

REPORT DOCUMENTATION PAGE

Form Approved
OMB NO. 0704-0188

Public Reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comment regarding this burden estimates or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188,) Washington, DC 20503.

1. AGENCY USE ONLY (Leave Blank)		2. REPORT DATE November 6, 2003	3. REPORT TYPE AND DATES COVERED Final Progress Report 9 Aug 10 (August 2000-November 2003)	
4. TITLE AND SUBTITLE Processing of Metal Matrix Composites through Severe Plastic Deformation			5. FUNDING NUMBERS DAAD19-00-1-0488	
6. AUTHOR(S) Terence G. Langdon				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of Southern California. Los Angeles, CA 90089-1453			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U. S. Army Research Office P.O. Box 12211 Research Triangle Park, NC 27709-2211			10. SPONSORING / MONITORING AGENCY REPORT NUMBER 40660.54-MS	
11. SUPPLEMENTARY NOTES The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.				
12 a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.			12 b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) This is the Final Progress Report for an ARO research program extending over a period of 3 years. The program was designed to evaluate the processing of materials using the procedure of Equal-Channel Angular Pressing (ECAP) in which a coarse-grained bulk solid is subjected to severe, but controlled, plastic deformation. Two metal matrix composites were investigated in detail: an aluminum 2009 alloy reinforced with 25% SiC particulates and an aluminum 6061 alloy reinforced with 10% alumina particulates. The results demonstrate the potential for achieving high strength and excellent mechanical properties in these two composites. Additional collaborations were established with other leading groups in the field and this led to many new insights in the field of ECAP processing. All of these new developments are described in detail in the publications arising from this program.				
14. SUBJECT TERMS Equal-channel angular pressing, metal matrix composites, severe plastic deformation, ultrafine-grained materials			15. NUMBER OF PAGES 9	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OR REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION ON THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UL	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

REPORT DOCUMENTATION PAGE (SF298)
(Continuation Sheet)

Statement of the problem:

This program was initiated to evaluate the processing of materials using the procedure of Equal-Channel Angular Pressing (ECAP) where a bulk solid is subjected to severe plastic deformation. It is now well established that ECAP can produce polycrystalline bulk materials with ultrafine grain sizes, typically in the submicrometer or even the nanometer range. The main emphasis of the program was devoted to investigating the potential for using ECAP to process and strengthen metal matrix composites.

Two different composites were used in this program: an aluminum 2009 alloy reinforced with 25% SiC particulates and an aluminum 6061 alloy reinforced with 10% alumina particulates. In addition, we were able to leverage our activities on ECAP in order to establish collaborations with other major teams throughout the United States and around the world. These collaborations provided much new insight into the ECAP process and gave the personnel working on the ARO program an excellent opportunity to become acquainted with new experimental techniques and procedures.

Summary of the achievements:

This has been a remarkably successful program for two reasons. First, we were able to obtain excellent results on the aluminum metal matrix composites and we showed the potential for achieving remarkably high strength and good mechanical properties. Second, our collaborations led to joint publications on ECAP with groups at the California Institute of Technology, Los Alamos National Laboratory, Arizona State University, Air Force Materials Laboratory, Naval Postgraduate School, University of California at Irvine, QED Extrusion Developments, Inc., McGill University and Rockwell International. We also developed extensive collaborations with overseas groups in Japan, Russia, Spain and Hungary. All of these collaborations are reflected in the numerous publications arising from this ARO program which are listed in the next section.

