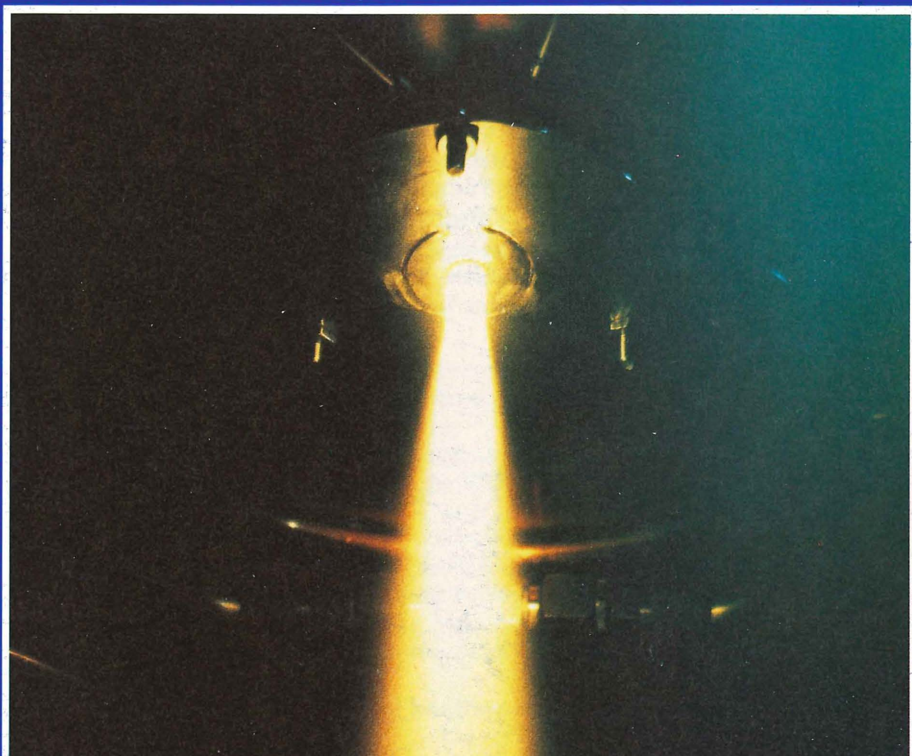
VAMAS



BULLETIN NO. 19
July 1995

Versailles Project on Advanced Materials and Standards
• Canada • France • Germany • Italy • Japan • UK • USA • EC •

VAMAS

The Versailles Project on Advanced Materials and Standards (VAMAS) supports trade in high technology products through international collaborative projects aimed at providing the technical basis for drafting codes of practice and specifications for advanced materials. The scope of the collaboration embraces all agreed aspects of enabling science and technology - databases, test methods, design methods, and materials technology - which are required as a precursor to the drafting of standards for advanced materials. VAMAS activity emphasizes collaboration on pre-standards measurement research, intercomparison of test results, and consolidation of existing views on priorities for standardization action. Through this activity, VAMAS fosters the development of internationally acceptable standards for advanced materials by the various existing standards agencies.

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Cover: Exit stream of molten metal droplets from the die of a supersonic inert gas atomization system. Powder atomization technology can produce powders with unique properties due to very high chemical homogeneity, metastable phases, and other novel microstructures.

Photograph courtesy of National Institute of Standards & Technology, Gaithersburg, MD, USA

VAMAS

• Table of Contents •

Foreword

The 18th meeting of the VAMAS Steering Committee was hosted by the International Organization for Standardization (ISO), and followed the publication of the VAMAS developed unified classification system for advanced technical ceramics as the inaugural issue of the ISO publication series, *Technology Trends Assessment*. I encourage all TWAs to foster a closer relationship wherever possible between VAMAS and ISO and with the IEC as described below.

A. M. Raeburn, General Secretary, International Electrotechnical Commission (IEC), attended the SC session and reported that the draft Memorandum of Understanding between the IEC and VAMAS, similar to the ISO/VAMAS MOU, was under ballot by the IEC members. This MOU provides a framework for cooperation with the IEC in the general area of functional materials. The Petten planning workshop endorsed starting new work projects related to functional materials to complement the existing focus on structural materials. VAMAS TWA 16, Superconducting Materials, has established a strong liaison with IEC TC 90, Superconductivity.

Continuing the recent trend, two new TWAs have been established. In the first action, TWA 20 on Measurement of Residual Stress was approved under the leadership of Prof. George Webster, Imperial College, UK. The initial focus is directed at neutron methods for determining near-surface and bulk residual stresses. The second TWA was established in response to industry needs for valid mechanical property test methods for hardmetals. This activity, TWA 21, Mechanical Measurements for Hardmetals, will be under the leadership of Dr. Bryan Roebuck, NPL, UK, with very strong industrial participataon.

It is with great pleasure that I announce that Mr. Toru Amano of the Ministry of International Trade and Industry (MITI) and Mr. Ryo Imoto of the Science and Technology Agency (STA) have joined the SC representing Japan. I am looking forward to the continued enthusiastic contributions of the Japanese delegation and the strong commitment of Japanese researchers to the TWA programs. The SC extends sincere thanks to retiring SC members Mr. Akihiko Iwahashi and Mr. Joichi Takagi for their hard work and support of VAMAS and its goals.

On a final note, I call your attention to the end of a VAMAS era. Dr. Ernest Hondros, founder and first VAMAS Chairman has retired as Director of the EU Joint Research Center. Dr. Hondros provided the spark and dedication needed to bring together the disparate international materials community to accelerate the introduction of advanced materials into the world's economy. Although no longer representing the EU on the VAMAS Steering Committee, I and future Chairmen of VAMAS will, I am sure, continue to call on Dr. Hondros for advice and guidance.

Harry L. Rook
Chairman

• Standards Highlights •

VAMAS fosters the development of internationally acceptable standards for advanced materials by the various existing national, regional, and international standards agencies. A major focus for each Technical Working Area is to further strengthen its ties to the standards-writing community. With the increasing number of concluded pre-standards research projects, it is essential that the results be rapidly transferred to standards-writing organizations. Although not every pre-standards research project produces definitive test results in direct support of a specific standards effort, we continue to see the impact of VAMAS efforts through their recognition in an increasing number of adopted standards.

Standards Highlights identifies draft or adopted standards documents from national, regional, or international standards bodies that are based all or in part on technical outputs from VAMAS TWAs. In the absence of a central standards clearinghouse, VAMAS participants are strongly encouraged to notify the Secretariat of any such adopted standards and to send a copy to the VAMAS Secretary.

Recent Adopted standards include:

1] JIS R 1617, ***Testing Method for Fracture Toughness of High Performance Ceramics at Elevated Temperatures,*** adopted in 1993, Japanese Industrial Standard Committee. VAMAS contributor - TWA 3, Ceramics, G. Quinn, Chairman.

