MATERIALS SCIENCE & ENGINEERING

27-750/ 27-550
Advanced Characterization and Microstructural Analysis

Spring Semester 2005

Course Description
The purpose of *Advanced Characterization and Microstructural Analysis* is to acquaint the student with a carefully selected set of characterization tools relevant to the quantification of microstructure. The motivation for the course is problem solving in the areas of property measurement (e.g. grain boundary energy) and prediction of microstructural evolution (e.g. in grain growth and recrystallization). The specific objectives are to develop skills and understanding in the following areas: (1) crystallographic preferred orientation (texture) and its representation by pole figures, inverse pole figures and orientation distributions; (2) methods of measuring texture such as X-ray diffraction and Electron Back Scatter Diffraction with reference to orientation mapping; (3) the basis for elastic and plastic anisotropy in texture; (4) stereology and image analysis; (5) scanning electron microscopy (SEM) and atomic force microscopy (AFM). Emphasis will be placed on the use and understanding of software tools for texture data acquisition & analysis (e.g. orientation distribution determination from pole figure data, and automated electron back-scatter diffraction/EBSD/OIM) and prediction of anisotropy (e.g. calculation of yield surfaces for plastic deformation).
3 hours lecture.

Recommended Pre-requisites: 27-201 (Structure of Materials), 27-202 (Defects in Materials), 27-301(Microstructure and Properties I).

Textbook: Kocks, U. F., C. Tomé, and H.-R. Wenk, Eds. (1998). *Texture and Anisotropy*, Cambridge University Press, Cambridge, UK, ISBN 0-521-79420-X. This is now available as a paperback. An additional book that is very useful because of its coverage of electron back scatter diffraction is *Texture Analysis: Macrotexture, Microtexture & Orientation Mapping*, by Val Randle and Olaf Engler (2000), Gordon & Breach, Amsterdam, Holland, ISBN 90-5699-224-4. A book with considerable mathematical detail on texture is Adam Morawiec's *Orientations and Rotations* (2003), Springer, ISBN 3-540-40734-0.

Topics Covered
1. Overview of Microstructural Characterization Techniques
   - Optical Microscopy
   - Electron Microscopy
     Transmission EM (TEM)
     Scanning EM (SEM)
   - Atomic Force Microscopy (AFM)
   - Specialty Microscopies: acoustic, NMR, cathodoluminescence
   - Texture Measurement

X-ray diffraction (pole figures, Laue)
Electron diffraction (EBSD, OIM); geometry of EBSD data acquisition
Neutron diffraction

2. Analysis of Characterization data
   - Stereology
     Serial sectioning (e.g. alignment of parallel sections)
     Percolation Analysis (e.g. for electrical conductivity)
     Shape and Cluster Analysis (e.g. of particles)
     Reconstruction techniques 3D for digital microstructures
     Boundary tangent analysis to obtain 5-parameter distributions
   - Representation of Texture
     Mathematical Representations
     Graphical Representations
     Crystal, Sample symmetry
     Discrete vs. Continuous Representations
     Grain Boundary texture – misorientation (3-parameter) vs. boundary normals (5-parameter)
     Lattice Curvatures (geometrically necessary dislocations)
3. Calculation of Orientation Distributions (OD) from Projections (pole figures)
   - Analysis of OD data
4. Calculation of Misorientation Distributions (MDs) from EBSD data (pole figures)
   - Analysis of MD data
   - Texture derived MD

4. Structure-Property Relationships
   - Anisotropy of second rank tensor properties, e.g. conductivity
   - Anisotropy of fourth rank tensor properties, e.g. elasticity
   - Anisotropy of non-linear tensor properties, e.g. plasticity

Course Objectives and Relationship to Program Objectives (Target Skills)

The motivation for this course is that many practical problems in materials science (and solid state physics) have to do with polycrystals and the fact that they behave differently depending on what direction is tested; this is known as *anisotropy*. Whether it is the mechanical strength, the magnetizability or the electrical properties, the methods used to quantify the anisotropy are the same. Although the field of texture & anisotropy has grown up as a separate subdiscipline, it is actually part of the broader topic of microstructure-property relationships. There is also a close relationship to materials processing because the texture of a material is dependent on its history.