As part of our activities on the ARO program, we co-organized the Symposium on Ultrafine-Grained Materials II which was held in Seattle, Washington, in February 2002 as part of the TMS Annual Meeting. We are now organizing a follow-up symposium entitled Ultrafine-Grained Materials III which will be held in Charlotte, North Carolina, in March 2004 as part of the TMS Annual Meeting. This symposium is already breaking records with more than 120 abstracts received from around the world and, to date, more than 90 papers which will be printed in a special TMS book available at the meeting. On the international scene, I co-organized a symposium on Processing by Severe Plastic Deformation as part of the THERMEC-2003 Conference in Madrid, Spain, in June 2003, and I co-organized a Symposium on Bulk Nanomaterials which was held in Warsaw, Poland, in September 2003, as part of the Fall Meeting of the European Materials Research Society. On a personal level, recent successes that are due, at least in part, to the support received from ARO over the years include my election as a Fellow of the Royal Academy of Engineering (FREng) in 2002 and my receipt of the degree of Doctor Honoris Causa from the Russian Academy of Sciences in 2003 for my research on the physics of metals. I am also currently listed by ISI (Institute for Scientific Information, Philadelphia, PA) as #3 worldwide for the number of citations received to papers published in the field of Materials Science in the 5-year period of 1997-2001.

All of our results have been published in the scientific literature and a complete listing is given in the following section. A total of 49 papers have been published to date in peer-reviewed journals including 4 papers in *Acta Materialia*, 12 papers in *Materials Science and Engineering A*, 3 papers in *Metallurgical and Materials Transactions A*, 1 paper in *Journal of Materials Research* and 5 papers in *Scripta Materialia*. There have also been 13 papers published in conference proceedings and an additional 6 papers have been submitted or accepted for publication. All of these papers acknowledge the support of ARO and they contain a detailed description of the research performed as part of this program.

Papers published in peer-reviewed journals:

1. M. Furukawa, A. Utsunomiya, S. Komura, Z. Horita, M. Nemoto and T.G. Langdon, "Optimization for Superplasticity in Ultrafine-grained Al-Mg-Sc Alloys Using Equal-Channel Angular Pressing," *Materials Science Forum* 357-359, 431-436 (2001).
2. T.G. Langdon, M. Furukawa, M. Nemoto and Z. Horita, "Using Severe Plastic Deformation for Grain Refinement and Superplasticity," *Materials Science Forum* 357-359, 469-498 (2001).
3. Z. Horita, S. Lee, S. Ota, K. Neishi and T.G. Langdon, "Equal-Channel Angular Pressing as a Production Tool for Superplastic Materials," *Materials Science Forum* 357-359, 471-475 (2001).
4. S. Komura, M. Furukawa, Z. Horita, M. Nemoto and T.G. Langdon, "Optimizing the Procedure for Equal-Channel Angular Pressing for Maximum Superplasticity," *Materials Science and Engineering A* 297, 111-118 (2001).
5. A. Yamashita, Z. Horita and T.G. Langdon, "Improving the Mechanical Properties of Magnesium and a Magnesium Alloy through Severe Plastic Deformation," *Materials Science and Engineering A* 300, 142-147 (2001).
6. K. Oh-ishi, Z. Horita, D.J. Smith and T.G. Langdon, "Grain Boundary Structure in Al-Mg and Al-Mg-Sc Alloys after Equal-Channel Angular Pressing," *Journal of Materials Research* 16, 583-589 (2001).
7. S.L. Semiatin, P. Berbon and T.G. Langdon, "Deformation Heating and Its Effect on Grain Size Evolution during Equal-Channel Angular Extrusion," *Scripta Materialia* 44, 135-140 (2001).
8. T. Aida, K. Matsuki, Z. Horita and T.G. Langdon, "Estimating the Equivalent Strain in Equal-Channel Angular Pressing," *Scripta Materialia* 44, 575-579 (2001).
9. Z. Horita, M. Furukawa, M. Nemoto and T.G. Langdon, "Microstructural Control using Equal-Channel Angular Pressing," *Netsu-shori (Journal of The Japan Society for Heat Treatment)* 41, 68-74 (2001).
10. K. Neishi, T. Uchida, A. Yamauchi, K. Nakamura, Z. Horita and T.G. Langdon, "Low-Temperature Superplasticity in a Cu-Zn-Sn Alloy Processed by Severe Plastic Deformation," *Materials Science and Engineering A* 307, 23-28 (2001).
11. S. Komura, Z. Horita, M. Furukawa, M. Nemoto and T.G. Langdon, "An Evaluation of the Flow Behavior during High Strain Rate Superplasticity in an Al-Mg-Sc Alloy," *Metallurgical and Materials Transactions A* 32A, 707-716 (2001).
12. T. Fujita, H. Hasegawa, Z. Horita and T.G. Langdon, "Diffusion in Ultrafine-Grained Al-Mg Alloys," *Defect and Diffusion Forum* 194-199, 1205-1210 (2001).
13. B.Q. Han and T.G. Langdon, "Factors Contributing to Creep Strengthening in Discontinuously-Reinforced Materials," *Materials Science and Engineering A* 322, 73-78 (2002).
14. S. Lee, A. Utsunomiya, H. Akamatsu, K. Neishi, M. Furukawa, Z. Horita and T.G. Langdon, "Influence of Scandium and Zirconium on Grain Stability and Superplastic Ductilities in Ultrafine-Grained Al-Mg Alloys," *Acta Materialia* 50, 553-564 (2002).
15. M. Furukawa, Z. Horita, M. Nemoto and T.G. Langdon, "The Use of Severe Plastic Deformation for Microstructural Control," *Materials Science and Engineering A* 324, 82-89 (2002).
16. K. Neishi, Z. Horita and T.G. Langdon, "Grain Refinement of Pure Nickel Using Equal-Channel Angular Pressing," *Materials Science and Engineering A* 325, 54-58 (2002).
17. Y. Fukuda, K. Oh-ishi, Z. Horita and T.G. Langdon, "Processing of a Low-Carbon Steel by Equal-Channel Angular Pressing," *Acta Materialia* 50, 1359-1368 (2002).