Recent Draft standards include:

1] Draft ASTM Standard, ***Fractography and Characterization of Fracture Origins in Advanced Ceramics,*** under development by ASTM Committee C28, Advanced Ceramics, VAMAS Contributor - TWA 3, Ceramics, G. Quinn, Chairman.

• Feature Article •

ISO TECHNICAL COMMITTEE 206 ON FINE CERAMICS

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In November 1992, the International Organization for Standardization (ISO) formally approved the establishment of a new Technical Committee (ISO/TC 206) on Fine Ceramics in response to a proposal from the Japanese member body. Currently, the membership of ISO/TC 206 is composed of eight P(Participant)-members and twenty-five O(Observer)-members. The first plenary meeting of ISO/TC 206 took place on May 26-27, 1994 in Tokyo, Japan. At this meeting, the following items were discussed and approved: the provisional Title and Scope, New Work Item Proposals, the Organization Structure of ISO/TC 206, and Cooperation and Liaisons with other organizations including VAMAS.

1 Introduction

In response to a proposal of "Early-Stage Standardization" by the ISO/IEC Presidents' Advisory Board on Technological Trends, the Japanese member body, the Japanese Industrial Standards Committee (JISC) made a formal proposal to ISO to establish a new ISO Technical Committee (TC) on Fine Ceramics. Following a ballot among the ISO member bodies, the ISO Council approved the establishment of this new technical committee in November 1992. In December 1992, the ISO Technical Board (TB) registered this new technical committee as ISO/TC 206 and approved the following provisional title and scope for the committee:

Title: Fine ceramics
Scope: Standardization in the field of fine ceramics powders, monolithic ceramics, fine ceramics based composite materials, and fine ceramics coatings.

The ISO/TB allocated the secretariat for ISO/TC 206 to JISC (Japan). The JISC appointed Dr. Takashi Kanno (Research Center, Asahi Glass Co., Ltd., Japan) as Secretary and the ISO/TB appointed Mr. Samuel Schneider (Materials Science and Engineering Laboratory, National Institute of Standards and Technology, USA) as ISO/TC 206 Chairman.[1]

2 Existing Standardization Activities

Standardization activities on Fine Ceramics are currently being carried out by the following organizations:

(1) Divisional Council on Ceramics of Japanese Industrial Standards (JIS)[2]
(2) Committee C28 on Advanced Ceramics of the American Society for Testing and Materials (ASTM Committee C28)[3]
(3) Technical Committee on Advanced Technical Ceramics of European Committee for Standards (CEN/TC 184)[4]
(4) Versailles Project on Advanced Materials and Standards (VAMAS)[5]
- Technical Working Area on Wear Test Methods (TWA 1)
- Technical Working Area on Ceramics (TWA 3)
- Technical Working Area on the Technical Basis for a Unified Classification System for Advanced Ceramics (TWA 14)

(5) Cooperative Program on Ceramics for Advanced Engines and Other Conservation Applications (Annex II) of International Energy Agency (IEA)
- Subtask 7 on Mechanical Properties of Structural Ceramics
- Subtask 8 on Ceramic Powders Characterization

3 Recent Activities of ISO/TC 206

3.1 Preliminary Meeting of ISO/TC 206 in Hawaii

An "Introduction to ISO/TC 206 Meeting" was held on November 8, 1993 during the 1993 American Ceramic Society (ACerS) Pac Rim Meeting in Hawaii. Twenty-four scientists participated in this meeting from seven countries (Australia, Canada, China, Germany, Japan, South Africa and USA). In this meeting, the Secretary reported the circumstances of the establishment and the membership of ISO/TC 206. The recent standardization activities on Fine Ceramics in JIS, ASTM C28 and CEN/TC 184 were reviewed. Open discussions were held on the provisional title and scope of ISO/TC 206 as well as the new work items and organization structure for ISO/TC 206. Since resources are limited, it was agreed to consider establishing work item priorities for initial activities.

3.2 Questionnaire Concerning New Work Item Proposals

In response to the decisions made at the Hawaii meeting, a questionnaire identifying possible New Work Item Proposals was circulated to P- and O- members. Using the summary of the questionnaire responses, the Secretariat prepared the document of Draft New Work Item Proposals for the first plenary meeting.

4 The First Plenary Meeting of ISO/TC 206 in Tokyo

4.1 Membership of ISO/TC 206 on Fine Ceramics

The membership (as of July 1995) is given in Table 1. There are currently eight P-members and twenty-five O-members. The first plenary meeting of ISO/TC 206 was held in Tokyo on May 26-27, 1994. The attendees were as follows:

P-members: Australia, Indonesia, Japan, Rep. of Korea, Malaysia and the USA
O-members: Germany, United Kingdom, CEN/TC 184

4.2 Title and Scope of ISO/TC 206

ISO/TC 206 approved the revised title and scope as given in the following:

Title:	Fine Ceramics
Scope:	Standardization in the field of fine ceramic materials and products in all forms: powders, monoliths, coatings and composites, intended for specific functional applications including mechanical, thermal, chemical, electrical, magnetic, optical and combinations thereof. The term "fine ceramics" is defined as "a highly engineered, high performance, predominantly nonmetallic, inorganic material having specific functional attributes".

*[note] Alternative terms for fine ceramics are advanced ceramics, engineered ceramics, technical ceramics, or high performance ceramics

4.3 New Work Item Proposals

On the basis of the questionnaire summary concerning initial priorities of new work items for ISO/TC 206, a list of New Work Item Proposals was approved as given in Table 2.

4.4 Organization Structure for ISO/TC 206

ISO/TC 206 approved the formation of Working Groups with conveners, as given in Table 3, to address the new work items in Table 2. Also approved was the formation of an advisory group on planning in order to develop a work plan of future new work items.

4.5 Cooperation and Liaisons with Other Organizations

ISO/TC 206 requested that a CEN member state become a P-member for the purpose of providing a convener for the draft work item on classification only, or alternatively through the Vienna Agreement between ISO and CEN that CEN/TC 184 convenes and drafts the work item on classification for parallel development/voting.

It was agreed that ISO/TC 206 would determine whether it is appropriate that a liaison be established with IEA (International Energy Organization)/Annex II for:

Subtask 7	Mechanical Properties of Structural Ceramics
Subtask 8	Ceramic Powders Characterizataon

ISO/TC 206 approved the establishment of a category A liaison with four VAMAS working groups:

VAMAS/TWA	1	Wear Test Methods
VAMAS/TWA	3	Ceramics
VAMAS/TWA	10	Material Databanks
VAMAS/TWA	14	Unified Classification Systems for Advanced Ceramics

ISO/TC 206 resolved to establish a category A liaison with the International Ceramic

Federation in the area of terminology.