The formal goal of the course therefore is to instruct students to advanced concepts of microstructural characterization. These include stereology, topology, and texture and methods of measuring microstructure including crystallographic orientation. In addition, the impact of microstructure on the directionality of materials behavior is discussed with respect to mechanical behavior. Thus the course has the most impact on Outcome A, development of a knowledge of mathematics, physics, chemistry, materials and statistics to identify, formulate and solve the problems encountered in the production or application of a material. The discussion of anisotropy addresses Outcome G, development of an ability to employ the techniques, skills and tools of modern engineering practice in materials engineering. Through classroom interaction and presentation of projects and/or homeworks, communication skills are developed (Outcome C). The examples of application of quantitative microstructural techniques addresses both the design of systems (Outcome E) and the application of core concepts in materials science (Outcome B).

Class Schedule. This is a 12 unit class for graduates (9-unit class for undergraduates) Spring, 2005, and meets twice a week for a total of 4 hours (3 hours for ugrads), 11:30-1:20, Tuesday and Thursday (11:30-12:50 for undergraduate students). Each class will have a 90-minute period for discussion of basic concepts at the undergraduate level, followed by a 30-minute period for graduates only. The graduates should expect to cover mostly quantitative material in the second part of each lecture. Note that undergraduate students should be prepared for a variable ending time since the actual balance between the two periods will depend on the topic under discussion. The lectures will be given by Prof. Anthony Rollett (CMU) and Prof. Peter Kalu (Georgia Tech and FAMU). Since a videolink is used to connect classrooms at CMU, PSU, Lehigh and at FAMU/FSU, each lecture will be made available as a powerpoint file at the following website shortly before the class begins: neon.mems.cmu.edu/rollett/27750/27750.html.

Contribution to meeting the professional component (undergraduates). 27-550 is primarily intended to introduce students to the concepts required to quantify microstructure, including texture (crystallographic preferred orientation) and to connect microstructure to the elastic and plastic behavior of engineering materials. Practical examples of the impact of anisotropy based on microstructure are introduced to motivate the discussion, e.g. earring in beverage cans, directionality in the electrical properties of superconductors.

Course Assistants. The course assistants for grading of homeworks etc. are Christopher Roberts, 3307 Wean Hall, 8-8692 and Jason Gruber, 2323 Wean Hall, 8-2711.

Prepared by Prof. Anthony D. Rollett, December 2005. The instructor can be reached in his office, Wean 4315, by phone, 8-3177, or by email, rollett@andrew.cmu.edu.

Desired Outcomes for Students* in the MSE Program

MSE Program Outcomes	**27-750**
A. The ability to apply a knowledge of mathematics, physics, chemistry, materials and statistics to identify, formulate and solve the problems encountered in the production or application of a material.	*H*
B. An ability to apply core concepts in materials science (structure, properties, processing and performance) to materials engineering problems.	*I*
C. An ability to communicate effectively.	*I*
D. An ability to design and conduct experiments with an emphasis on relating properties and processing to structure.	*L*
E. An ability to relate materials selection and performance to design of engineered systems and components.	*I*
F. An ability to function responsibly and ethically in a professional, multidisciplinary environment and as an individual or as a member of a team.	*I*
G. An ability to employ the techniques, skills and tools of modern engineering practice in materials engineering.	*H*
H. Recognition of the need for lifelong scholarship.	*I*
I. A knowledge of contemporary issues.	*L*
J. The broad education necessary to understand the impact of engineering solutions in a global and societal context	*L*

H indicates that the course is expected to strongly support the outcome; I indicates intermediate support; L indicates that the course is expected to have a lesser impact on the outcome.

* This table is directed to undergraduate students but may also be of interest to graduate students.

Lecture Schedule

Lecturers: A.D. (Tony) Rollett *[ADR]* at CMU; Peter Kalu *[PK]* at FAMU/FSU

Timetable of Lectures

Lectures take place on Tuesdays and Thursdays and run from 11:30am to 12:50 for undergraduates, with an additional section from 12:50-1:20 for graduates students only.