18. A.P. Zhilyaev, B.-K. Kim, G.V. Nurislamova, M.D. Baró, J.A. Szpunar and T.G. Langdon, **Orientation Imaging Microscopy of Ultrafine-Grained Nickel**,@ Scripta Materialia **46**, 575-580 (2002).
19. M. Furukawa, Z. Horita and T.G. Langdon, **Factors Influencing the Shearing Patterns in Equal-Channel Angular Pressing**,@ Materials Science and Engineering A332, 97-109 (2002).
20. A.P. Zhilyaev, G.V. Nurislamova, M.D. Baro, R.Z. Valiev and T.G. Langdon, **Thermal Stability and Microstructural Evolution in Nickel after ECAP**,@ Metallurgical and Materials Transactions **33A**, 1865-1868 (2002).
21. S.D. Terhune, D.L. Swisher, K. Oh-ishi, Z. Horita, T.G. Langdon and T.R. McNelley, **An Investigation of Microstructures and Grain-Boundary Evolution during ECA Pressing of Pure Aluminum**,@ Metallurgical and Materials Transactions **33A**, 2173-2184 (2002).
22. K. Oh-ishi, Y. Hashi, A. Sadakata, K. Kaneko, Z. Horita and T.G. Langdon, **Microstructural Control of an Al-Mg-Si Alloy Using Equal-Channel Angular Pressing**,@ Materials Science Forum **396-402**, 333-338 (2002).
23. T. Fujita, Z. Horita and T.G. Langdon, **Diffusion in Fine-Grained Al Alloys Having Low and High Angle Grain Boundaries**,@ Materials Science Forum **396-402**, 1061-1066 (2002).
24. A.P. Zhilyaev, G.V. Nurislamova, S. Suriñach, M.D. Baró and T.G. Langdon, **Calorimetric Measurements of Grain Growth in Ultrafine-Grained Nickel**,@ Materials Physics and Mechanics **5**, 23-30 (2002).
25. Z. Horita, K. Matsubara, K. Makii and T.G. Langdon, **A Two-Step Processing Route for Achieving a Superplastic Forming Capability in Dilute Magnesium Alloys**,@ Scripta Materialia **47**, 255-260 (2002).
26. T. Fujita, Z. Horita and T.G. Langdon, **Characteristics of Diffusion in Al-Mg Alloys with Ultrafine Grain Sizes**,@ Philosophical Magazine A **82**, 2249-2262 (2002).
27. S.C. Vogel, I.J. Beyerlein, M.A.M. Bourke, C.N. Tomé, P. Rangaswamy, C. Xu and T.G. Langdon, **Texture in Equal-Channel Angular Pressed Aluminum and Nickel**,@ Materials Science Forum **408-412**, 673-678 (2002).
28. Y. Huang and T.G. Langdon, **Characterization of Deformation Processes in a Zn-22% Al Alloy Using Atomic Force Microscopy**,@ Journal of Materials Science **37**, 4993-4998 (2002).
29. S. Ota, H. Akamatsu, K. Neishi, M. Furukawa, Z. Horita and T.G. Langdon, **Low-Temperature Superplasticity in Al Alloys Processed by Equal-Channel Angular Pressing**,@ Materials Transactions **43**, 2364-2369 (2002).
30. C. Xu and T.G. Langdon, **Influence of a Round Corner Die on Flow Homogeneity in ECA Pressing**,@ Scripta Materialia **48**, 1-4 (2003).
31. S. Lee, M. Furukawa, Z. Horita and T.G. Langdon, **Developing a Superplastic Forming Capability in a Commercial Aluminum Alloy Without Scandium or Zirconium Additions**,@ Materials Science and Engineering A342, 294-301 (2003).
32. A.P. Zhilyaev, G.V. Nurislamova, B.-K. Kim, M.D. Baro, J.A. Szpunar and T.G. Langdon, **Experimental Parameters Influencing Grain Refinement and Microstructural Evolution During High-Pressure Torsion**,@ Acta Materialia **51**, 753-765 (2003).
33. Y. Huang and T.G. Langdon, **Creep Behavior of Discontinuously-Reinforced Metal Matrix Composites**,@ JOM **55** (1) 15-20 (2003).
34. M. Kamachi, M. Furukawa, Z. Horita and T.G. Langdon, **An Experimental Investigation of the Shearing Characteristics in Equal-Channel Angular Pressing**,@ Materials Science and Engineering A347, 223-230 (2003).
35. K. Neishi, Z. Horita and T.G. Langdon, **Achieving Superplasticity in Ultrafine-Grained Copper: Influence of Zn and Zr Additions**,@ Materials Science and Engineering A352, 129-136 (2003).
36. M. Furukawa, Z. Horita and T.G. Langdon, **Factors Influencing Microstructural Development in Equal-Channel Angular Pressing**,@ Metals and Materials International **9**, 141-149 (2003).
37. A.P. Zhilyaev, M. Furukawa, Z. Horita and T.G. Langdon, **Processing and Properties of Bulk Ultrafine-Grained Materials Produced through Severe Plastic Deformation**,@ Solid State Phenomena **94**, 3-12 (2003).