ISO/TC 206 approved the formation of liaisons with other relevant ISO or IEC technical committees, e.g.:

ISO/TC 3	Limits and fits
ISO/TC 24	Sieves, sieving and other sizing methods
ISO/TC 33	Refractories
ISO/TC 164	Mechanical testing of metals
IEC/TC 15	Insulating materials

4.6 The Second Plenary Meeting of ISO/TC 206 in Malaysia

The second plenary meeting is scheduled for May 1995 in Malaysia as a three-part session. To lead off, the Standards and Industrial Research Institute of Malaysia (SIRIM) will host a workshop on fine (advanced) ceramics. Following the workshop, the four ISO/TC 206 working groups will hold their individual meetings. The ISO/TC 206 main meeting will close the plenary meeting.

5 Summary

In response to a proposal of "Early-Stage Standardization" by ABTT, ISO/TC 206 on Fine Ceramics was established in November 1992. At the first plenary meeting in May 1994, the four New Work Item Proposals and the Working Groups to address each work item were apprgved. Harmonized International Standards on Fine Ceramics are to be prepared on the basis of established and draft standards developed by national and regional standards organizations. Cooperative activities between ISO/TC 206 and VAMAS project are anticipated.

6 Acknowledgement

The author thanks Mr. S. Schneider, Chairman, ISO/TC 206 and Dr. J. G. Early, Secretary, VAMAS, for assistance in the preparation of this article.

7 References

1. T.Kanno, *Scope of International Standardization of Fine (Advanced) Ceramics*, Presented at the 8th CIMTEC, Firenze, Italy - June 30,1994.
2. K.Matsuhiro and M.Matsui, *Present Status of Standardization for Fine Ceramics in Japan*, Presented at the International Gas Turbine and Aeroengine Congress and Exposition, Cincinnati, Ohio - May 24-27, 1993.
3. G.D.Quinn, *Standards Activities, ASTM Committee C-28, Advanced Ceramics - A Progress Report*, ACerS Bull., 71, No.10 (1992) 1508.
4. J.J.Kubler and R.Morrell, *European Standardization Activities for Advanced Technical Ceramics*, Presented at the International Gas Turbine and Aeroengine Congress and Exposition, Cincinnati, Ohio - May 24-27,1993.
5. J.G.Early, *VAMAS: Phase II(1992-1997) Status Report*, VAMAS Bulletin No.17 (1994) pp. 3-5.

Table 1 Membership of ISO/TC 206 on Fine Ceramics (as of July 1995)

P (Participant)-members (8)

Australia	Standards Australia (SAA)
China	China State Bureau of Technical Supervision (CSBTS)
Indonesia	Dewan Standardisasi National (DSN)
Japan	Japanese Industrial Standards Committee (JISC)
Korea, Republic of	Bureau of Standards (KBS)
Malaysia	Standards and Industrial Research Institute of Malaysia (SIRIM)
Russian Federation	Committee of the Russian Federation for Standardization, Metrology and Certification (GOST R)
USA	American National Standards Institute (ANSI)

O (Observer)-members (25)

Austria	Osterreichisches Normunginstitut (ON)
Belgium	Institut Belge de Normalisation (IBN)
Cuba	Comite Estatal de Normalizacion (NC)
Denmark	Dansk Standard (DS)
Ecuador	Instituto Ecuatoriano de Normarizacion (INEN)
Egypt	Egyptian Organization for Standardization and Quality Control (EOS)
France	Association Francaise de Normalisation (AFNOR)
Germany	Deutsches Institut fur Normung (DIN)
Italy	Ente Nazionale Italiano di Unificazione (UNI)
Jamaica	Jamaica Bureau of Standards (JBS)
Netherlands	Netherlands Normalisatie-Instituut (NNI)
Norway	Norges Standardiseringsforbund (NSF)
Philippines	Bureau of Product Standards (BPS)
Poland	Polish Committee for Standardization (PKNMiJ)
Slovakia	Standards and Metrology Institute (SMIS)
South Africa	South Africa Bureau of Standards (SABS)
Spain	Asociacion Espanola de Normalizacion y Certificacion (AENOR)
Sweden	Standardiseringskommissionen i Sverige (SIS)
Switzerland	Swiss Association for Standardization (SNV)
Thailand	Thai Industrial Standards Institute (TISI)
Turkey	Turk Standardlari Enstitusu (TSE)
Ukraine	State Committee of Ukraine for Standardization (DSTU)
United Kingdom	British Standards Institution (BSI)
Yugoslavia	Savezn i za standardizacij u (SZS)
Uganda	Uganda National Bureau of Standards (UNBS)

Table 2 New Work Item Proposals of ISO/TC 206 on Fine Ceramics

Work Item	Title
NWI 1	Test Methods for Particle Size Distribution of Ceramic Powders
NWI 2	Test Methods for Flexural Strength of Monolithic Ceramics at RT
NWI 3	Test Methods for Hardness of Monolithic Ceramics at RT
NWI 4	Classification of Fine Ceramics

Table 3 Working Groups of ISO/TC 206 on Fine Ceramics

Working Group	Title	Convener
WG 1	Particle Size Distribution of Ceramic Powders	JAPAN Mr. Jun-Ichiro Tsubaki, Nagoya University
WG 2	Flexural Strength of Monolithic Ceramics at RT	USA Mr. George Quinn, National Institute of Standards and Technology
WG 3	Hardness of Monolithic Ceraeics at RT	JAPAN Mr. Shyuji Sakaguchi, National Industrial Research Institute of Nagoya
WG 4	Classification of Fine Ceramics	CEN/TC184/WG1 (Under consideration)

• Recent VAMAS Outputs •

EXTENDED ABSTRACT

"ISO/VAMAS TECHNOLOGY TRENDS ASSESSMENT ISO/TTA 1
Advanced Technical Ceramics - Unified Classification System"
TWA 14 - Classification of Advanced Ceramics

S. Schneider, Chairman
National Institute of Standards and Technology
Gaithersburg, Maryland, USA

To respond to the need for global collaboration on standardization questions at early stages of technological innovation, the International Organization for Standardization (ISO) Council decided to establish a new series of ISO publications named "Technology Trends Assessments" (ISO/TTA). These publications are the results of either direct cooperation with prestandardization organizations or ad hoc workshops of experts concerned with standardization needs and trends in emerging fields. Technology Trends Assessments are thus the result of prestandardization work or research. As a condition of publication by ISO, ISO/TTAs shall not conflict with existing or draft International Standards but shall contain information that would normally form the basis of standardization. It is intended that these publications will contribute towards rationalization of technological choice prior to market entry.

