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Abstract. A presentation (including abstracts) of scientific and technical publications and lectures by the staff of the Metallurgy Department during 1988 is given. The list comprises journal papers, conference papers, reports, lectures and poster presentations in the following categories: Publications, Lectures and Poster Presentations.

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Contents

1. Publications

1. **Andersen, S.I.; Brøndsted, P.; Frederiksen, H.; Jensen, F.; Kjøller, J.; Lilholt, H.; Lystrup, Aa.; Mikkelsen, C.; Olsson, J.**, Fiberforstærket Plast (Fibre-Reinforced Plastics). (Risø National Laboratory, Roskilde, 1988) ·p.

»Fibre-Reinforced Plastics« is a textbook for a course on fibre composite materials. The course was developed for Dansk Metalarbejderforbund (The Danish Metal Workers' Society) and held two times in 1988 for members of Dansk Metalarbejderforbund. The textbook (in Danish) describes the basic principles for fibre reinforced materials in the following captions: Introduction to fibre reinforced plastics, fibre and matrix materials, materials properties, lamination theory and design criteria, fabrication technology, materials testing, application in Danish industry, safety and environment, literature.

2. **Andersen, S.I.; Lilholt, H.; Pedersen, O.B.** (eds.), Mechanical and Physical Behaviour of Metallic and Ceramic Composites. 9. Risø International Symposium on Metallurgy and Materials Science, Risø, 5-9 Sep 1988. (Risø National Laboratory, Roskilde, 1988) 534 p.

3. **Andersen, S.I.; Lilholt, H.; Lystrup, Aa.**, Materials Data for WT Design Basis: Fatigue Properties of Glass Fibre Reinforced P· yester. In: Euroforum New Energies Congress and Exhibition. Summaries of Workshop Papers on European R+D. Euroforum New Energies, Saarbrücken, 24-28 Oct 1988. (Commission of the European Communities, Brussels, 1988) paper W.8.3.

4. **Andersen, S.I.; Lilholt, H.**, Fatigue of Glass/Polyester Composite Materials for Wingblades. In: European Community Wind Energy Conference. Proceedings. Herning, 6-10 Jun 1988. Palz, W. (ed.), (H.S. Stephens & Associates, Bedford, 1988) (EUR-11885) p. 342-346.

Glassfibre reinforced polyester is considered a load bearing material for wingblades. The long-time fatigue properties (up to 10^8 cycles) are under investigation. Well defined materials are used, with volume fractions of 50% fibres and fibre orientations of 0° ± 10°, ± 45°, ± 60° and combinations. Results on some of these materials will be discussed in relation to fatigue curves, change in stiffness during fatigue, models for the damage development and property changes, and the possible design considerations which can be derived from these results.

5. **Andersen, S.I.; Lilholt, H.; Lystrup, Aa.**, Materials Data for WT Design Basis: Fatigue Properties of Glass Fibre Reinforced Polyester. In: Wind Energy - 2. Proceedings of the 2. Contractors' Meeting. Brussels, 23-24 Nov 1987. Rasmussen, B.; Caratti, G. (eds.), (Harwood Academic Publishers, Chur, 1988) (EUR-11519) p. 231-240.

Within the WT design basis fatigue properties form a subaction; one part of this subaction is fatigue of glass-fibre reinforced polyester. The subaction programme will study selected materials and properties, which are representative for current materials and loadings on windturbine rotorblades. The new aspects of the programme are the relatively new materials, which are now widely used by the European windturbine

industry, the need for performance data at more than 10^8 fatigue cycles, and the establishment of design criteria, e.g. based on sufficient stiffness or sufficient strength during the lifetime of the rotorblades.

6. **Barker, I.**; Ralph, B.; **Hansen, N.**, Characterization of Dislocation Cells in Deformed FCC Metals. In: Strength of Metals and Alloys. ICSMA 8. Vol. 1. 8. International Conference on the Strength of Metals and Alloys, Tampere, 22-26 Aug 1988. Kettunen, P.O.; Lepistö, T.K.; Lehtonen, M.E. (eds.), (Pergamon Press, Oxford, 1988) (International Series on the Strength and Fracture of Materials and Structures) p. 277-282.

The development of dislocation cells in pure polycrystalline aluminium has been evaluated over a tensile strain range, 0.1- 0.3, using transmission electron microscopy (TEM). The results are compared with a more limited test series on pure polycrystalline copper. Measurements of both the cell sizes and the cell misorientations have been made, the latter using microdiffraction, and the results compared with previous studies in the literature.

7. Bay, B.; **Hansen, N.**, Microbands in Deformed Aluminium. In: Strength of Metals and Alloys. ICSMA 8. Vol. 1. 8. International Conference on the Strength of Metals and Alloys, Tampere, 22-26 Aug 1988. Kettunen, P.O.; Lepistö, T.K.; Lehtonen, M.E. (eds.), (Pergamon Press, Oxford, 1988) (International Series on the Strength and Fracture of Materials and Structures) p. 193-198.

The deformation microstructure of cold rolled (10 and 30%), polycrystalline aluminium (99.996%) has been studied with special emphasis on the structure and crystallographic orientation of microbands. The dislocation arrangement in microbands has been examined by transmission electron microscopy and the crystallographic orientation change both within the microbands and between the microbands have been measured on Kikuchi diagrams obtained by microdiffraction. The formation of microbands and their development as a function of strain are discussed as well as the effect of microbands on the deformation pattern.

8. **Bentzen, J.J.**; Andersen, N.H.; **Poulsen, F.W.**; **Sørensen, O.T.**; Schram, R., Evaluation of 2- and 4-Point Conductivity Measurements on Oxide Ion Conductors. Solid State Ionics (1988) v. 28/30 p. 550-559.

A comparison between different ac measuring techniques has been performed and evaluation methods for the determination of ionic conductivity in oxygen conductors are described. 2- and 4-point impedance measurements using two different frequency response analysers (Solartron FRA-1174 and FRA-1250) are compared. The materials studied were polycrystalline cubic ceria-gadolinia, tetragonal zirconia-yttria ceramics and single crystalline YSZ. Empirical rules for the determination of conductivity by geometrical methods from »overlapping« semicircles in the complex plane representation of the immittance data were established. This was supported by model calculations and non-linear least squares fitting techniques.

9. **Bilde-Sørensen, J.B.**; Smith, D.A., A Theoretical Consideration of Some Structural Developments During Diffusional Creep. In: Strength of Metals and Alloys. ICSMA 8. Vol. 2. 8. International Conference on the Strength of Metals and Alloys, Tampere, 22-26 Aug 1988. Kettunen, P.O.; Lepistö, T.K.; Lehtonen, M.E. (eds.), (Pergamon Press, Oxford, 1988) (International Series on the Strength and Fracture of Materials and Structures) p. 869-874.

Most of the structural studies of materials deformed in diffusional creep were made before the contemporary understanding of the grain boundary structure was developed. Some of the observations made in these early studies could not be explained in terms of the continuum models available then; this applies for instance to the observation that denuded zones in particle-containing materials seldom are formed symmetrically around the boundaries and to the observation of apparent backwards grain boundary sliding. In the present paper it is shown that these early structural observations can be accounted for when considered in terms of the theory for grain boundary dislocation structures.

10. **Brøndsted, P.**; Slind, T.; Solin, J., Fatigue Testing. Establishment of a Standard Method for Fatigue Testing Under Variable Load Amplitudes Simulating Offshore Load Spectra. Risø-M-2714 (1988) 78 p.

11. Cole, W.P.; Babaud, J.; **Hansen, N.**; Johnson, D.; Spruit, F.; Tölg, G., Evaluation of the Community Bureau of Reference 1983-87. Cost-Shared Research. EUR-11358 (1986) (Research Evaluation Report, 23) 48 p.

12. Damkroger, B.K.; **Juul Jensen, D.**; Edwards, G.R., In-Situ Measurement of Phase Transformation Kinetics Using Neutron Diffraction. Scr. Metall. (1988) v. 22 p. 287-291.