38. Y. Huang and T.G. Langdon, Using Atomic Force Microscopy to Evaluate the Development of Mesoscopic Shear Planes in Materials Processed by Severe Plastic Deformation, Materials Science and Engineering A358, 114-121 (2003).
39. K. Matsubara, Y. Miyahara, Z. Horita and T.G. Langdon, Developing Superplasticity in a Magnesium Alloy through a Combination of Extrusion and ECAP, Acta Materialia 51, 3073-3084 (2003).
40. K. Matsubara, Y. Miyahara, K. Makii, K. Neishi, Z. Horita and T.G. Langdon, Using Extrusion and ECAP Processing to Achieve Low Temperature and High Strain Rate Superplasticity, Materials Science Forum 419-422, 497-502 (2003).
41. Y. Miyahara, K. Matsubara, K. Neishi, Z. Horita and T.G. Langdon, Superplastic Properties of Ultrafine-Grained Mg Alloys Processed by Extrusion Plus Equal-Channel Angular Pressing, Materials Science Forum 419-422, 551-556 (2003).
42. M. Furukawa, Z. Horita, A.P. Zhilyaev and T.G. Langdon, Developing Ultrafine-Grained Microstructures through the Use of Severe Plastic Deformation, Materials Science Forum 426-432, 2631-2636 (2003).
43. K. Ohashi, T. Fujita, K. Oh-ishi, K. Kameko, Z. Horita and T.G. Langdon, "Microstructural Control of a Precipitate-Hardenable Al-Ag Alloy Using Severe Plastic Deformation," Materials Science Forum 426-432, 2637-2642 (2003).
44. S.C. Vogel, D.J. Alexander, I.J. Beyerlein, M.A.M. Bourke, D.W. Brown, B. Clausen, C.N. Tomé, B.R. Von Dreele, C. Xu and T.G. Langdon, "Investigation of Texture in ECAP Materials Using Neutron Diffraction," Materials Science Forum 426-432, 2661-2666 (2003).
45. M. Furukawa, Y. Fukuda, K. Oh-ishi, Z. Horita and T.G. Langdon, An Investigation of Deformation in Aluminum Single Crystals Using Equal-Channel Angular Pressing, Materials Science Forum 426-432, 2711-2716 (2003).
46. A.P. Zhilyaev, J. Gubicza, S. Suriñach, M.D. Baró and T.G. Langdon, "Calorimetric and X-ray Measurements in Ultrafine-Grained Nickel," Materials Science Forum 426-432, 4507-4512 (2003).
47. C. Xu, W. Dixon, M. Furukawa, Z. Horita and T.G. Langdon, Developing Superplasticity in a Spray-Cast Aluminum 7034 Alloy through Equal-Channel Angular Pressing, Materials Letters 57, 3588-3592 (2003).
48. M. Kamachi, M. Furukawa, Z. Horita and T.G. Langdon, Equal-Channel Angular Pressing Using Plate Samples, Materials Science and Engineering A361, 258-266 (2003).
49. C. Xu, M. Furukawa, Z. Horita and T.G. Langdon, "Achieving a Superplastic Forming Capability through Severe Plastic Deformation," Advanced Engineering Materials 5, 359-364 (2003).