In 1991, ISO and VAMAS began to explore the development of a more formal linkage between the two organizations, recognizing the role of VAMAS in developing the technical basis for developing standards for advanced materials. Recognizing that a formal relationship with ISO would accelerate advanced materials standards development, VAMAS and ISO signed a Memorandum of Understanding (MoU) in 1993 governing mutual cooperation, particularly in the area of joint publications. ISO had already established the new Technology Trends Assessments publication series to highlight the results of prestandardization research. Based on the MoU, appropriate VAMAS-developed documents would be published and disseminated in the ISO/TTA series.
9The inaugural document, ISO/TTA 1 issued in April 1994, was developed by VAMAS[1,2] and reports the results of the Technical Working Area (TWA) 14 of VAMAS. This TWA had the task of proposing a classification of advanced technical ceramics and which retains responsibility for the technical content of this ISO/TTA. The ISO technical Board approved the publication of this classification as an ISO/TTA in August 1993 and this publication has been brought to the attention of Technical Committee ISO/TC 206, Fine Ceramics, for use in its standardization work.

The primary vision of this ISO/TTA is to propose a classification system for advanced technical ceramics (also known as fine ceramics or advanced ceramics) which can form the basis for a multi-level database. This classification system is intended to meet the following objectives:

- it should provide a comprehensive description of materials, products and applications of advanced technical ceramics
- it should be able to accommodate new materials and products as they become available
- it should be accessible via the following four descriptor fields, either individually or in combination: Application; Chemical character (including form); Processing;^Eand Property data
- its coding system should be machine readable, thereby providing a means of sorting data with in descriptor fields
- its coding system should be such that it can be simplified by truncation and elimination of redundant characters or, where only limited information is required, by limitation of the number of descriptor fields
- the coding system should be simple to use and employ characters and strings which are both easy to recognize and relate to classification information.

The term "advanced technical ceramics" covers a wide range of materials which may be used in diverse applications. For this ISO/TTA it is assumed that advanced technical ceramics include materials in the following forms: monolithic ceramics; powders; composite ceramics; fibers; glasses; glass ceramics; coatings; and porous materials and, in addition, halides and single crystals. Specifically excluded from the classification system are the following: elemental carbon, except for specific ceramic forms such as diamond, vitreous carbon and chemical vapor deposited graphite; elemental silicon, other than when it forms an integral component of or precursor for an advanced technical ceramic; elemental germanium and other elemental or compound semi-metallic substances; tradition ceramics based on clay, including whitewares, sanitary wares, floor and wall tiles, and building ceramics such as bricks and pipes; and unshaped and shaped refractories and bulk glasses for tonnage applications.

The mode of use of the classification system will be determined by the objective behind its use. It is not the purpose of this ISO/TTA to define how the system should be used, but examples are given of how it might be used. It is intended that the user can define the coding combination and level of detail to suit their particular purpose.

EXTENDED ABSTRACT

VAMAS Technical Report No. 19
"Fractography of Advanced Structural Ceramics:
Results from the VAMAS Round Robin Exercise"
by J. J. Swab, U.S. Army Research Laboratory
G. D. Quinn, NIST, Gaithersburg, MD USA

Fractography of ceramic specimens and components is critical in the design and future use of ceramic materials in commercial applications. In 1992 the U.S. Department of Defense released Military Handbook 790 "Fractography and Characterization of Fracture Origins in Advanced Structural Ceramics" (MIL HDBK-790) which furnished guidelines for the comprehensive interpretation of ceramic fractographic information. Even with the release of this handbook there were still some issues which warranted further study.

A round robin exercise sponsored by the Versailles Project on Advanced Materials and Standards (VAMAS) was conducted to determine the applicability of the handbook and to attempt to clarify any ambiguous sections or issues. The exercise was divided into three topics. Topic No 1 addressed the detection and interpretation of machining damage on photographs of ceramic specimens. Topic No 2 dealt with the fractographic analysis of ceramic specimens. Topic No 3 was optional, and asked the participants to perform fractography on a ceramic material of their choice. There were a total of seventeen agencies/institutes/laboratories which participated in the exercise. The group included eight government laboratories, one academic institute, and eight industrial organizations.

This report summarizes the results from this round robin exercise, identifies areas of concern which require further study, provides amendments that will be made to the handbook and evaluates each of the round robin participants fractographic analysis.

The results from Topic No 1 showed that there are problems in detecting and interpreting machining damage in advanced ceramics. These problems stem from a lack of understanding of how machining damage can manifest itself in various ceramic materials. Topic No 2 indicated that the guidelines and characterization scheme outlined in the handbook are adequate to completely characterize fracture origins in ceramics but some refinements are necessary. There was a good to excellent consensus in origin characterization in many cases. The instances where concurrence was not forthcoming helped the round robin organizers understand where improvements to MIL HDBK-790 should be made and also highlighted the key steps that are integral to a proper fractographic evaluation.

General Conclusions

1) Fracture mechanics was not used enough to assist in the characterization of fracture origins.
2) In many instances fractographers failed to use all available information about the material and its history during the characterization.
3) Characterization of the fracture origin size is difficult in many instances.
4) Characterization of origins from photographs or a single specimen can be misleading.
5) Fractographers must examine the mating halves of the primary fracture surface.
6) Fractographers must examine the external surfaces of the specimen or component.
7) Few participants were familiar with fracture mirror size analysis. There is a need for new mirror constants for today's advanced ceramic materials.

Amendments to MIL HDBK-790

General:

1) Actual photographs of fracture features (mirror and hackle lines) on the fracture surfaces will be added to complement the schematics.
2) Use of fracture mechanics will be explained more clearly and illustrated. It shall also be required as a step in the characterization of fracture origins.
3) Examination of both halves of the primary fracture surface will be required.
4) Examination of the external surfaces will be required.
5) Additional information (e.g. list of mirror constants) will be added.

Characterization Scheme:

1) The definition of surface and edge as possible origin locations will be clarified.
2) An example of an origin located near-to-the-surface and a definition of near surface will be included.
3) The method to characterize the origin size will be defined better. For machining damage and other origins located at the surface which have a semielliptical shape the characteristic dimension is the depth.
4) A possible revision may be to include mirror size as an optional, fourth attribute for an origin.

• Recent VAMAS Outputs •

EXTENDED ABSTRACT

VAMAS Technical Report No. 20
"Validation of a Draft Tensile Testing Standard
for Discontinuously Reinforced MMC"

by B. Roebuck, J. D. Lord, and L. N. McCartney
National Physical Laboratory
Teddington, UK

There is a need for a better tensile testing standard for discontinuously reinforced metal matrix composites (MMC). Use of the current ISO standard for metals leads to unsatisfactory uncertainties in the property values measured, particularly for Young's modulus and proportional limit. Following analysis of the results of a UK exercise to examine the sources of uncertainty in the measurement of the tensile properties of SiC reinforced Al alloys a draft procedure was written for tensile tests on particulate MMC at ambient temperatures. The draft procedure recommends appropriate testpiece dimensions, testing rates, methods of gripping, and strain measurement techniques. It also defines methods of measurement of Young's modulus, proportional limit, proof stress, tensile strength and elongation to failure. It contains a recommended proforma for the test report in anticipation of future database requirements. The style of the draft procedure is similar to that adopted for the current EN tensile testing standards, EN10002 part 1 (tensile tests for metals) and its sister document for aerospace materials EN2002-1 part 1. Two validation exercises have been carried out to examine the utility of the draft procedure.