CMU Semester starts Jan 10th; course at FSU/FAMU will start at the same time

Week 1

Jan. 11th *[ADR]* Introduction to Microstructure, including texture (crystallographic orientation): examples of engineering problems involving texture; What is a Texture Component? Miller indices and Euler angles; orientation as rotation; stereographic projections; Pole Figures;

Jan. 13th *[ADR]* Mathematics of conversion from Miller indices to a rotation matrix to Euler angles. Tour of popLA. Example of analysis of a set of pole figure data measured for a sample of low carbon steel to obtain an orientation distribution (function), using the popLA software package. This will be a hands-on demonstration with opportunities for students to demonstrate their own use of the package. The accompanying homework will require students to use the package to generate a "standard set" of plots and other analyses. Students will be required to refine the defocusing and background corrections in order to optimize the solution.

Homework 1: construction of PFs; projections; application of popLA to a data set provided by the instructors

Week 2

Jan. 18th *[ADR]* Different representations of rotations and orientations, especially matrices, axis-angle pairs, Rodrigues vectors, quaternions, axis transformations, active (vector) rotations, relationships between them.

Jan. 20th *[Chris Roberts + Jason Gruber]* *** Review session (with TAs); X-RAY LAB SESSION TO MEASURE TEXTURE ON STUDENT-GENERATED SAMPLES;

Homework 2: practice with popLA to analyze a data set with iteration on the defocusing correction; exercises on locating components, conversion from one representation to another, maps of components in various spaces

Week 3

Jan. 25th *[ADR]* Concept of Orientation Distribution; Orientation space; OD maps; Euler angles; discrete vs. functional ODs; Texture Components (review); Groups (elementary theory for graduate students).

Jan. 27th *[ADR]* Different methods of representing ODs; Symmetry; Sample vs. Crystal Symmetry; Effect of symmetry on Representation of Texture; square, polar plots;.

Homework: analysis of students' samples' pole figure data with popLA; conversions of sets of discrete data to intensities in orientation space; calculation of locations in pole figures from texture component locations in orientation space.

Week 4

Feb. 1st *[ADR]* Volume fractions; invariant measure; how to extract useful information from data sets;
Feb. 3rd *[ADR]* Electromigration resistance in Interconnects, Fiber textures, Inverse Pole Figures, examples of fiber textures in thin film, Cu, HTSC.

Homework: Microscopy exercises (PK)

Week 5
[SIPS/Prognosis meeting] ADR away for part of the week
Feb. 8th *[PK]* Specimen Preparation; Scanning Electron Microscopy (SEM); diffraction; extension to the TEM.
Feb. 10th *[PK]* EBSD/ Orientation Imaging Microscopy (OIM).

Homework: literature search; stereology, topology questions

Week 6
[TMS Annual Meeting] ADR and PK in San Francisco all week
Feb. 15th *[ADR]* Grain Boundaries; Misorientation calculation
Feb. 17th *[ADR]*

Homework: calculation of OD's from measured textures; calculation of volume fractions

Week 7 (Week 8 at FAMU/FSU)

Feb. 22nd *[ADR]* Misorientations; Rodrigues vectors, space;
Feb. 24th *[PK]* Transmission Electron Microscopy

Homework: **Mid-term take-home**

Week 8

Mar 1st *[ADR]* (a) Analysis of EBSD data (b) Grain boundary properties.
Mar. 3rd *[ADR]* (a) Analysis of EBSD data, contd. (b) What is a Coincident Site Lattice? CSL boundaries.

Homework: mastery of tensor algebra

Week 9
[PET Technical Review – OSU, Columbus] ADR away intermittently
Spring Break at both CMU and FSU/FAMU ; no live classes
Mar. 8th
Mar. 10th

Homework:

Week 10

Mar. 15th *[ADR]* Quantification of Microstructure: Stereology; Delesse's Principle; Elementary results.
Mar. 17th *[ADR]* Stereology: second phase particles, mean free path between particles, nearest neighbor distances, particle pinning of dislocations/boundaries.

Homework5: Stereology, image analysis, use of ImageJ

Week 11

Mar. 22th *[PK]* The origin and causes of texture in bulk materials (primarily thermomechanical processing).
Mar. 24th *[PK]* Thermomechanical processing and its effect on texture, contd.;

Homework 6: texture development in thermomechanical processing

Week 12

Mar. 29th *[ADR]* (a) Topology of Grain Boundary Networks; (b) Key aspects of EBSD data acquisition
Mar. 31st *[ADR]* Introduction to Percolation; k^{th} Nearest Neighbor Analysis; Pair Correlation Functions

Homework: calculation of percolation of a network; pair correlation function.