Papers published in conference proceedings:

1. K. Matsubara, A. Utsunomiya, M. Furukawa, Z. Horita and T.G. Langdon, Superplasticity of Aluminum Alloys Containing Various Solid Solution Elements Processed Using Equal-Channel Angular Pressing, The Fourth Pacific Rim International Conference on Advanced Materials and Processing (PRICM4) (S. Hanada, Z. Zhong, S.W. Nam and R.N. Wright, eds.), pp. 2003-2006. The Japan Institute of Metals, Sendai, Japan (2001).
2. K. Neishi, T. Fujinami, K. Oh-ishi, Z. Horita and T.G. Langdon, Superplasticity in Cu-Zn-Zr Alloys Processed by Equal-Channel Angular Pressing, The Fourth Pacific Rim International Conference on Advanced Materials and Processing (PRICM4) (S. Hanada, Z. Zhong, S.W. Nam and R.N. Wright, eds.), pp. 2007-2010. The Japan Institute of Metals, Sendai, Japan (2001).
3. K. Neishi, T. Uchida, A. Yamauchi, K. Nakamura, Z. Horita and T.G. Langdon, Attaining Low-Temperature Superplasticity in a Cu-Zn-Sn Alloy Using Equal-Channel Angular Pressing, The Fourth Pacific Rim International Conference on Advanced Materials and Processing (PRICM4) (S. Hanada, Z. Zhong, S.W. Nam and R.N. Wright, eds.), pp. 2011-2014. The Japan Institute of Metals, Sendai, Japan (2001).