The draft tensile testing standard for discontinuously reinforced metal matrix composites (MMC) has been validated by use in two intercomparisons, one in the UK and one internationally through VAMAS. The UK exercise used UK sourced testpieces of SiC particulate reinforced Al alloy [SiC_p reinforced 2124 Al alloy] and the VAMAS exercise measured the properties of a USA sourced SiC whisker reinforced Al alloy [SiC_w reinforced 2009 Al alloy]. The validation exercises confirmed the utility of the draft standard, (in particular the report proforma and the guidelines on modulus measurement) and quantified the uncertainties in property measurement associated with different strain measurement methods.

Analysis of the results from the VAMAS and UK intercomparisons has indicated the need for a small number of changes to the procedure, including the results proforma. The draft procedure will be modified to take account of these changes (proportional limit, strain rate) and submitted to the appropriate standards bodies for approval. The measurement uncertainties were very much reduced by use of the new test procedure with much of the improvement due to the use of double sided strain measurement systems.

• Recent VAMAS Outputs •

EXTENDED ABSTRACT

"VAMAS Tests of Structural Materials at Liquid Helium Temperature"
by T. Ogata, K. Nagai, K. Ishikawa
National Research Institute for Metals
Tsukuba, Japan
Advances in Cryogenic Engineering, Vol. 40, 1994

A series of international, interlaboratory comparisons of tensile and fracture-toughness tests for prestandardization and refining of these test procedures at liquid-helium temperature using the same materials has been coordinated under the Versailles Project on Advanced Materials and Standards (VAMAS). High strength austenitic stainless steels, YUS170 and SUS316LN, and a titanium alloy were used for this program. The two stainless steels were chosen because they have a high yield strength and good fracture toughness at cryogenic temperatures and both exhibit at liquid helium temperature the so-called "serration" or load drop deformation behavior. The titanium alloy was chosen as representing a high strength-lower toughness material.

Two series of round robin tests have been completed to date. Sixteen laboratories from five nations participated in the first series, and eleven laboratories from six nations participated in the second series. The first series focused on identifying problems and errors that could occur in testing. The results pointed out the necessity of a basic approach to microstrain measurement at liquid helium temperature and load-cell calibration for tensile tests, and the effect of the testing variables on the fracture toughness test.

Based on these results, a revised testing procedure was employed for the second round robin test series. In the tensile tests, constant crosshead control was used with a maximum nominal strain rate. Calibration of the load cell and extensometer was carried out according to the standard procedure of each laboratory and reported with the test results of yield strength, ultimate tensile strength, elongation, reduction of area, and Young's modulus. The fracture toughness tests were conducted in accordance with the standards ASTM E813-87 and -88 ANNEX.

Further study is needed on the effects of the serration and the testing variables of specimen side-grooving, machine control mode, and strain rate. To further refine the tensile testing and fracture testing standards, this program is being extended to a lower strength, lower toughness 2219 aluminum alloy and a composite material.

• Recent VAMAS Outputs •

EXTENDED ABSTRACT

"Comparison of Wear and Friction Measurements of TiN Coatings"
by E. Santner
Bundesanstalat für Materialforschung und -prüfung (BAM)
Berlin, Germany
Tribologia, Vol. XXVI, No. 1, 1995

The preliminary evaluation of an international interlaboratory comparison of wear and friction measurement results on TiN coated steel samples is presented. Following an accepted test procedure 28 laboratories from 12 countries performed friction and wear tests on identical samples which were produced in the same way. The aim of this VAMAS project was to obtain information on the reproducibility of test results to prepare an internationally-agreed test methodology for wear and friction of inorganic coatings.

The samples for the ball on disk tests were composed of a 10 mm diameter stationary ball and a 42 mm diameter, 4 mm thick rotating disk. A TiN coating was chosen because this coating is widely used in industrial applications and should be available with high reproducibility. The balls and disk were made from M50 (DIN 1.3552) steel; the ball hardness was 780-830 (HV 0&2) and 600-800 (HV 0.2) for the disks before coating; and the roughness was about 0.5 µm for the disks and 0.06 µm for the balls before coating. After coating by a plasma-assisted physical vapour deposition process, the roughness was about 1.4 µm. In addition, uncoated M50 balls and silicon nitride (Si_3N_4) balls were distributed for the test program.

Three test campaigns were followed: (1) TiN-coated M50 disks against M50 uncoated ball; (2) TiN-coated steel ball against TiN-coated disks; and Si_3N_4 ball against TiN-coated disks. Tests were carried out under the following conditions: laboratory air; no lubricant; no mechanical surface finishing; specimens cleaned prior to each test; specimens held 30 minutes in 50% humid air before the start of the test; continuous unidirectional sliding motion; 0.1 m/s velocity; 10N normal load; and a sliding distance of 1000 m for campaign (1) and (3) and 200 m for campaign (2). Wear scar diameter on the balls, wear track diameter and width and cross-sectional area together with friction coefficient after different sliding distances have been reported from 19 of the participating laboratories.

The titles, project objectives, and project leaders of the thirty-one TWA 2 work projects are given below.

TWA 2 Project Objectives

1 Development of thin oxide films as reference materials (M P. Seah)
To develop and produce certified reference materials, with validation through laboratories in Member States experienced in the growth of Ta_2O_5 and in measuring oxide thicknesses to define (i) the sputtering rate of argon ion guns to better than ±3%, and (ii) the instrumental depth resolving capability to better than ±2%.

2 Development of calibration data for the energy scales of Auger-electron spectrometers (M P Seah, C J Powell)
To develop traceable data for Cu, Ag, and Au to calibrate the energy scale of Auger-electron spectrometers and to test these data and the relevant protocol for their validity on instruments in Member States to better than ±3 x repeatability or ±0.2 eV.

3 Procedures for quantitative X-ray photoelectron spectroscopy (C J Powell, J E Fulghum)
To produce and characterize thin-film structures in order to test electron transport models developed for angle-resolved XPS.

4 Measurement of spatial resolution in AES
To devise a reference material and associated procedures to enable spatial resolution in AES to be accurately defined over the range 10 nm to 1000 nm. To test this against in-house procedures of laboratories and manufacturers in Member States.

5 Development of reference materials prepared by ion implantation (W H Gries, D Gould)
To establish a primary system of accurately calibrating dopant levels in semiconductor materials. To establish a system of accurately relating secondary standards to the primary ones and of working standards to those secondary ones to test the results against other reference materials from Member States by using those as working standards.