Mathematical models describing the kinetics of isothermal transformation kinetics were originally derived by Johnson and Mehl, and Avrami. Over the years these equations have been studied and modified but still form the basis for a description of isothermal phase transformation kinetics. For practical purposes, however, a prediction of transformation behaviour under continuous cooling conditions is desired. Several attempts to model transformation kinetics for continuous cooling have been made. Usually, the approach taken has been to treat continuous cooling as a series of discrete isothermal steps. Each step is then an increment of transformation, to be added to the other increments. In most cases, the attempts at theoretical models have been hampered by a relative lack of experimental verification.

13. **Domanus, J.C.**, Recording Radiographic Images on Nitrocellulose Film in Neutron Radiography of Nuclear Reactor Fuel. In: Proceedings of the 4. European Conference on Non-Destructive Testing. Vol. 3. 4. European Conference on Non-Destructive Testing, London, 13-17 Sep 1987. Farley, J.M.; Nichols, R.W. (eds.), (Pergamon Press, Oxford, 1988) (International Series on Materials Evaluation and Non-Destructive Testing) p. 2170-2179.

14. **Domanus, J.C.**, International Neutron Radiography Newsletter No. 15 - NRWG Test Program Part 1. Br. J. Non-Destr. Test. (1988) v. 30 p. 40-42.

In the Euratom Neutron Radiography Working Group (NRWG) Test Program 11 neutron radiography facilities from seven centers in six countries of the European Community participated since 1981. The items under investigation (beam purity and sensitivity indicators, calibration fuel pin) and the 30 film/converter combinations with which those items are neutron radiographed are described. Two types of measuring instruments (profile projector and travelling microdensitometer) are used for the dimensional measurements. The scope of Part I and II of the Test Program is explained.

15. Domanus, J.C., Neutron Radiography. Techniques and Applications. In: Procedes de Controle non Destructifs. Seminaire et Exposition. Liege, 4-5 Feb 1988. (Institut Superieur Industriel Liegeois, Liege, 1988) p. 18.1-18.21.

After describing the principles of the »in pool« and »dry« installations, techniques used in neutron radiography are reviewed. Use of converter foils with silver halide films for the direct and transfer methods is described. Advantages of the use of nitrocellulose film for radiographying radioactive objects are discussed. Dynamic imaging is shortly reviewed. Standardization in the field of neutron radiography (ASTM and Euratom Neutron Radiography Working Group) is described. The paper reviews main fields of use of neutron radiography. Possibilities of use of neutron radiography at research reactors in various scientific, industrial and other fields are mentioned. Examples are given of application of neutron radiography in industry and the nuclear field.

16. El Sayed Ali, M.; **Toft Sørensen, O.**, Determination of Young's Modulus by Knoop Indentation Measurements. Risø-M-2681 (1988) 18 p.

Marshall, Noma and Evans proposed a simple method for measurements of Young's modulus by the Knoop indentation technique. In order to obtain reliable data by this technique, however, it is necessary that the indenter is very carefully aligned in order to obtain perfectly symmetrical impressions. In the present work a correction method is proposed by which accurate results can be obtained even on asymmetrical impressions which is usually obtained. By measurements on various zirconia toughened ceramic materials it is demonstrated that the E-values obtained using this correction method are very similar to literature data determined by other techniques.

17. El Sayed Ali, M.; **Toft Sørensen, O.**, Practical Application of Stepwise Isothermal Dilatometry for Characterization of Sinterability of Powder Compacts. Risø-M-2694 (1988) 20 p.

Stepwise isothermal dilatometry (SID) is a useful technique for sintering studies. With this technique isothermal shrinkage is characteristically determined as a function of temperature without imposing conditions such as heating rate or temperature on the specimen. Sintering is thus performed under equilibrium conditions and the information obtained is directly related to the properties of the specimens. In the present work the temperature for maximum densification rate was determined for various yttria partially stabilized zirconia powders (YPSZ). Plotting this temperature versus the crystallite size of the starting powders showed a linear relationship indicating that this technique can be used to characterize the sinterability of these powders. As the maximum densification rate for most ceramic powders is believed to be at the temperature at which grain growth is initiated, this technique can also be used to predict conditions for production of fine grained ceramics.

18. El Sayed Ali, M.; **Toft Sørensen, O.**, Effect of Cutting on Fracture Strength of Yttria Partially Stabilized Zirconia. Risø-M-2682 (1988) 36 p.

Yttria partially stabilized zirconia (YPSZ) is an interesting construction material which can be produced both with a high fracture strength and with a good fracture toughness. For this material as well as for other ceramic materials the properties of the final specimens not only depend on the composition and the preparation conditions (pressing mode, sintering temperature etc.), but also on the surface characteristics. In a previous work it was observed that cutting followed by polishing gave a

considerable increase in the fracture strength. In this work the effect of cutting as well as the influence of the pressing mode is examined in greater detail.
From the results obtained it is concluded that cutting of one or two surfaces of the test specimens indeed produces a large increase in the fracture strength - after sintering the strength was about 550 MPa whereas the strength was increased to 823 MPa when both the surface under compression and tension in 4-point bend testing was prepared by cutting. By reducing the thickness of the test specimen the strength could even be increased to 944 MPa when both these surfaces were prepared by cutting. The mechanism responsible for this surface strengthening is considered to be domain reorientation of the tetragonal phase.

19. **Eldrup, M.**; Jensen, K.O., Trapping Rates into Cavities in Al: Temperature and Size Effects. In: European Meeting on Positron Studies of Defects. Proceedings. Vol. 1, Part 2. Wernigerode, 23-27 Mar 1987. Dlubek, G.; Brümmer, O.; Brauer, G.; Hennig, K. (eds.), (Martin-Luther-Universität, Halle-Wittenberg, 1987) (Wissenschaftliche Beiträge, 57) Paper SL 9, 8 p.

Positron specific trapping rates into voids and helium bubbles have been measured as a function of temperature and cavity size. Qualitatively the data show the behaviour expected from a model similar to that of Nieminen et al. (1979), but quantitatively the agreement fails. If trapping into shallow traps at low temperatures is assumed, the disagreement is removed. For cavities of radii larger than 5 nm diffusion limited trapping is observed at room temperature. The positron diffusion constant is found to agree with earlier determinations, if a time dependence of the trapping rate is taken into account.

20. Grant, E.M.; **Hansen, N.; Juul Jensen, D.**; Ralph, B.; Stobbs, W.M., Texture and Microstructure Development During Grain Growth in Copper. In: ICOTOM. 8. International Conference on Textures of Materials. Proceedings. Santa Fe, 20-25 Sep 1987. Kallend, J.S.; Gottstein G. (eds.), (The Metallurgical Society Inc., Warrendale, 1988) p. 711-716.

Grain growth in copper (99.999%) indicates that relatively few grains grow very large and that this growth ceases before the matrix is consumed. The cause of this change in grain size distsribution has been investigated by texture measurements and by microstructural observations. Neutron diffraction techniques have been used to study bulk texture change during grain growth and backscattered selected area channelling patterns (BSCP's) have been used to obtain information about local texture changes. The microstructural development during grain growth has been studied by transmission electron microscopy (TEM).
In the as-recrystallized state the bulk texture agrees reasonably well with the distribution of grain orientations obtained by BSCP's and correlations between adjacent grain orientations are not observed. After grain growth has taken place the grain orientation distribution shows that it is specifically the large developing grains which tend to have near (111) orientations. It is also observed that the orientations of the majority of the smaller grains which surround a large grain are at relatively low angles of misorientation to it or to its primary twin orientations.
The observed texture changes are related to the change in the grain size distribution, which is discussed on the basis of the local texture measurements. Also the grain growth characteristics are considered on basis of the TEM observations of the microstructural development during grain growth.

21. Gundtoft, H.E., Ultrasonic Examination of Ceramics and Composites for Porosities in an Automatic Scanning System. Risø- M-2711 (1988) 16 p.