4. M. Furukawa, S. Ohta, Z. Horita, S. Lee and T.G. Langdon, **Mechanical Properties of an Al-2024 Alloy after Equal-Channel Angular Pressing**,@ Light Metals 2002 (T. Lewis, ed.), pp. 733-747. The Canadian Institute of Mining, Metallurgy and Petroleum, Montreal, Canada (2002).
5. T.R. McNelley, D.L. Swisher, Z. Horita and T.G. Langdon, **Influence of Processing Route on Microstructure and Grain Boundary Development during Equal-Channel Angular Pressing of Pure Aluminum**,@ Ultrafine Grained Materials II (Y.T. Zhu, T.G. Langdon, R.S. Mishra, S.L. Semiatin, M.J. Saran and T.C. Lowe, eds.), pp. 15-24. The Minerals, Metals and Materials Society, Warrendale, PA (2002).
6. C. Xu and T.G. Langdon, **Homogeneity in Ultrafine-Grained Aluminum Prepared by Equal-Channel Angular Pressing**,@ Ultrafine Grained Materials II (Y.T. Zhu, T.G. Langdon, R.S. Mishra, S.L. Semiatin, M.J. Saran and T.C. Lowe, eds.), pp. 163-172. The Minerals, Metals and Materials Society, Warrendale, PA (2002).
7. Y. Huang, C. Xu, S. Lee, M. Furukawa, Z. Horita and T.G. Langdon, **Processing of an Aluminum-6061 Metal Matrix Composite by Equal-Channel Angular Pressing**,@ Ultrafine Grained Materials II (Y.T. Zhu, T.G. Langdon, R.S. Mishra, S.L. Semiatin, M.J. Saran and T.C. Lowe, eds.), pp. 173-182. The Minerals, Metals and Materials Society, Warrendale, PA (2002).
8. Z. Horita, K. Neishi and T.G. Langdon, **Grain Refinement of Copper-Based Alloys Using ECAP**,@ Ultrafine Grained Materials II (Y.T. Zhu, T.G. Langdon, R.S. Mishra, S.L. Semiatin, M.J. Saran and T.C. Lowe, eds.), pp. 449-457. The Minerals, Metals and Materials Society, Warrendale, PA (2002).
9. M. Furukawa, Z. Horita and T.G. Langdon, **Developing Superplasticity at High Strain Rates through ECAP Processing**,@ Ultrafine Grained Materials II (Y.T. Zhu, T.G. Langdon, R.S. Mishra, S.L. Semiatin, M.J. Saran and T.C. Lowe, eds.), pp. 459-468. The Minerals, Metals and Materials Society, Warrendale, PA (2002).
10. B.Q. Han and T.G. Langdon, **Significance of Microstructural Thermal Stability in an Al-2219 Alloy Processed by Severe Plastic Deformation**,@ Ultrafine Grained Materials II (Y.T. Zhu, T.G. Langdon, R.S. Mishra, S.L. Semiatin, M.J. Saran and T.C. Lowe, eds.), pp. 485-494. The Minerals, Metals and Materials Society, Warrendale, PA (2002).
11. M. Furukawa, Z. Horita and T.G. Langdon, **Developing a High Strain Rate Superplastic Forming Capability in Aluminum Alloys**,@ First and Second International Symposia on Superplasticity and Superplastic Forming Technology (D.C. Dunand and D.G. Sanders, eds.), pp. 15-24. ASM International, Materials Park, OH (2003).
12. Y. Huang, C. Xu, M. Furukawa, Z. Horita and T.G. Langdon, **Developing a Processing Route for Grain Refinement in an Al-6061 Metal Matrix Composite**,@ Hot Deformation of Aluminum Alloys III (Z. Jin, A.J. Beaudoin, T.R. Bieler and B. Radhakrishnan, eds.), pp. 357-364. The Minerals, Metals and Materials Society, Warrendale, PA (2003).
13. C. Xu and T.G. Langdon, **Development of a Homogeneous Microstructure in Pure Aluminum Processed by ECAP**,@ Hot Deformation of Aluminum Alloys III (Z. Jin, A.J. Beaudoin, T.R. Bieler and B. Radhakrishnan, eds.), pp. 373-380. The Minerals, Metals and Materials Society, Warrendale, PA (2003).