6 XPS intensity calibration and stabilization with polymeric reference materials (C E Bryson)
To test the stability of XPS instruments in Member States in the analysis of polymeric materials. Polymeric reference materials will be developed to test for (i) accuracy of line position, and (ii) for peak area intensity with standard charge compensation schemes.

7 Correction methods for backscattering in AES (J P Langeron)
To test the validity of methods of calculating the primary and secondary electron backgrounds by comparing the results with experimental determinations under various conditions of E_p and θ_i. Various calculations schemes will be assessed for their overall accuracy.

8 Reference methods for sputtering rates in oxides (H J Grabke)
Oxides of relevant metals have been made with defined quantities of materials to establish sputtering rates and to see the extent to which thermal oxides agree with sputter deposited films. A limited number of reference samples have been developed.

9 Intercomparison of Auger electron intensity measurements (M P Seah)
The methodology for calibrating all instruments for absolute intensity functions has been developed and tested to meet the targets set in all Member States. Recommendations for instrument

improvements have been made and all appropriate work published.

10 Development of a Standard Data Transfer Format (W A Dench)
This format has been developed through discussions in all Member States, has been published and is now in use in some commercial data systems for data export and in others for data import. A draft ISO standard will be prepared for discussion in ISO TC/201.

11 Multitechnique characterization of oxygen vacancies in alumina (C Le Gressus)
This work shows the importance of defects in dielectrics and their role in the surface charging of insulators. The general problem of charging does not seem resolved although a number of separate approaches are now possible. The project is terminated in its present form.

12 Calibration of surface layers by nuclear reaction analysis (I V Mitchell)
NRA is an absolute analytical technique that is surface sensitive by not surface specific. It is an excellent method for traceable quantification of adsorbates. this work will reinforce the traceable infrastructure of AES and XPS.

13 Tests of algorithms for data processing in AES - Factor analysis and intensity P R Underhill)
Commercial software illustrates excellent examples but the reliability of the different implementations is not characterized. This project has produced a survey of ways of dealing with the problem and how to treat random uncertainties.

14 Tests of algorithms for background substraction in XPS (S Tougaard)
This work is crucial to quantification in XPS and also AES. A large amount of work has been completed in one Member State. To test the work in other Member States, either data recorded elsewhere will be analyzed or software will be distributed.

15 Evaluation of SNMS sensitivity factors (M Anderle)
This project is concerned with the establishment of sensitivity factors for plasma source SNMS instruments used for depth profiling.

16 Intercomparison of surface analysis of thin aluminum oxide films (P Marcus)
A study of many laboratories in four Member States showed that ARXPS could usefully define oxide thicknesses if the relevant attenuation lengths could be calibrated by correlation with NRA. The work led to Project 31.

17 Quantitative AES of Au/Cu alloys (R Shimizu)
This study showed clearly the need to calibrate each spectrometer individually by using reference materials close to the analyte in composition. Work led to Projects 25 and 28.

18 Evaluation of LOGIT for the measurement of interface widths of an NBS thin film reference material (J Fine)
Interface shapes in sputter-depth profiling are traditionally characterized by one parameter. This work allows a more detailed characterization with least squares fitting and uncertainties, so improving the measurement methodology.

19 Round Robin SIMS study of impurities in GaAs crystals (S Kurosawa)
This study seeks to define consistency and traceability in SIMS studies. Reference samples have been prepared and are being distributed for analysis in four Member States.

20 Round Robin AES study of Co-Ni alloys (K Yoshihara)
This study parallels that of Proj. 17 but has made use of Projs. 29 and 30 in intercomparisons.

21 Tests of Algorithms for the analysis of multicomponent spectra in XPS (A F Carley)
All XPS software systems currently sold allow peak separation from unresolved multicomponent systems. Many use different lineshapes (not always divulged) and different fitting criteria. These may be assessed and homogenized with test data most easily when manufacturers have completed the VAMAS standard format import and export systems.

22 Calibration of channel electron multiplier detection efficiency stabilities (M P Seah)
Calibrations established in Proj. 9 were re-appraised after 2 years as theoretical predictions indicated that AES instrument calibrations would drift. Some did and some did not. Depending on the type of use, the calibration interval may be set at between 1 month and 1 year.

23 Absolute calibration of XPS instrument intensity scales (M P Seah)
This study parallels Proj. 9 but for XPS. Work is complete and a traceable calibration service will be set up.

24 Conventions for spectral data bases (R N Lee)
This project is part of a large effort in ASTM E49 which is nearing completion and will lead to documentary standards.

25 Quantitative XPS of Au-Cu alloys (K Yoshihara)
Project 17 is forerunner to this project. All reference material is now consumed.

26 Theoretical assessment of escape depth (R Shimizu)
There is a great need for a general understanding of the role of elastic scattering in electron spectroscopy. Project completed in 1990.

27 Multi-line reference material for differential AES intensity calibration (M P Seah)
Proj. 9 homogenised AES intensities from different instruments and allowed them to be traceable to absolute standards. Older analysers only work in the differential mode so a reference sample was made to allow these instruments to be calibrated traceably to the instruments used for direct spectral analysis.

28 Quantitative XPS of Co-Ni alloys (K Yoshihara)
This project follows Projs. 17 & 25. Results have been acquired from 20 laboratories. Analysis of results is in progress concerning methodology and background removal.

29 Development of a file format translation system (K Yoshihara)
This project is essential part of Proj. 30 and is complete.

30 Development of a Common Data Processing System (K Yoshihara)
This system has been developed and supplied to several Member States for use and evaluation. The system does not replace commercial systems but provides a research test-bed for new ideas. The system is available with a manual and regular upgrades.

31 Intercomparison of the effects of attenuation length on determination of thin oxide film thicknesses (P Marcus)
This project has shown the validity of the Beer-Lambert law for light element oxides.

Overall, progress has been good. Two of the three computer software projects are drawing to a close. In Project 18, the parameterisation of interface shapes in depth profiling, interlaboratory studies show that the LOGIT system is both robust and accurate. In Project 24, the establishment of the data dictionary for describing spectra for data bases is nearly complete and will soon be published. Project 13, involves factor analysis, a commonly used procedure in many fields. Although this procedure is beginning to be used in surface analysis, the VAMAS project has been slowed due to limited resources.

Regarding data processing, the Standard Data Transfer Format (Project 10) has been approved as a new ISO work item. Instrument manufacturers and software suppliers are installing it as a facility so that technology shall move from an era in which analysts were largely confined to the instruments supplier's software into one in which the analyst may easily use the most appropriate software. Groups can relate their work through a common software despite having widely differing instruments. This second stage has been the successful object of Project 30 which is producing a new MS-Windows version of the programme. Analysts can readily use a common processing system with a number of interesting and unique features.