Week 13
Apr. 5th *[ADR]* Introduction to the Taylor model; the Bishop-Hill model.
Apr. 7th *[ADR]* Plastic Anisotropy; Schmid's Law.

Homework: solution of Bishop-Hill equations for single crystals (use of matlab or mathematica advised)

Week 14

Apr. 12th *[ADR]* Yield Surfaces.
Apr. 14th *[ADR]* Rate Sensitive Yield.

Homework:

Week 15

Apr. 19th *[ADR]* Application of Taylor Model for anisotropy:Plastic Anisotropy: r-value, polycrystal yield surfaces
Apr. 21st *[ADR]* Elastic anisotropy

Exam: Take-home

Week 16
Last Week of Classes at CMU
Apr. 26th *[ADR]* Student Presentations; see below for a schedule.
Apr. 28th *[ADR]* Student Presentations, continued. Presentations will count for 20% of the (take-home) final. The topic for presentation is anisotropy (yield surface, or r-value variation, or simply some ratio of yield stresses in different directions) of the material or specimen characterized for part A of the mid-term.

Unassigned lectures:

Calculation of OD's from PF's – the 'fundamental equation of texture'; methods involving spherical harmonic functions; calculation of ODs from PFs using discrete methods..
Triple Junctions, equilibrium at junctions, networks of boundaries.
Conversions between different grain boundary descriptions.

Unassigned homeworks:

Calculation of volume fractions along the beta fiber in rolled Cu (Hwk 3 from Spg 2000).

Measurement of a set of PF data (each site to provide a specimen: CMU specimens = 6111 aluminum alloy, provided by Prof. D. Embury, McMaster Univ.)

Presentation Schedule, 26th and 28th April:

Tuesday, 26th		
Time		Name
11:15	Samuel	Adedokun
11:25	Jamma	Bouhattate
11:35	Manuel	Ramos
11:45	Charney	Davey
11:55	Nicholas	Bembridge
12:05	Daniel	Braley
12:15	Jeffrey	Cooper
12:25	Robert	Campman
12:35	Sinan	Filiz
12:45	Daniel	Hennessy
Thursday, 28th		
11:15	Benjamin	Lawson
11:25	Sukbin	Lee
11:35	Samuel	Lim
11:45	Jeremiah	Macsleyne
11:55	Stephen	Sintay
12:05	Dejan	Stojakovic
12:15	Xianping	Wu
12:25	Hari	Duvvuru
12:35	Chris	Hovanec
12:45	Thirumalesh	Bannuru

Test, Exams, Grading Policy

Homeworks: 1 per week	100 points
Exams: two (take home)	see weighting below

Grading Policy	A > 90%
	B > 80%
	C > 65%
	D > 55%

The instructor will request an Oral exam in borderline cases.

Weighting:	Homeworks	50
	Exams	50

Notes: the distribution between the two exams is 20% for the mid-term and 30% for the final (comprehensive). 20% of the Final will be assessed on the presentation.

BOOKS

Cullity, B. D. (1978). *Elements of X-ray Diffraction*, Addison-Wesley, Reading, Mass.

Bunge, H. (1982). *Texture Analysis in Materials Science*. London, Butterworths. (located in the reference section)

Gottstein, G. and L. S. Shvindlerman (1999). *Grain Boundary Migration in Metals*, CRC Press, Boca Raton, FL, ISBN 0-8493-8222-X.

Howe, J.M. (2000). *Interfaces in Materials*, Wiley Interscience, New York, NY, ISBN 0-471-13830-4.

* Kocks, U. F., C. Tomé, and H.-R. Wenk, Eds. (1998). *Texture and Anisotropy*, Cambridge University Press, Cambridge, UK.

Morawiec, A., *Orientations and Rotations* (2003), Springer (Europe), ISBN 3-540-40734-0.

Nye, J. F. (1957). *Physical Properties of Crystals*. Oxford, Clarendon Press.

Ohser, J. and F. Mücklich (2000), *Statistical Analysis of Microstructures in Materials Science*., Chichester, England: Wiley, 381pp, ISBN 0-471-97486-2.

Randle, V. and O. Engler (2000). *Texture Analysis: Macrotexture, Microtexture & Orientation Mapping*, Gordon & Breach, Amsterdam, Holland, ISBN 90-5699-224-4.