Papers submitted or accepted for publication but not yet published:

1. T. Fujita, Z. Horita and T.G. Langdon, **Diffusion Behavior in Fine-Grained Al-Mg and Al-Zn Alloys Processed by Equal-Channel Angular Pressing**,@ Materials Science and Engineering (submitted for publication).
2. M. Furukawa, Z. Horita and T.G. Langdon, **Processing by Equal-Channel Angular Pressing: Applications to Grain Boundary Engineering**,@ Interface Science (in press).
3. C. Xu, M. Furukawa, Z. Horita and T.G. Langdon, **Achieving a Superplastic Forming Capability through Severe Plastic Deformation**,@ Proceedings of the Second International Conference on Severe Plastic Deformation (in press).
4. M. Furukawa, H. Akamatsu, Z. Horita and T.G. Langdon, **Properties of Aluminum Alloys Processed**

Using a 60 Degrees Die,@ Proceedings of the Second International Conference on Severe Plastic Deformation (in press).

5. Z. Horita, K. Matsubara and T.G. Langdon, AProduction of Superplastic Mg Alloys Using Severe Plastic Deformation,@ Proceedings of the Second International Conference on Severe Plastic Deformation (in press).
6. K. Neishi, Z. Horita and T.G. Langdon, AGrain Refinement and Superplastic Properties of Cu-Zn Alloys Processed by Equal-Channel Angular Pressing,@ Proceedings of the Second International Conference on Severe Plastic Deformation (in press).

Participating scientific personnel:

Dr. Y. Huang (Post-doctoral fellow): female

Mr. S. Lee (student): male

Ms. C. Xu (Ph.D. student: received her Ph.D. degree while working on the ARO program): female

Inventions:

None

MASTER COPY: PLEASE KEEP THIS "MEMORANDUM OF TRANSMITTAL" BLANK FOR REPRODUCTION PURPOSES. WHEN REPORTS ARE GENERATED UNDER THE ARO SPONSORSHIP, FORWARD A COMPLETED COPY OF THIS FORM WITH EACH REPORT SHIPMENT TO THE ARO. THIS WILL ASSURE PROPER IDENTIFICATION. NOT TO BE USED FOR INTERIM PROGRESS REPORTS; SEE PAGE 2 FOR INTERIM PROGRESS REPORT INSTRUCTIONS.

MEMORANDUM OF TRANSMITTAL

U.S. Army Research Office
ATTN: AMSRL-RO-BI (TR)
P.O. Box 12211
Research Triangle Park, NC 27709-2211

November 6, 2003

- | | |
|--|--|
| <input type="checkbox"/> Reprint (Orig + 2 copies) | <input type="checkbox"/> Technical Report (Orig + 2 copies) |
| <input type="checkbox"/> Manuscript (1 copy) | X <input type="checkbox"/> Final Progress Report (Orig + 2 copies) |
| | <input type="checkbox"/> Related Materials, Abstracts, Theses (1 copy) |

CONTRACT/GRANT NUMBER: DAAD19-00-1-0488

REPORT TITLE: Processing of Metal Matrix Composites through Severe Plastic Deformation

is forwarded for your information.

SUBMITTED FOR PUBLICATION TO (applicable only if report is manuscript):

Sincerely,

Terence G. Langdon

William E. Leonhard Professor of Engineering
University of Southern California
Los Angeles, CA 90089-1453