A recently completed round robin in Project 2 shows that, in general, the newer XPS instruments with monochromators may not be able to use Auger electron peaks for accurate energy calibration. Project 3 which is at the heart of quantifying surface layers by Angle-resolved XPS is also moving towards fruition as the many computational algorithms are tested. However, the need to find reference materials with a known structure to test the algorithms will be difficult to solve. Interaction with the calibration methods of Project 12 using accurate nuclear beam techniques is now more feasible. The problem of XPS reference materials is the topic of Projects 6, 25 and 28. Project 25 is complete but Project 28 needs more international participation.

Reference materials are an extremely important aid to analysts. It is generally accepted that the most accurate method of quantifying any spectroscopy is to calibrate with an appropriate reference material with a matrix as close as possible to that of the specimen. If one could do better by the first principles route one could re-certify the reference material more accurately but this is rarely feasible. For true surface analysis, reference materials are very difficult to produce since surfaces tend to be unstable outside the ultra-high vacuum (UHV) environment. The only surface reference sample that we are aware of is the steel fracture samples in which the surface is prepared by fracture in the UHV by impact. These give submonolayers of phosphorus (P) and tin (Sn) segregants (Mat. Sci. Tech. 8, 1023-1035, 1992). This is also the case for the sputter depth profile certified reference material of Project 1 (still available) and for the SIMS materials of Projects 5 and 19. A number of SIMS reference materials exist but only boron in silicon from NIST is currently available with certification. It is expensive to develop and certify these standards and so in Project 5 an approach is being developed of primary, secondary and working standards to make the process more economic. Resources continue to be a concern but it is hoped that the establishment of ISO/TC 201 and its work program will assist the VAMAS efforts.

Technical Working Area 3

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Objectives

- To undertake pre-standardization research on the reliability and reproducibility of test procedures for advanced technical ceramics

Seven projects have been completed in TWA 3 as listed in Table I. VAMAS final reports have been prepared for projects 2 through 6 and are available from NIST or the parent organizing laboratory for each project. In most instances, open literature summary reports have been published as well.

The high-temperature fracture toughness project, No 4, organized by the Japan Fine Ceramic Center (JFCC) was completed in 1993. VAMAS Report No. 16, *VAMAS Round Robin on Fracture Toughness of Silicon Nitride at High Temperature,* was published by JFCC in December 1993. This project involved 12 laboratories and used single-edged precracked beam (SEPB), chevron notch (CN), and single-edged V-notched beam specimens at up to 1200°C in air or inert atmosphere. A summary paper, *VAMAS Round Robin on Fracture Toughness of Silicon Nitride,* was accepted for publication in 1994 by the American Ceramic Society. A short summary paper was also presented at the 8th CIMTEC Conference in Florence, Italy in July 1994. A Japanese Industrial Standard, JIS R 1617, was adopted in 1994 and is based in part on the results of the VAMAS round robin project.

The fracture toughness by the surface crack in flexure (SCF) method project, No 6, was organized by the National Institute of Standards and Technology and EMPA, the Swiss Federal Research Laboratory and completed in September 1993. The SCF method was used successfully on three advanced ceramics by as many as 20 laboratories. VAMAS Report No. 17, *Fracture Toughness of Advanced Ceramics by the Surface Crack in Flexure (SCF) Method: A VAMAS Round Robin,* was published by NIST in June 1994. A short summary paper was presented at eh American Ceramic Society Conference in

Cocoa Beach in January 1994 and subsequently published in Ceramic Engineering and Science Proceedings, Volume 15, No. 5, September-October 1994. In addition, a condensed summary paper was presented at the 8th CIMTEC Conference. A draft fracture toughness standard has been prepared by ASTM Committee C28, Advanced Ceramics in conjunction with ASTM Committee E8, Fracture and Fatigue. The new draft draws heavily upon the experiences of the VAMAS project.

Table I. TWA 3 Completed Projects

Project Number	Title	Organizing Laboratory	Beginning and End Year
1	Dynamic Fatigue Strength	NIST, USA	1987-1990
2	Hardness	NPL, UK	1988-1989
3	Fracture Toughness, Room Temperature	JFCC, Japan	1989-1992
4	Fracture Toughness, High Temperature	JFCC, Japan	1990-1993
5	Quantitative Microscopy	NPL, UK CTK, NL	1991-1992
6	Fracture Toughness by SCF	NIST, USA	1992-1993
7	Fractographic Analysis	NIST, USA EMPA, Switz.	1993-1994

The fractographic analysis of fracture origins project, No 7, was completed in late 1993. This round robin entailed the examination of photographs and actual fracture surfaces by 17 participating laboratories. The project was organized by the U.S. Army Research Laboratory in cooperation with NIST. In many instances there was a good consensus in the origin characterization, but in others, there was not. A detailed study of the causes of the interpretation agreements and disagreements led to a better understanding of the processes that are critical to a proper fractographic characterization in advanced ceramics. VAMAS Report No.19 has been prepared and will be distributed in early 1995. Condensed summary reports have been presented at and published in the proceedings of the following conferences: American Ceramic Society, Cocoa Beach, January 1994; American Ceramic Society, Cocoa Beach, January 1995, both published in Ceramic Engineering and Science Proceedings; 8th CIMTEC, Florence, Italy, July 1994; and the 48th Meeting of the Mechanical Failures Prevention Group, Wakefield, Massachusetts, April 1994. A comprehensive summary paper will be prepared for the Conference on Fractography of Glasses and Ceramics at Alfred University, Alfred, NY, in June 1995.

A new project began in October 1994: *Fracture Toughness of Ceramic Composites.* This project, organized by the JFCC, has 16 laboratories participating from Japan, Europe, Canada, and the USA. It features single-edged notched beam (SENB), single-edged V-notch beam (SEVNB), and single-edged precracked beam (SEPB) testing on SiC whisker-reinforced silicon nitride matrix specimens at room temperature.

Planning and preliminary experiments are underway for a new project on *instrumented hardness* or *recording hardness* of ceramics. The Federal Institute for Materials Research (BAM) is coordinating this project with some assistance from NIST. Hardness and depth of penetration will be measured by instrumented hardness machines. The details of the project are currently being refined. Either Berkovich or Vickers indenters will be used at loads up to 1N or 10N in a borosilicate crown glass and a silicon nitride ceramic.

Preliminary planning is underway for new projects on oxidation resistance, quantitative microscopy characterization of second phase and/or porosity content, and surface roughness of ceramic parts.

POLYMER BLENDS

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Objectives

- To provide the technical basis for drafting standards test procedures for new, high performance polymer alloys and blends in five complementary technical areas: melt flows; dynamic testing; thermal properties; morphology; and mechanical properties

In September 1994 an international conference on polymers "Polymat '94" took place at Imperial College in London, attended by some three hundred delegates. Among the delegates were the national representatives of TWA 4, Multiphase Polymers who made contributions to the Polymer Blends sessions, organized by the Chair of TWA 4. The conference provided an opportunity for detailed discussions between the national representatives and other delegates on the technical issues of current interest to the TWA. A further presentation of the group's activities was made by a poster prepared by the Chair.