Using a very precise scanning system and computer evaluation, we can get quantitative results from automatic ultrasonic examination. In this paper two examples dealing with nonmetallic materials are presented.
In a ceramic plate (>1 inch thick) small spherical porosities (down to 0.1 mm) would harm the final product. Several artificial defects made in the plate were used for calibration and optimisation of the technique. Areas with natural defects were viewed with a microscope. Good agreement with the predicted values from the ultrasonic examination was found. From the NDT-examination the exact position of a porosity is known in all 3 coordinates (x, y and z). The size of the defect can also be measured. A single porosity with a diameter of 0.1 mm can be detected.
Carbon-reinforced composites were examined. 8 prepregs were stacked and hardened in an autoclave to form a sheet (1 mm thick). Air trapped in the material resulted in porosities in the final product. A double through transmission-scanning technique was used for the examination. The porosity percentages were determined by the NDT-technique, and agreement with destructively determined values on samples from the same sheet was found.

22. Gundtoft, H.E., Examination of Fibre Composites by Ultrasound for Defect Inspection and Determination of Material Properties. Risø-M-2732 (1988) 16 p.

Fibre composites may be produced by stacking prepregs impregnated with epoxy and hardening those in an autoclave. Results from different non-destructive ultrasonic methods used on this product are presented.
Two techniques (double through transmission and reflector) are developed from C-scan. They are useful for finding delaminations and porosities. An attempt was made to determine the porosity content in the plates non-destructively with the reflector technique.
A third technique (called »in-plane transmission«) is a contact method with separated transmitter and receiver on the same side of the plate (50 mm apart). The wave form of the received signal is digitized, and several so called »stress wave factors« are calculated from the digitized values. The sound velocity is also calculated. Measurement has been made on materials in different thicknesses and with variation in fibre orientation and fibre material.
Results from scanning with the reflector technique and in-plane transmission measurement on the same samples are compared.

23. Gundtoft, H.E., Ultrasonic Examination of Ceramics and Composites for Porosities in an Automatic Scanning System. In: Proceedings of the 4. European Conference on Non-Destructive Testing. Vol. 3. 4. European Conference on Non-Destructive Testing, London, 13-17 Sep 1987. Farley, J.M.; Nichols, R.W. (eds.), (Pergamon Press, Oxford, 1988) (International Series on Materials Evaluation and Non-Destructive Testing) p. 1751-1759.

Same abstract as 22.

24. Hansen, N., Materialeteknologi i dag og i morgen (Materials Technology Today and Tomorrow). Nyhedsbrev Teknologinævnet (1988) (no.5) p. 15.

Knowledge on many technological aspects must be present before a new material can be used in practice. By research it is now possible to »taylor-make« materials.

25. **Hansen, N.; Bilde-Sørensen, J.B.,** Risøs nye elektronmikroskop (Risø's New Electron Microscope). In: Årsskrift. Villum Kann Rasmussen Fonden og Velux Fonden af 1981. Beretning om fondenes virke i tiden 1. juli 1986 - 31. december 1987. Kann Rasmussen, A.; Landbo, I.-M. (eds.), (Villum Kann Rasmussen Fonden, Klampenborg, 1988) p. 17-21.

26. **Hansen, N.; Juul Jensen, D.,** Texture and Flow Stress of Cold-Drawn Aluminium Alloys. In: Strength of Metals and Alloys. ICSMA 8. Vol. 1. 8. International Conference on the Strength of Metals and Alloys, Tampere, 22 - 26 Aug 1988. Kettunen, P.O.; Lepistö, T.K.; Lehtonen, M.E. (eds.), (Pergamon Press, Oxford, 1988) (International Series on the Strength and Fracture of Materials and Structures) p. 475-480.

The tensile flow stress (0.2% offset) and the crystallographic texture has been determined for a number of cold-drawn aluminium alloys with and without aluminium oxide particles. The parameters have been the plastic strain (0.2 - 3.0) and the volume concentration of dispersed particles (max. 3.8%). Based on ODF-information, M factors have been calculated assuming the validity of the Taylor deformation model. By accounting for texture strengthening the flow stress of a texture free material has been determined. It is found that texture strengthening is negligible for small strains (below one) whereas for larger strain the texture effect is significant. By taking texture strengthening into account the effect of particles and dislocation cells on the work hardening behaviour is analyzed.

27. **Hansen, N.; Juul Jensen, D.; Liu, Y.L.,** Microstructure and Creep Strength of an Aluminium Composite with Silicon Carbide Fibres. In: Mechanical and Physical Behaviour of Metallic and Ceramic Composites. 9. Risø International Symposium on Metallurgy and Materials Science, Risø, 5-9 Sep 1988. Andersen, S.I.; Lilholt, H.; Pedersen, O.B. (eds.), (Risø National Laboratory, Roskilde, 1988) p. 365-371.

The creep strength has been determined at 673 K for an aluminium composite containing 2 vol.% of SiC fibres. The composite has been manufactured by a powder metallurgy technique and contains 0.8 vol.% of finely dispersed Al_2O_3 particles. The addition of SiC fibres increases the creep strength significantly when compared with the matrix material without fibre addition. An increase of the same order has been obtained by recrystallization of the extruded composite. In total the composite has a high creep strength due to a large recrystallized grain size and a combined effect of dispersion strengthening and fibre reinforcement. Finally it has been observed that the creep behaviour of the composite is quite similar to that observed for aluminium containing a fine dispersion of Al_2O_3 particles.

28. **Hansen, N.; Juul Jensen, D.,** Effect of Metallurgical Parameters on the Microstructure, Texture and Flow Stress of FCC Metals and Alloys. In: L'Innovazione per la qualita. Innovation for Quality. 22. International Metallurgy Congress. Vol. 1. Bologna, 17-19 May 1988. (Associazione Italiana di Metallurgia, Milan, 1988) p. 279-283.

The effect of cold deformation and recrystallization on the microstructure of metals is described with special emphasis on the behaviour of aluminium and aluminium alloys. The parameters are the plastic strain, the grain size and the volume fraction and size of second phase non-deformable particles. On basis of the microstructural

changes during cold deformation and recrystallization the textural evolution is discussed. Finally the flow stress-strain behaviour and the occurrence of anisotropy is related to the microstructure and texture.

29. **Hansen, N.; Leffers, T.**, Microstructures, Textures and Mechanical Properties After Large Strain. Rev. Phys. Appl. (1988) v. 23 p. 519-531.

Microstructure, texture and mechanical properties of polycrystalline materials after medium and large strains are reviewed. The existing deformation models are discussed on the basis of the evidence presented, and mechanical properties and microstructure are correlated. Finally, anisotropy and constitutive relations are discussed briefly.

30. **Horsewell, A.; Bilde-Sørensen, J.B.**, Anvendelse af transmissionselektronmikroskopi i materialeforskningen i Danmark (The Application of Transmission Electron Microscopy Techniques in Materials Research in Denmark). Materialnyt (1988) (no.3) p. 47-48.

The abstract appeared in Risø-M-2705.

31. **Horsewell, A.; Singh, B.N.**, Materialer og fusionsteknologi (Materials for Fusion Technology). In: Nye materialer til energisektoren. Dansk Metallurgisk Selskabs Vintermøde, Karrebæksminde, 4-6 Jan 1988. Lilholt, H.; Gundel, P.H. (eds.), (Dansk Metallurgisk Selskab, Lyngby, 1988) p. 129- 140.

New and improved materials are required before fusion power can become viable technology. Materials requirements and current research aimed at solving materials problems for the 'first-wall' blanket, neutron shielding and magnets are described.

32. **Horsewell, A.; Singh, B.N.**, Influence of Grain and Subgrain Boundaries on Void Formation and Growth in Aluminium Irradiated with Fast Neutrons. In: Radiation-Induced Changes in Microstructure. 13. International Symposium. Part 1. Seattle, 23-25 Jun 1986. Garner, F.A.; Packan, N.H.; Kumar, A.S. (eds.), (ASTM, Philadelphia, 1987) (ASTM Special Technical Publication, 955) p. 220-229.