Reid, C. N. (1973). *Deformation Geometry for Materials Scientists*. Oxford, UK, Pergamon.

Sutton, A. P. and R. W. Balluffi (1995). *Interfaces in Crystalline Materials*. Clarendon Press, Oxford, UK.

Underwood, E. E., *Quantitative Stereology*, (1970), Addison Wesley Longman, ISBN: 0201076500.

Links: a sampling from a recent search in Google with "crystallographic texture".

Quantitative **Texture** Analysis using x-ray and neutron **...**
QTA Internet Course. **...** Learn how to Quantitatively Determine the
Crystallographic
Texture of materials using x-ray and neutron diffraction **...**
pecdc.univ-lemans.fr/qta/ - 6k - Cached - Similar pages

JMR Abstracts: November 1997 Vol. 13, No. 11
Article Substrate strain induced **crystallographic texture** in sputtered vanadium metal films M. Ghanashyam Krishna, KK Mallick, AK Bhattacharya (University of
...
www.mrs.org/publications/jmr/jmra/1998/nov/027.html - 3k - Cached - Similar pages

JMR Abstracts: October 1998
Article A method for **crystallographic texture** investigations using standard x-ray
equipment MD Vaudin * , MW Rupich + , M. Jowett + , GN Riley, Jr. + , JF **...**
www.mrs.org/publications/jmr/jmra/1998/oct/027.html - 4k - Cached - Similar pages
[More results from www.mrs.org]

ASTRO-group: **Crystallographic texture**
Crystallographic texture. experimental methods, quantitative **texture** analysis (ODF); prediction of **texture** based anisotropic properties **...**
www.mtm.kuleuven.ac.be/Research/ASTRO/Crystal.html - 6k - Cached - Similar pages

Session A25 - Laser Ablation and Low-Energy Beam-Assisted **...**
... This abstract was not submitted electronically. [A25.04]
Crystallographic Texture in Films Using Ion Beams. **...**
flux.aps.org/meetings/YR97/BAPSMAR97/abs/S250.html - 10k - Cached - Similar pages

Crystallographic Texture Determinations From Elevated-Temper **...**
... [J22.02] **Crystallographic Texture** Determinations From Elevated-Temper ature Suspectibility Measurements. **...**
flux.aps.org/meetings/YR9596/BAPSMAR96/abs/S2230002.html - 2k - Cached - Similar pages
[More results from flux.aps.org]

Untitled
THE PROCESS OF SHEAR BAND FORMATION IN PLANE STRAIN COMPRESSION OF FCC METALS:
EFFECTS OF **CRYSTALLOGRAPHIC TEXTURE**. L. Anand and SR Kalidindi. ABSTRACT. **...**
arvind.coe.drexel.edu/faculty/surya/html/anand3.html - 3k - Cached - Similar pages

Untitled
AN APPROXIMATE PROCEDURE FOR PREDICTING THE EVOLUTION OF **CRYSTALLOGRAPHIC TEXTURE**
IN BULK DEFORMATION PROCESSING OF FCC METALS. SR Kalidindi and L. Anand **...**
arvind.coe.drexel.edu/faculty/surya/html/anand1.html - 2k - Cached - Similar pages
[More results from arvind.coe.drexel.edu]

Crystallographic Texture and the Austenite Grain Structure of **...**
Crystallographic Texture and the Austenite Grain Structure of Low-Alloy Steel Weld
Deposits SS Babu, HKDH Bhadeshia and L.-E. Svensson. Abstract. **...**
www.msm.cam.ac.uk/phase-trans/abstracts/columnar.aust.html - 2k - Cached - Similar pages

Crystallographic Texture in Mechanically Alloyed ODS MA956 and **...**
Crystallographic Texture in Mechanically Alloyed ODS MA956 and MA957 Steels
TS Chou and HKDH Bhadeshia University of Cambridge. Abstract. **...**
www.msm.cam.ac.uk/phase-trans/abstracts/ma956.texture.html - 3k - Cached - Similar pages
[More results from www.msm.cam.ac.uk]

CRYSTALLOGRAPHIC TEXTURE AND MECHANICAL ANISOTROPY
Preliminary Program. INTERNATIONAL CONFERENCE ON **CRYSTALLOGRAPHIC**
TEXTURE AND MECHANICAL ANISOTROPY. **...**
www.engfnd.org/pastconf/7bkpre.html - 12k - Cached - Similar pages

