$30,000

Title: "AASERT Proposal" on Electric Field Assisted Combustion Synthesis of High-Density Powder Mixture Compacts

Sponsor: ARO

Annual Funding: \$25,000



## APPENDIX E

### Major Honors and Awards

#### A.M. Gokhale

1. Selected for **Special Creativity Based Award** by Division of Materials Research, N.S.F. The award comes with a two year research grant.
2. **Appointed to editorial advisory board** of Acta Stereologica
3. **Member of International Advisory Board** of International Advisory Board for 9<sup>th</sup> International Congress for Stereology held in Copenhagen, Denmark, August, 1995.
4. **Vice-President** of International Society for Stereology for the period 1992-1995 (by election).

#### J. Hampikian

1. Recipient of NSF Career Award, 1996-2001

#### W.S. Johnson

1. NASA Tech Brief Award, July 1995

#### D.L. McDowell

1. Elected Fellow of ASME
2. Selected as Regent's Professor, Georgia State University System
3. Member of U.S. National Committee on Theoretical and Applied Mechanics, National Research Council

#### T.H. Sanders, Jr.

1. Inducted as a Fellow in ASM, October 1995.

### **A. Saxena**

1. Fellow ASM International (announcement pending)
2. Vice-Chairman, ASTM Committee 3.08 on Fatigue and Fracture, 1/96 -
3. Certificate of Appreciation for continuing leadership of Crack Growth Behavior Subcommittee of ASTM E.08.

### **R. Talreja**

1. Boeing - A.D. Welliver Summer Fellowship Award, 1996.

### **N.N. Thadhani**

1. Former undergraduate student, Mr. Stephen Glade, received the Department of Defense, Graduate Research Fellowship. He is currently a graduate student in Professor William Johnson's group at CalTech.
2. Graduate student, Mr. Jong-Heon Lee, received a 2nd place award (silver prize) from Samsung Electronics, Korea, under Samsung's Humantech thesis award program in the field of science and engineering, open worldwide to students of Korean descent. Of the total 4000 total papers/thesis submitted, and 126 selected for oral presentations in Korea, Mr. Hong-Heon Lee was one of the ten, second place winners

### **C. Ume**

1. Appointed Associate Editor, ASME Journal of Electronic Packaging, January 1, 1996.
2. Appointed Technical Editor (USA Region), Journal of Mechatronics, March 1996.