High purity aluminium was irradiated at 120 °C to fast neutron fluence between 2 x 10^{21} *and 5 x* 10^{24} n/m^2. *Variations in void density and void size in the vicinity of grain and subgrain boundaries have been analyzed. The results document that vacancy accumulation is enhanced in a wide zone up to 15 μm from grain boundaries. The magnitude of the enhanced vacancy accumulation varies as a function of distance from the grain boundary. The presence of subgrain boundaries enhances the vacancy accumulation within the subgrain, and the vacancy accumulation varies markedly as a function of subgrain size. The results are discussed in terms of the consequences of an initial vacancy concentration gradient near grain boundaries on further vacancy accumulation. The maintenance and evolution of vacancy supersaturation gradients are considered in terms of transport and screening of interstitials during vacancy accumulation in the peak zone.*

33. Jensen, K.O.; **Eldrup, M.; Singh, B.N.**; Linderoth, S.; Bentzon, M.D., Positronium-Like Positron States in He Bubbles in 600 MeV Proton-Irradiated Al. J. Phys. F (1988) v. 18 p. 1091-1108.

Aluminium samples containing He bubbles produced by 600 MeV proton irradiation at temperatures in the range 655 728K have been investigated by positron annihilation. Both lifetime and angular correlation (AC) measurements have been made. Measurement temperatures ranged from 10 to 300 K. A very narrow component (FWHM = 1.6 mrad) is present in the AC spectra. This component is interpreted to be due to a positronium-like positron state in the He bubbles. The width of the narrow component indicates that the state is not free positronium (Ps) in the bubble interior but a Ps-like state at the bubble surface. The corresponding He bubble component in lifetime spectra has a lifetime value of 450 - 480 ps. The intensities of this lifetime component and of the narrow AC component indicate that only about half of the positrons trapped in bubbles contribute to the narrow AC component. It is suggested that this could be due to different momentum distributions of the annihilating electron-positron pair parallel and perpendicular to the bubble surface. The Ps-like state is attributed to the presence of impurity atoms, possibly Na, at the surfaces of the bubbles. In addition, positron trapping at dislocations in the samples is discussed.

34. Jensen, K.O.; **Eldrup, M.; Singh, B.N.**; Victoria, M., Helium Bubbles in Aluminium Studied by Positron Annihilation: Determination of Bubble Parameters. J. Phys. F (1988) v. 18 p. 1069-1089.

This paper demonstrates that it is possible to obtain information from the positron annihilation technique about rare-gas bubbles in metals, i.e. the gas density inside bubbles and the average bubble size and concentration. This is done by a detailed study of aluminium in which He bubbles are introduced by irradiation at temperatures in the range 375-485 K with 600 MeV protons. The samples are studied both in the as-irradiated state and after annealing at temperatures up to 873 K. Evaluation of bubble parameters is made from positron lifetime results employing a theoretical relation between positron lifetime and He density in bubbles and a semi-empirical relation between positron-specific trapping rate and cavity radius. Results are compared with determination of bubble parameters by other experimental methods. In addition, one dimensional angular correlation curves for He bubbles as a function of He density are determined.

35. Jensen, K.O.; **Eldrup, M.; Pedersen, N.J.**; Evans, J.H., Annealing Behaviour of Copper and Nickel Containing High Concentrations of Krypton Studied by Positron Annihilation and Other Techniques. J. Phys. F (1988) v. 18 p. 1703-1724.

Bulk copper and nickel samples containing 3 and 5 at.% krypton respectively have been studied by conventional positron annihilation techniques. Most of the emphasis has been placed on the changes in positron lifetime and angular correlation parameters during isochronal annealing from ambient up to near the metal melting points. The study was complemented by transmission and scanning electron microscopy, together with macroscopic measurements of weight and dimensions. These techniques, combined with previous studies, provide a fairly detailed picture of both the as-prepared materials, where the krypton is present as a high density of solid phase precipitates (solid bubbles), and the subsequent marked response of the substructure to annealing. A number of features are of particular interest. The onset temperature for bubble coalescence events is correlated with the melting temperatures of the solid Kr inside the bubbles. At higher temperatures extensive swelling is observed prior to and simultaneously with the release of the majority of the krypton. The structure after the Kr release contains micrometre-sized pores and 10 nm bubbles. This structure partly recovers at higher temperatures, but sufficient krypton is *retained in the pores to maintain a large swelling up to close to the metal melting points. Positrons are found to become trapped at the Kr-metal interface in Kr bubbles, an there is clear evidence for a quantitative relation between lifetime and Kr density. Both these features are in agreement with the recent theory of Jensen and Nieminen. Finally, positron trapping into dislocation is observed to occur at a rate much lower than that predicted from published specific trapping rates.*

36. **Juul Jensen, D.**; Fast Texture Measurements by Neutron Diffraction. Technique and Applications. In: L'Innovazione per la qualita. Innovation for Quality. 22. International Metallurgy Congress. Vol. 1. Bologna, 17-19 May 1988. (Associazione Italiana di Metallurgia, Milan, 1988) p. 469-483.

A technique for fast texture determination by neutron diffraction is described. With the technique a complete texture analysis requires from 15 to 45 minutes measuring time and the kinetics of the development in single texture components can be studied with a time resolution of the order of seconds. It is shown how these two measuring principles can be used for in-situ kinetic investigations of recrystallization. The potential of the technique for problems related to metallurgical practice is demonstrated by an approach of texture tailoring in commercially pure aluminium. Finally it is discussed how the technique can be used in the study of hot working and phase transformations.

37. **Juul Jensen, D.; Hansen, N.**, Flow Stress Anisotropy in Commercially Pure Aluminium. In: Strength of Metals and Alloys. ICSMA 8. Vol. 1. 8. International Conference on the Strength of Metals and Alloys, Tampere, 22-26 Aug 1988. Kettunen, P.O.; Lepistö, T.K.; Lehtonen, M.E. (eds.), (Pergamon Press, Oxford, 1988) (International Series on the Strength and Fracture of Materials and Structures) p. 373-378.

The plastic anisotropy of cold-rolled commercially pure aluminium (99.6%) has been investigated. Sample parameters were the initial grain size (35, 80 and 40 μm) and the degree of plastic strain (ε = 0.2 and 2.0). Textures were determined by neutron diffraction and Taylor M-factors were calculated. Flow stresses (0.2% offset) were measured at room temperature as a function of the angle to the rolling direction, and the effect of texture on the flow stress was accounted for on basis of the M-factors. It is discussed how the flow stress anisotropy is affected by texture and microstructure.

38. **Juul Jensen, D.; Hansen, N.**; Humphreys, F.J., Effect of Metallurgical Parameters on the Textural Development in FCC Metals and Alloys. In: ICOTOM. 8. International Conference on Textures of Materials. Proceedings. Santa Fe, 20-25 Sep 1987. Kallend, J.S.; Gottstein G. (eds.), (The Metallurgical Society Inc., Warrendale, 1988) p. 431-444.

The textural development during cold deformation and recrystallization is strongly related to metallurgical parameters such as initial grain size and size and volume fraction of second phase particles. Such relationships are described with reference to the microstructural changes for medium and high stacking fault energy fcc metals.
Deformation textures depend strongly on the deformation mode and the degree of deformation. The present paper is mainly concerned with deformation by rolling to strains in the range 0.2 - 3.0. The textural development is discussed on the basis of microstructural observations and is compared with predictions based on different deformation models. In general the effect of varying the initial grain size or introdu-

cing second phase particles is to change the strength of the deformation texture and this finding is related to effects of the metallurgical parameters on the deformation pattern.
Recrystallization textures depend on the mechanisms for nucleation and growth. The formation of recrystallization textures (e.g. the cube texture) in pure metals is not reviewed whereas the behaviour of particle containing materials is discussed in detail based on recent experimental observations. Parameters in these experiments were the volume fraction of large (>0.1 - 1 µm) and small particles (>0.1 µm). The observed textural changes are related to the formation and growth of recrystallization nuclei and the relationships between the development in texture and microstructure are discussed.

39. **Juul Jensen, D.; Lilholt, H.;** Withers, P.J., Determination of Fibre Orientations in Composites with Short Fibres. In: Mechanical and Physical Behaviour of Metallic and Ceramic Composites. 9. Risø International Symposium on Metallurgy and Materials Science, Risø, 5-9 Sep 1988. Andersen, S.I.; Lilholt, H.; Pedersen, O.B. (eds.), (Risø National Laboratory, Roskilde, 1988) p. 413-420.