Trans Tech Publications: Relationship between **Crystallographic ...**
... Relationship between **Crystallographic Texture** and Dilatometric Behaviour of a Hexagonal Polycrystalline Material. **...**
www.scientific.net/html/0-87849-802-8_529.html - 3k - Cached - Similar pages

Trans Tech Publications: An Analysis of the Influence of ...
... An Analysis of the Influence of **Crystallographic Texture** on Residual Stress Estimation for Metallic Films and Coatings. ...
www.scientific.net/html/0-87849-742-0_311.html - 3k - Cached - Similar pages
[More results from www.scientific.net]

Home Page
... Measuring **crystallographic texture** in thin films.
Mark D. Vaudin The **crystallographic texture** of ...
www.ceramics.nist.gov/programs/thinfilms/texture.html - 11k - Cached - Similar pages

Crystallographic Texture
CRYSTALLOGRAPHIC TEXTURE ANALYSIS OF Ti-6Al-4V POROUS CORES.
ginsburg.ipm.virginia.edu/research/posters/dtq2jweb1/texture.htm - 1k - Cached - Similar pages

THE **CRYSTALLOGRAPHIC TEXTURE** AND PROPERTIES OF METALL MATERIALS ...
The **crystallographic texture** and properties of metall materials,
recieved by the PDME-method. ...
rqten.indialinks.com/abstracts/abs210.html - 3k - Cached - Similar pages

Untitled
... Measurement and Representation of **Texture** Gradients
in Thick Aluminum Plate. ... Sponsored by the National ...
www.mae.cornell.edu/dplab/MPM/Turner/turnerTitle.html - 1k - Cached - Similar pages

THE **CRYSTALLOGRAPHIC** FABRIC AND **TEXTURE** OF SIDERITE IN ...
THE **CRYSTALLOGRAPHIC** FABRIC AND **TEXTURE** OF SIDERITE IN CONCRETIONS: IMPLICATIONS
FOR SIDERITE NUCLEATION AND GROWTH PROCESSES Mark W. Hounslow, Geography Dept ...
geog-main.lancs.ac.uk/cemp/publications/00hounspap.htm - 6k - Cached - Similar pages

Activités récentes
... JL PEETERS "Torsional behaviour of perlitic wires according to their **crystallographic**
texture" A paraître dans Wire Journal International (July) 1999-06-08. ...
www.letam.sciences.univ-metz.fr/activitesRecentes.htm - 58k - Cached - Similar pages

[Mikrostruktur und Umformtechnik]
... Science 30 (1995) 47-52. "Inhomogeneity of the **crystallographic texture** in a hot
rolled austenitic stainless steel" D. Raabe: Computational Materials Science 3 **...**
www2.mpie-duesseldorf.mpg.de/msu-web/Publikationen/liste_raabe.htm - 36k - Cached - Similar pages

[Untitled]
S0825. THE DETERMINATION AND IMAGING OF **CRYSTALLOGRAPHIC TEXTURE** USING ELECTRON
BACKSCATTER DIFFRACTION. DJ Dingley, TexSEM Laboratories, Provo, Utah and The **...**
crystsun1.unige.ch/iucr-top/cong/17/iucr/abstracts/abstracts/ S0825.html - 3k - Cached - Similar pages

[- Click to Select - -]
The Influence of **Crystallographic Texture** and Interstitial
Impurities on the Mechanical Behavior of Zirconium. **...**
doc.tms.org/Site/products.nsf/LookupUNID/13CC57C4779F632D8525694B00534B08?OpenDocument - 10k - Cached - Similar pages

[JEM Abstracts: September 1997]
... Crystallographic Texture of C54 Titanium Disilicide as a Function of Deep Submicron
Structure Geometry V. SVILAN, KP RODBELL, LA CLEVENGER, C. CABRAL, JR., RA **...**
www.tms.org/pubs/journals/JEM/9709/abstracts-9709.html - 33k - Cached - Similar pages

[Titre de page]
... 6T1 : High temperature furnace for **crystallographic**
texture measurements. A new furnace has been **...**
www-llb.cea.fr/tr/00/news00.html - 12k - Cached - Similar pages