The open technical meeting of TWA 4 followed immediately upon the close of the main conference and was attended by the national representatives and six members of the UK technical working party. Following an introduction by Dr. Partridge (TWA 4 Chair), Dr. Rides of the National Physical Laboratory (NPL) made a presentation on the status of the development of mould design for a standard 15cm x 15cm plaque specimen. The discussion centered upon the best interaction between this project (part of a programme on Advanced Materials sponsored by the UK Department of Trade and Industry) and the morphology and property characterization activities of the TWA to achieve efficient iterative progress towards the provision of design data samples for multiphase polymers. The current materials used are short glass fibre reinforced PP and PBT and the specific programme requirements were identified as follows:

- image analysis of fibre orientation in plaque mouldings, supplied by NPL, for comparisons with computer predictions;

- assessment of repeatability/reproducibility of image analysis data for fibre orientation;

- modulus determinations parallel and transverse to flow direction in the plaque mouldings;

- other mechanical property measurements to quantify the anisotropy of the mouldings; and

- critical evaluation of the predictive methods for relating the modulus and the fibre orientation distribution.

Dr. Partridge of Cranfield University (UK) followed with a report on the current status of fracture testing procedures relevant to multiphase polymers. The European Structural Integrity Society (ESIS) Technical Committee on Polymers and Composites is finalizing its ISO proposal on a J-integral test procedure, following the acceptance by ISO of the Linear Elastic Fracture Mechanics (LEFM) [K_C/G_C] protocol. The Essential Work of Fracture as well as Impact testing procedures continue to be investigated using a range of isotropic polymeric materials. Testing of polymer blend samples which contain uniformly dispersed sub-micrometer particles presents no additional problems. Conversely, attempts to formalize a LEFM procedure for short fibre reinforced plastics by an Appendix to the above mentioned ISO protocol have run into difficulties.

Whilst there is an intrinsic fracture mechanical problem in defining a property of an inhomogeneous material, the need for a characterizing parameter is recognized. Discussion of this problem is a main agenda item for the next ESIS TC4 meeting in Les Diablerets, Switzerland, 17-19 May 1995. Samples of the VAMAS NPL-produced plaques (see earlier), with characterized morphologies, are available for critical testing pending the outcome of the Les Diablerets meeting. The problem is likely to be re-visited for all the other fracture test procedures in the case of partially compatibilized polymer blends.

The final presentation of the meeting was given by Prof. Nishi of Tokyo University, Japan. It was a detailed account of the results of the 1st round robin exercise on Morphology Quantification, which had been performed on a centrally distributed set of TEM micrographs of a commercial compatibilized polymer blend. The large range of hardware and software utilized by different groups in the member countries was highlighted. This is compounded with serious difficulties in deciding on the appropriate level of contrast cut-off for particle definition. The 52-page summary report compiled by Nishi and Ikehara concludes that "for particle analysis it is very important to show binarised data and to explain the method of binarisation" and that for analysis of the spatial distribution of particles "no analysis standard exists and binarised data must be presented together with a definition of parameters or functions used to describe the distribution". The report, intended to be published as a VAMAS Technical Report in 1995, makes a compelling case for standardization in the area of digital image analysis before additional problems of morphology sample preparation can be addressed.

The following day the national representative from all the VAMAS countries, with the exception of Canada, met in a closed organizational meeting. The technical issues raised in the technical meeting were picked up with further technical discussions, leading to the formulation of an action plan for 1995. The next meeting of the national representatives is scheduled to coincide with the 1995 International Chemical Congress of Pacific Basin Societies, 17-22 December 1995, Honolulu, Hawaii, USA. It will again be linked with an open technical meeting, exact date and venue to be determined.

Technical Working Area 5

POLYMER COMPOSITES

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Objectives

- To assess and refine fracture toughness measurements for delamination crack growth
- To develop test procedures, data presentation, and failure criteria for fatigue of continuous fibre composites using flexural and tensile test conditions
- To develop creep test procedures for continuous multidirectional composites

The previous work program focused on fracture toughness, creep, and fatigue. It is hoped that a complete VAMAS report covering all of the mode I & II, static and fatigue delamination fracture toughness testing for Phase 1 of the program can be prepared in the near future. The VAMAS fracture toughness work closely followed the then ASTM procedure. The USA has recently proposed an ISO work Item based on their version (D5528) of the mode I test method and this work item has been supported by the UK. The VAMAS Report on the Phase 1 testing for tension and flexural fatigue modes has been used to support a UK proposal for an ISO new work item on tensile fatigue. The VAMAS program showed that this test mode was more repeatable than the flexure test method which is currently an ISO work item. The results from this VAMAS program and other extensive NPL fatigue projects has been assembled into a "Good Practice" guide for fatigue testing of polymer matrix composites.

Discussions on new TWA work projects revealed continuing interest in fatigue testing. Now that new ISO/CEN standards have been established for static tension test methods and are being established for other modes, a re-evaluation of this topic using the new agreed specimen sizes appears worthwhile. At the ISO TC61/SC13 meeting and at recent CEN and BSI meetings, requests have been made to identify topics for ISO consideration, either future standards or existing standards that are not adequate.

A possible candidate for a future research topic is compression-after-impact, as both the UK and Japan are developing miniature versions to provide a lower cost method of obtaining these data in response to concerns at the expense of the current Boeing method. There is extensive theoretical under-pinning research on predicting the damage modes occurring under different situations which can support the project. The Japanese have been asked to consider leading this effort.

• VAMAS Calendar •

TWA 17 (Cryogenic Structural Materials) Meeting in conjunction with the ICMC 95, Columbus, OH, USA	July 17, 1995
TWA 3 (Ceramics) Meeting in conjunction with the 6th Symposium on Fracture Mechanics of Ceramics, Nuclear Research Center, Karlsruhe, Germany	July 18-20, 1995
TWA 5 (Polymer Composites) in conjunction with the 10th International Conference on Composite Materials, Whistler, British Columbia, Canada	August 15, 1995
IVC-13/ICSS-9, including meeting of ISO/TC 201 (Surface Chemical Analysis) Yokohama, Japan	September 25-29, 1995
6th European Conference on Applications of Surface and Interface Analysis [ECASIA], Montreux Congress Centre, Montreux, Switzerland	October 9-13, 1995
TWA 17 (Cryogenic Structural Materials) Meeting in conjunction with the ICMC 96 Meeting, Fukuoka, Japan	May 1996
TWA 4 (Multiphase Polymers) Meeting in conjunction with the 1995 International Chemical Congress of Pacific Basin Societies, Honolulu, Hawaii, USA	December 1995
2nd International Meeting of Pacific Rim Ceramic Societies, PacRim 2, including meeting of ISO/TC 206 (Fine Ceramics), Cairns, Australia	July 1996

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