The fibre orientation distribution of short SiC-whiskers in an Al-matrix has been determined by neutron diffraction texture measurements and optical microscopy. The orientation distributions have been compared and discrepancies are discussed. Finally, the applicability, accuracy and speed of the two techniques are compared.

40. **Juul Jensen, D.; Lorentzen, T.;** Mortensen, K.; Clausen, K.N., Applied Materials Research at Risø National Laboratory. Neutron Diffr. Newslett. (1988) (Spring) p. 3-4.

A short overview of the neutron diffraction technique used at Risø National Laboratory for applied materials research is given. Instruments for small angle neutron scattering, texture measurements and internal stress measurements are described and examples of the ongoing research are reported.

41. **Knudsen, P.,** Brændselscelleudvikling i Danmark (Fuel Cell Development in Denmark). In: Föredrag från Nordisk Bränslecelldag. Sydkrafts Forskningsstiftelses och Statens Energiverks Symposium om Bränsleceller. Teknik, Utveckling, Demonstration, Malmö, 15 Sep 1988. (Sydkraft, Malmö, 1988) 7 p.

42. **Knudsen, P.; Bagger, C.; Carlsen, H.; Johansen, B.S.; Mogensen, M.,** Fission Gas Release in High-Burnup Fuel During Power Transients. In: Proceedings of the International Topical Meeting on LWR Fuel Performance. Williamsburg, 17-20 Apr 1988. (American Nuclear Society, La Grange Park, 1988) p. 189-203.

A series of short UO_2-Zr fuel pins of different designs were subjected to various power transients after irradiation to burnup in the range 1.7 - 5.3% FIMA (16 - 48 MWd/kgU). Instrumentation of the test fuel pins, enabled by refabrication, provided in-core measurement of the pressure evolution during the transient testing. Onset of fission gas release (FGR) occurred at 30 - 37 kW/m, to some extent depending upon the test variables: fill gas, initial gap size and burn-up. With two otherwise similar tests, there was an increase in FGR (at 42 kW/m) from 11 to 19%, with burnup increasing from 1.7 to 3.1% FIMA. Completion of FGR may take a very long time, e.g. more than 86 h at 42 kW/m and 4.6% FIMA. Compressive cladding stress upon *the fuel can delay and possibly reduce FGR. Extensive hot-cell examinations focussed upon local (radial, axial) data on fission product release and fuel structure. Even with significant FGR, no grain growth was observed in most of the tests. Test samples had significant amounts of fission gas on the grain boundaries, situated in pores of one to a few μm in size.*

43. **Knudsen, P.**; Schütz, P., Advanced Fuel Cell R&D in Denmark. In: Report of the IEA Workshop on Advanced Fuel Cells. Tokyo, 9-10 Jun 1988. (Agency of Industrial Science and Technology. Ministry of International Trade and Industry, Tokyo, 1988) p. 111-116.

The Danish R&D efforts related to advanced fuel cells are based on the high-temperature SOFC (solid oxide fuel cell) concept and the medium-temperature SSFC (solid state fuel cell) concept. Danish industry has developed a heat exchange reformer for fuel cell plants, this is now commercially available. Also, processes and catalysts for PAFC and MCFC are developed and marketed, Danish utilities are planning for 200 kW PAFC plants, this will provide operational experience with fuel cell power plants.

44. Krenk, S.; **Jeppesen, B.**, Calculation of Cross Section Properties of Wind Turbine Blades. In: European Community Wind Energy Conference. Proceedings. Herning, 6-10 Jun 1988. Palz, W. (ed.), (H.S. Stephens & Associates, Bedford, 1988) (EUR- 11885) p. 332-336.

Wind turbine blades generally have cross sections with a number of rather thin-walled cells. Traditionally the torsion and shear properties of such cross sections are evaluated by introducing an equivalent open section that is analysed and closed by suitably determined shear flows. The present paper formulates the torsion and shear problems in terms of simple finite elements with the warping function as the primary variable. In this approach there is no need to define any specific cell structure of the cross section, and the stiffness matrix for torsion and shear problem become identical. The method is ideally suitable for micro-computers, and an efficient PC implementation is presented.

45. **Leffers, T.**, Deformation Textures: Simulation Principles. Panelist's Contribution. In: ICOTOM. 8. International Conference on Textures of Materials. Proceedings. Santa Fe, 20-25 Sep 1987. Kallend, J.S.; Gottstein G. (eds.), (The Metallurgical Society Inc., Warrendale, 1988) p. 273-284.

After a general introduction, which includes a comparison of textures simulated with different programs, some of the topics to be dealt with by the working panel are discussed: the type of model to apply, the ambiguity problem and the related problem of rate sensitivity, the formation of the brass-type texture.

46. **Leffers, T.**; Asaro, R.J.; Driver, J.H.; Kocks, U.F.; Mecking, H.; Tomé, C.; Van Houtte, P., Deformation Textures: Simulation Principles. Panel Report. In: ICOTOM. 8. International Conference on Textures of Materials. Proceedings. Santa Fe, 20-25 Sep 1987. Kallend, J.S.; Gottstein G. (eds.), (The Metallurgical Society Inc., Warrendale, 1988) p. 265-272.

The panel discussion on simulation of deformation textures is summarized. The report covers nine out of ten preselected topics (there was not time to discuss the last topic, models for the formation of the brass-type texture).

47. Leffers, T.; Juul Jensen, D., The Early Stages of the Development of Rolling Texture in Copper and Brass. Textures Microstruct. (1988) v. 8/9 p. 467-480.

The texture development in copper and brass (15% zinc) is followed by neutron diffraction measurements from the early stage. The texture development is found to be different in the two materials from the very beginning (largely towards the respective final textures of copper and brass). As demonstrated by texture simulation starting with the experimental orientation distributions of the undeformed materials, the early difference in texture development is **not** *a result of the difference in initial texture. The conclusion of the texture measurements - and of earlier microstructural observations confirmed in the present work - is that the development of the brass-type texture cannot be explained by any of the proposed twinning theories. The only existing model capable of reproducing the development of the brass texture at moderate strains without disagreement with experimental observations appears to be the Sachs model, or rather a modified Sachs model.*

48. Leffers, T.; Juul Jensen, D.; Hansen, N., Various Effects of Grain Size on F.C.C. Rolling Textures. In: ICOTOM. 8. International Conference on Textures of Materials. Proceedings. Santa Fe, 20-25 Sep 1987. Kallend, J.S.; Gottstein G. (eds.), (The Metallurgical Society Inc., Warrendale, 1988) p. 449-454.

In the literature there are various references to grain-size effects on the development of deformation texture. The concept of such an effect is alien to most standard models for texture formation, which means that, apart from the possible practical importance, the effect has interesting theoretical implications.
In the present work we perform a critical examination of the reported cases of grain-size effects on the development of rolling textures in f.c.c. materials, all referring to differences in texture development between coarse-grained materials and »normal« fine-grained materials. Special emphasis is given to the question whether the apparent grain-size effect may actually be an effect of the difference in initial texture which normally accompanies a difference in grain size. In all the materials referred to in the present work the initial thickness of the plates of coarse-grained material to be rolled is sufficiently large compared to the grain size to make the materials proper polycrystals.
We distinguish between four different (but not necessarily unrelated) effects of grain size which are described in four sections - followed by a section with general concluding remarks.

49. Leffers, T.; Juul Jensen, D.; Major, B., Early-Stage Differences Between the Copper-Type and the Brass-Type Texture. In: ICOTOM. 8. International Conference on Textures of Materials. Proceedings. Santa Fe, 20-25 Sep 1987. Kallend, J.S.; Gottstein G. (eds.), (The Metallurgical Society Inc., Warrendale, 1988) p. 461-466.

The abstract appeared in Metallurgy Department Publications 1987.

50. Lilholt, H., Principper for mekaniske egenskaber af fiberforstærket keramik (Principles for the Mechanical Properties of Fibre-Reinforced Ceramics). In: Nye materialer til energisektoren. Dansk Metallurgisk Selskabs Vintermøde, Karrebæksminde, 4-6 Jan 1988. Lilholt, H.; Gundel, P.H. (eds.), (Dansk Metallurgisk Selskab, Lyngby, 1988) p. 243-267.