[Scientific Report 1992-1994]
... The **crystallographic texture** found in metallic materials plays a very important role
in most metal forming processes. First, the **texture** determines the plastic **...**
www.mtm.kuleuven.ac.be/Research/Report94/Chapter7.html - 21k - Cached - Similar pages
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[primer.htm]
... from sheet is also compromised. The weld area suffers from a random **crystallographic**
texture (grain structure), with reduced fatigue endurance (see Butting **...**

spectrum-cycles.com/primer.htm - 76k - Cached - Similar pages

the title!
... is also compromised. The weld area suffers from a random **crystallographic texture**
(grain structure), with reduced fatigue endurance (see Butting considerations **...**
www.racingcyclist.com/titaniumrevealed2.htm - 90k - Cached - Similar pages

Past Event, April 1998, ASM Chicago Regional Chapter
... John S. Kallend. "**Crystallographic Texture**, A Combination of the Invisible with the Incomprehensible". Tuesday, April 14th, 1998. **...**
mmae.iit.edu/~asmchi/past_events/1998/apr1998.html - 4k - Cached - Similar pages

Allen J. McGrew
... by Dr. Geoff Lloyd at Leeds University, Leeds, UK Integrated complete **crystallographic**
texture analysis with microstructural investigation to model strain path **...**
www.udayton.edu/~geology/faculty/mcgrew/ - 20k - Cached - Similar pages

JOURNAL ARTICLES
... YN Hsu and DN Lambeth, "The development and characterization of **crystallographic**
texture in thin films for magnetic recording," Ultrathin Films, Multilayers **...**
neon.mems.cmu.edu/laughlin/pdf/ARTICLES.html - 83k - Cached - Similar pages

Untitled
... opinions/questions. Synchrotron radiation Positions vacant **Crystallographic texture**
determination Biological crystallography and applications Anything else **...**
www.landfield.com/usenet/news.announce.newgroups/sci/sci.techniques.xtallography - 73k - Cached - Similar pages

Personal information for Lallit Anand
... in the past decade" Current Research (i) **Crystallographic texture** effects in thin
films and shape memory materials. (ii) Effects of surface micro-topographies **...**
me.mit.edu/people/anand.html - 13k - Cached - Similar pages

JOM Subject Index: **Texture**
... Incorporating **Crystallographic Texture** in Deformation Process Simulations" (Overview),
PR Dawson and AJ Beaudoin, Jr., September 1997, pp. 34-41, 83. **...**
www.tms.org/pubs/journals/JOM/indexes/texture.html - 4k - Cached - Similar pages
[More results from www.tms.org]

Texture and Anisotropy of Crystalline Materials
... the same name. The **crystallographic texture** describes the geometric arrangement of
crystallites (microstructure) in a polycrystalline material. It is important **...**
Description: **Texture** and Anisotropy of Crystalline reference
Category: Science > Technology > Materials
www.texture.de/index_e.htm - 6k - Cached - Similar pages

Untitled
... or **texture**. **Crystallographic texture** may be tailored to enhance the performance
through optimization of materials and deposition processes. The fundamental **...**
www.hypernexinc.com/technicalnote1.htm - 5k - Cached - Similar pages

Instrument for **Texture** Mapping
... ABSTRACT. Traditionally the **crystallographic texture** has been measured by x-ray
diffraction methods using four circle goniometers. Such measurements are slow **...**
www.hypernexinc.com/Instrument_for_Texture_Mapping.html - 19k - Cached - Similar pages
[More results from www.hypernexinc.com]

(IUCr-**Crystallographic** Education Online) Educational Resources
... QTA Internet Course Learn how to Quantitatively Determine the **Crystallographic Texture**
of materials using x-ray and neutron diffraction by D. Chateigner and A **...**
www.iucr.org/cww-top/edu.index.html - 21k - Cached - Similar pages

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... material that has a high degree of in-plane and out-of-plane **crystallographic texture** and can be produced in long lengths. Epitaxial HTS films on single **...**
www.ornl.gov/HTSC/htspc8/sect-1.htm - 101k - Cached - Similar pages

Texture Measurement and Analysis Capabilities
... Measurement of bulk **crystallographic texture** is supported by two X-ray units located
in the CMS. Each of these systems incorporates four-circle goniometers for **...**
www.ccp14.ac.uk/ccp/web-mirrors/popla/cms/texture.html - 7k - Cached - Similar pages

Abstracts

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