51. **Lilholt, H.**, The Strength of Metal Matrix Composites under Mechanical and Thermal Loadings. In: Strength of Metals and Alloys. ICSMA 8. Vol. 1. 8. International Conference on the Strength of Metals and Alloys, Tampere, 22-26 Aug 1988. Kettunen, P.O.; Lepistö, T.K.; Lehtonen, M.E. (eds.), (Pergamon Press, Oxford, 1988) (International Series on the Strength and Fracture of Materials and Structures) p. 61-79.

Mechanisms for strengthening of metals are described in relation to metallic composites. The basic deformation mechanisms and maximum strength contributions during tensile loading are analysed. In the field of creep behaviour simple models are used to account for the effect of volume content and aspect ratio of fibres. The (two-phase) materials contain internal stresses and these are discussed. The maximum strength level can be reduced by relaxation mechanisms, and these are illustrated by examples including composites such as Cu with W-fibres and Al with SiC-fibres. Measurements of internal stresses by neutron diffraction are described, and relaxation after thermal loading is discussed.

52. **Lilholt, H.**, Strengthening and Internal Stresses in Composites Under Mechanical and Thermal Loading. In: Mechanical and Physical Behaviour of Metallic and Ceramic Composites. 9. Risø International Symposium on Metallurgy and Materials Science, Risø, 5-9 Sep 1988. Andersen, S.I.; Lilholt, H.; Pedersen, O.B. (eds.), (Risø National Laboratory, Roskilde, 1988) p. 89-107.

The microstructure and strength of metal matrix composites are presented with special reference to the maximum attainable strength level under mechanical and thermal loadings. The basic strength contributions are discussed for the creep properties of metallic composites. The internal stresses are evaluated and the relaxation mechanisms are discussed. Examples are given of relaxation in several composite materials. The possibility of exploiting those features which may be useful in designing composites for long term applications, are discussed.

53. **Lilholt, H.**, Kompositmaterialer giver mange løfter. Fly, rumfart, biler og vindmøller bliver berørt af den intense forskning indenfor materialer (Composite Materials Offer Many Promises. Aeroplanes, Space Technology, Cars and Wind Mills Will Be Affected by the Intensive Research Within Materials). Forskning og Samfund (1988) (no. 5) p. 24-28.

54. **Lilholt, H.**, Kompositmaterialer - når det kniber (Composite Materials - At a Pinch). Nyhedsbrev Teknologinævnet (1988) (no.5) p. 30.

55. **Lilholt, H.**, Models for Creep of Fibrous Composite Materials. Mater. Forum (1988) v. 11 p. 133-139.

Models for the creep behaviour of fibrous composite materials are reviewed. The models describe the creep rate and the strength contributions during creep. In this presentation an attempt is made to classify the composites into three groups: aligned composites, off-axis composites and general composites. The models include cases where the fibres remain rigid in a creeping matrix and cases where both fibres and matrix are creeping, and also the transition between these two (extreme) cases. An attempt is made to include multiaxial creep in the models; this becomes particularly relevant for off-axis and general composites.

56. **Lilholt, H.**, Internal Stresses in Metal Matrix Composites. In: Advancing with Composites. International Conference. Milan, 10-12 May 1988. Crivelli Visconti, I. (ed.), (Centro Materiali Compositi, Naples, 1988) p. 463-490.

Strengthening mechanisms are described for metallic composites with special reference to mechanical properties. In the field of creep behaviour some simple models for the effect of volume content and orientation of fibres are reviewed. A microstructural model involving debonding at the fibres is described and some experimental support is given. In the (general) field of the internal stresses in two-phase materials, the experimental method of neutron diffraction to record bulk internal stresses is mentioned, and some experiments on a metal matrix composite under thermal loading are used to illustrate the subject and the technique.

57. **Lilholt, H.**, Materials Data for WT Design Basis: Fatigue Properties of Glass Fibre Reinforced Polyester. In: Wind Energy - 1. Proceedings of the 1. Contractors' Meeting. Brussels, 5-6 May 1986. Voort, E. Van der; Grassi, G. (eds.), (Harwood Academic Publishers, Chur, 1988) (EUR-11248) p. 165-169.

58. **Lilholt, H.**; Gundel, P.H. (eds.), Nye materialer til energisektoren (New Materials for the Energy Sector). Dansk Metallurgisk Selskab. Vintermødet, Karrebæksminde, 4-6 Jan 1988. (Dansk Metallurgisk Selskab, Lyngby, 1988) 405 p.

59. **Lystrup, Aa.**, Nye materialer til vindmøllevinger. Fiberforstærket plast som konstruktionsmateriale for vinger (New Materials for Wind Mill Wing Blades. Fibre-Reinforced Plastics as a Construction Material for Wing Blades). In: Nye materialer til energisektoren. Dansk Metallurgisk Selskabs Vintermøde, Karrebæksminde, 4-6 Jan 1988. Lilholt, H.; Gundel, P.H. (eds.), (Dansk Metallurgisk Selskab, Lyngby, 1988) p. 269-281.

Important properties for modern wind turbine blades are properties such as: Light, stiff, strong optimum, aerodynamic design and surfaces, and good wear resistance. Blades built of fibre reinforced plastics have all those properties. The basic materials properties, different blade design and manufacturing processes for fibre-reinforced blades are discussed.

60. **Lystrup, Aa.**, Computer Aided Filament Winding of Flat Angle-Ply Test Specimens. In: 2. International Conference on Automated Composites 88. Proceedings. Noordwijkerhout, 26-28 Sep 1988. (The Plastics and Rubber Institute, London, 1988) p. 13/1-13/6.

A computer controlled wet filament winding technique is used to fabricate high quality transparent flat fatigue test specimens of angleplied glass fibre reinforced polyester. The laminates are produced by winding wetted fibres onto a steel plate mandrel, and the analytical expression for the movement of the feed-eye of the filament winding machine is described as a function of the desired fibre orientation and the geometry of the steel plate mandrel.
The process is very versatile and suited for producing small quantities of laminates of »prepreg-type« quality with individual choice of fibre and matrix material.

61. Maschio, S.; **Toft Sørensen, O.**, Mechanical Properties and Microstructure of Zirconia Toughened Alumina. Risø-M-2675 (1988) 20 p.

Powders of zirconia toughened alumina containing 15vol.% ZrO_2 -non-stabilized as well as stabilized with 3mole% Y_2O_3 - were prepared using two techniques: hydrolysis of a $ZrOCl_2 \cdot 8H_2O$ solution with or without addition of $Y(NO_3)_3 \cdot 5H_2O$ followed by hydrolysis of Al-sulphate (here called »direct hydrolysis«) and by hydrolysis of the Zr-Y-solution onto a commercial Al_2O_3 powder in a slurry. By both techniques it was possible to obtain powders which when sintered at 1600 °C gave specimens with reasonable good mechanical properties - median bend strength values in the range 326-346 MPa and k_{Ic} values in the range of 4.2-5.16 $MPam^{1/2}$. The highest k_{Ic} value was actually obtained with the powder prepared by hydrolysis of non-stabilized zirconia in the Al_2O_3-slurry, which after sintering, however, only contained 20 vol.% t-ZrO_2. From this observation it is concluded that microcracking is the controlling mechanism for fracture toughness in contrast to transformation toughening which is believed to control the bend strength. Finally, SEM micrographs on polished and thermally etched sintered surfaces showed that these specimens were very fine grained (mean grain size 0.3 mm) with an even distribution of the zirconia grains in the Al_2O_3-matrix.

62. **Mogensen, M.,** Passivation of Lithium in $SOCl_2$, SO_2Cl_2 and SO_3. In: Primary and Secondary Ambient Temperature Lithium Batteries. Proceedings. Honolulu, 18-23 Oct 1987. Gabano, J.P.; Takehara, Z.; Bro, P. (eds.), (The Electrochemical Society, Pennington, 1988) p. 229-243.

The passivation of Li electrodes in liquid cathodes has been studied by ac impedance and SEM during exposure times up to four years. The liquid cathodes are 1.8M $LiAlCl_4$ in $SOCl_2$, 1.2M $LiAlCl_4$ + 0.6M SO_2AlCl_3 in $SOCl_2$, 1.5M $LiAlCl_4$ in SO_2Cl_2 and 0.5M $LiAsF_6$ in $SO_2 2SO_3$. In the acid $SOCl_2$ a dramatic difference in passivation rates were observed between different Li electrode arrangements. The results are rationalized through a kinetic model in which the rate determining step changes with exposure time. Nucleation and growth of Li salt crystals are important steps in the formation of the passivating solid electrolyte layers.

63. **Pedersen, O.B.,** Dislocations and the Strength of Metallic Composites. In: Mechanical and Physical Behaviour of Metallic and Ceramic Composites. 9. Risø International Symposium on Metallurgy and Materials Science, Risø, 5-9 Sep 1988. Andersen, S.I.; Lilholt, H.; Pedersen, O.B. (eds.), (Risø National Laboratory, Roskilde, 1988) p. 157-182.

The low temperature tensile and cyclic plasticity of pure and fibre strengthened metals are discussed on a unified basis of dislocation mechanisms and continuum mechanics. It is pointed out that the Eshelby accommodation factor for PSB walls in cyclically saturated metals depends sensitively upon the wall orientation. The strong matrix hardening in fibre strengthened metals is caused by a direct interplay between the constituent phases. This interplay is shown mainly to reflect elastic heterogeneity in the case of copper with high volume fractions of long tungsten fibres. The simple source-shortening model is confirmed by existing data, but cyclic experiments are still needed at high volume fractions.

64. **Pedersen, O.B**, Mapping of Low-Temperature Fatigue. Rev. Phys. Appl. (1988) v. 23 p. 690.

Low temperature single slip deformation of well-annealed fcc single crystals occurs in successive stages, as revealed for example by the shape of the tensile stress-strain curve. When a constant plastic strain is applied cyclically in push-pull the dislocation microstructure also builds up the successive stages. The stages of plastic flow, *structural change and fracture can be summarized in »fatigue mechanism maps« of plastic strain amplitude versus cycle number. Maps were constructed for single crystals of copper, aluminium and molybdenum deformed at roomtemperature.*

65. **Pedersen, O.B.**, Mapping of Basic Fatigue Mechanisms. In: Basic Mechanisms in Fatigue of Metals. Proceedings. Brno, 12-14 Apr 1988. Lukas, P.; Polak, J. (eds.), (Academia, Prague, 1988) p. 169-183.

The dislocation mechanisms by which cyclic plasticity causes fatigue fracture in successive stages of structure-change are discussed in the light of recent work. Parallels between dislocation processes in two-phase and single-phase systems have led to several »composite models« whose domains of application define fields in »fatigue mechanism maps«: Coffin-type diagrams of constant plastic strain amplitude versus cycle number. The applications, limitations and possible extensions of the models and maps are discussed in this short review.

66. **Pedersen, O.B.**; Lisiecki, L.L., The Effect of Temperature on Cyclic Saturation in Copper. In: Strength of Metals and Alloys. ICSMA 8. Vol. 1. 8. International Conference on the Strength of Metals and Alloys, Tampere, 22-26 Aug 1988. Kettunen, P.O.; Lepistö, T.K.; Lehtonen, M.E. (eds.), (Pergamon Press, Oxford, 1988) (International Series on the Strength and Fracture of Materials and Structures) p. 719-724.

Single slip oriented copper single crystals were cyclically strained in tension-compression at constant low plastic shear amplitude at a temperature of 77K and examined by electron microscopy. The observations were compared with data available for other temperatures and discussed in the light of current theory. It was found that a reduction in temperature from 293K to 77K appears to double the length of the plateau in the cyclic stress-strain curve.

67. **Poulsen, F.W.**; Andersen, N.H.; Clausen, K.N.; Sadoway, D.R.; Øgendal, L., Super-Ionic Conduction in Alkali Metal Hexachloro Niobates and Tantalates. Solid State Ionics (1988) v. 28/30 p. 271-275.

Ac-conductivity, DSC, and neutron diffraction studies of the ionic conductors $KNbCl_6$ and $KTaCl_6$ are presented. The first order phase transition to the super ionic state occur at temperatures in the range 299-334 °C. Conductivities up to 0.35 S/cm are observed. The lowest transition is from a hexagonal to a cubic fcc structure, whereas no definite conclusion could be drawn concerning the structure of the super ionic phases, since only three diffraction peaks were observed in the diffractograms.

68. **Schrøder Pedersen, A.**; **Bilde-Sørensen, J.B.** (eds.), Metallurgy Department. Publications 1987. Risø-M-2705 (1988) 44 p.

A presentation (including abstracts) of scientific and technical publications and lectures by the staff of the Metallurgy Department during 1987 is given. The list comprises journal papers, conference papers, reports, lectures and poster presentations in the following categories: Publications, Lectures and Poster Presentations.

69. **Schrøder Pedersen, A.**; **Bilde-Sørensen, J.B.**; **Hansen, N.** (eds.), Metallurgy Department. Annual Progress Report for 1987. Risø-R-561 (1988) 55 p.

Selected activities of the Metallurgy Department at Risø National Laboratory during 1987 are described. The work is presented in four chapters. Materials Science, Materials Engineering, Materials Technology and Energy Programmes. A survey is given of the Department's participation in international collaboration and of its activities within education and training. Furthermore, the main numbers illustrating the Department's economy are given. Lists of staff members, visiting scientists, publications, lectures and poster presentations are included.

70. **Singh, B.N.**; Foreman, A.J.E., Cascade Stability and Cavity Nucleation. J. Nucl. Mater. (1988) v. 155/157 p. 1258-1262.

The possibility that the concurrent generation of collision cascades and gas atoms during irradiation may enhance the cavity nucleation is examined. The number of helium atoms required to prevent cascade collapse in Cu, Al and 316 stainless steel is calculated. It seems rather unlikely that at realistic helium generation rates the cascades can be stabilized in the form of three-dimensional cavity embryos. The role of uncollapsed vacancy aggregates in cavity nucleation is evaluated by calculating the probability of helium atoms reaching the aggregates within their lifetime. The effect of collision cascades on cavity nucleation is found to depend very sensitively to the stability against collapse, size and structure of the cascades and the mobility of gas atoms.

71. **Singh, B.N.**; Foreman, A.J.E., Transport of Helium to Grain Boundaries During Irradiation. In: Radiation-Induced Changes in Microstructure. 13. International Symposium. Part 1. Seattle, 23-25 Jun 1986. Garner, F.A.; Packan, N.H.; Kumar, A.S. (eds.), (ASTM, Philadelphia, 1987) (ASTM Special Technical Publication, 955) p. 345-357.

The rate of accumulation of helium at grain boundaries is one of the important parameters determining the integrity and lifetime of the structural components of a fusion reactor. A diffusion calculation is made of the flux of helium to a grain boundary. The flux is found to depend on the gas production rate, the width of the cavity denuded zone, and the cavity sink strength in the grain interior. The calculated accumulation of helium is in good agreement with the measured gas content of grain boundaries in aluminium, PE16 and 316 stainless steel. The flux of helium to grain boundaries increases with helium generation rate, but the increase is less than proportional to the generation rate. The loss of helium to grain boundaries during the nucleation of the bubbles within the grains has been estimated; no great loss is expected to occur. However, the loss would be considerably enhanced if any delay in bubble nucleation were to occur because of incubation effects. The role of material variables is found to be diffucilt to predict at present.

72. **Singh, B.N.**; Lohmann, W.; Ribbens, A.; Sommer, W.F., Microstructural Changes in Commercial Aluminium Alloys Caused by Irradiation with 800 MeV Protons. In: Radiation-Induced Changes in Microstructure. 13. International Symposium. Part 1. Seattle, 23-25 Jun 1986. Garner, F.A.; Packan, N.H.; Kumar, A.S. (eds.), (ASTM, Philadelphia, 1987) (ASTM Special Technical Publication, 955) p. 508-519.

Commercial Al-Mg and Al-Mg-Si alloys were irradiated in the Los Alamos Meson Physics Facility (LAMPF) with 800 MeV protons. The irradiation experiment was carried out at a temperature between 40 to 100 °C to a dose level of ≤ 0.2 dpa. Post-irradiation microstructure and mechanical properties of these alloys have been investigated. For comparison, a parallel investigation was conducted on unirradiated

reference specimens as well as on unirradiated annealed (981 h at 100 °C, corresponding to time at temperature during irradiation) specimens. It was found that the cold-work microstructure in the Al-Mg alloy survives the thermal annealing treatment but dissolves during irradiation already at a dose level of ≤ 0.1 dpa. In the Al-Mg-Si alloy magnesium silicide (Mg-Si) type precipitates also survive the thermal annealing but dissolve during irradiation at a low dose level of ≤ 0.1 dpa. Post-irradiation mechanical testing demonstrated that the strength of these alloys is drastically reduced because of irradiation. The observed irradiation softening can be understood in terms of the observed microstructural changes caused by irradiation.
Al-Mg-Si alloy magnesium silicide (Mg-Si) type precipitates also survive the thermal annealing but dissolve during irradiation at a low dose level of ≤ 0.1 dpa. Post-irradiation mechanical testing demonstrated that the strength of these alloys is drastically reduced because of irradiation. The observed irradiation softening can be understood in terms of the observed microstructural changes caused by irradiation.
73. Thaulow, C.; **Debel, C.P.**; Søvik, O.P. (and others), Recommendations on Fracture Mechanics Testing. Prepared for NORDTEST. (SINTEF. Avdeling for Materialer og Bearbeiding, Trondheim, 1988) vp.

74. **Toft, P.**; **Borring, J.**; **Adolph, E.**, Pilot Plant Production at Risø of LEU Silicide Fuel for the Danish Reactor DR3. In: Proceedings of the 1986 International Meeting on Reduced Enrichment for Research and Test Reactors. Base Technology. Gatlinburg, 3-6 Nov 1986. ANL-RERTR-TM-9 (1988) p. 132-141.

75. **Toft Sørensen, O.**; **Bentzen, J.J.**; **Poulsen, F.W.**, Zirkoniumoxid forstærkede keramiske materialer: Fremstilling, egenskaber og anvendelser inden for energisektoren (Zirconia-Reinforced Ceramic Materials: Fabrication, Properties and Applications Within the Energy Sector). In: Nye materialer til energisektoren. Dansk Metallurgisk Selskabs Vintermøde, Karrebæksminde, 4-6 Jan 1988. Lilholt, H.; Gundel, P.H. (eds.), (Dansk Metallurgisk Selskab, Lyngby, 1988) p. 299-318.

76. **Toft Sørensen, O.**; Jensen, H., Keramiske iltsensorer (Ceramic Oxygen Sensors). Dansk Kemi (1988) v. 69 p. 68-72.

77. Victoria, M.; Green, W.V.; Gavillet, D.; **Singh, B.N.**; **Leffers, T.**, Nucleation and Growth of Precipitates and Helium Bubbles in a High-Purity Al-Mg-Si Alloy Irradiated with 600 MeV Protons. J. Nucl. Mater. (1988) v. 155/157 p. 1075-1078.

Irradiation-induced changes in the precipitation behaviour of age-hardening alloys are not yet well established. Very little is known about the problem of precipitation and precipitate stability particularly under fusion irradiation conditions leading to concurrent production of displacement damage and gaseous impurities at high rates. The main objective of the present work has been to study the effect of displacement damage, in the range from 0.01 to 1.63 dpa with simultaneous production of helium atoms at a high rate (214 appm/dpa) in a high purity Al-0.75% Mg-0.42% Si alloy; the composition is similar to that of the commercial type 6061 Al-Mg-Si alloy. In order to study the effect of irradiation on the nucleation and growth of precipitates and the aggregation of concurrently produced helium atoms, the alloy was irradiated in the solution annealed condition (535 °C, 35 min.). The irradiation temperature varied between 120 and 260 °C. After irradiation the nucleation growth and dissolution of Mg_2Si-type precipitates as a function of irradiation dose and temperature

were studied by transmission electron microscopy (TEM). The results show that the precipitation of Mg_2Si-type particles occurs on a finer scale during irradiation than during thermal aging of the solution treated Al-Mg-Si alloy (at the temperature of irradiation). The needle-shaped Mg_2Si-type precipitates in the thermally aged and irradiated specimens are found to lie along the < 100 > matrix directions.
Information regarding nucleation and growth of helium bubbles in the matrix at precipitates-matrix interfaces and at grain boundaries has also been obtained by TEM. Long rows of bubbles are found to be associated with the Mg_2Si-type precipitates. The bubbles at the precipitate-matrix interfaces and at the grain boundaries are found to grow faster than those in the matrix. The implications of these results will be briefly discussed.

78. Victoria, M.; Green, W.V.; **Singh, B.N.; Leffers, T.**, Nucleation, Growth, and Distribution of Cavities in the Vicinity of Grain Boundaries in Aluminium Irradiated with 600 MeV Protons. In: Radiation-Induced Changes in Microstructure. 13. International Symposium. Part 1. Seattle, 23-25 Jun 1986. Garner, F.A.; Packan, N.H.; Kumar, A.S. (eds.), (ASTM, Philadelphia, 1987) (ASTM Special Technical Publication, 955) p. 233-241.

High-purity aluminium (99.9999%) was irradiated with 600 MeV protons with a damage rate of 3.5 x 10^{-6} dpa/s and a helium generation rate of 214 atomic parts per million (appm) per dpa. The irradiation experiments were carried out at temperatures in the range 120 to 140 °C to doses up to 5 dpa. Transmission electron microscopy on irradiated specimens showed that voids are formed only in a narrow band in the vicinity of the void denuded zone along grain boundaries. Both the density and the size of voids in this band vary as a function of distance from the denuded zone. Changes in irradiation dose and temperature do not seem to affect the spatial distribution of voids in the band. These results are compared with the results obtained on high-purity aluminium irradiated with fast neutrons. The bubble formation behavior in the grain interior and in the band containing voids is briefly described. The effect of bubble formation on the growth behavior of voids is discussed.

79. **Waagepetersen, G.**, Beregning af flydning i limfuger samt udformning af zoner med konstante elastiske forskydningsspændinger (Yield in Adhesive Joints and Design of Zones with Constant Elastic Shear Stresses). Materialnyt (1987) (no.1) p. 17-31.

A method is given which, based on a simple elastic-plastic model, shows the distribution of shear stresses in the adhesive and gives a total picture of the development of the length of the yield zones and their strain as a function of load.
Methods are given for the design of adhesive joints with constant elastic shear stresses in the ends of the adhesive or throughout the whole length of the adhesive, obtained by varying the thickness of the adherends or of the adhesive or a combination of both. The characteristic yield properties of such designs are being determined. Internal stresses after yield and unloading are determined, and modified stress-distribution for new load is found. The constant elastic shear stress zones can be designed taking all relevant factors into consideration including various temperature stresses, bending moments in the adherends etc. Thereby zones with constant stresses will be generally usable also for single lap joints.

80. Walker, C.T.; Knappik, P.; **Mogensen, M.**, Concerning the Development of Grain Face Bubbles and Fission Gas Release in UO_2 Fuel. J. Nucl. Mater. (1988) v. 160 p. 10-23.

A series of scanning electron micrographs trace the development of gas bubbles on the grain faces in a transient tested BWR fuel. The observations indicate that gas bubbles nucleate on metallic precipitate particles and that bubble migration is prevented by the precipitates. X-ray fluorescence and electron probe microanalysis result show an accumulation of Xe on the grain boundaries at intermediate radial positions and high »in grain« retention in the centre of the fuel. These findings are acribed to high compressive forces in the fuel during the transient and an increase in the rate of thermal resolution with temperature. It is concluded that under transient conditions the magnitude of the local mechanical restraint and the existence of macroscopic pressure gradients are important in determining the behaviour of grain face bubbles. In a high pressure field both the bubbles and precipitates grow by Ostwald ripening and little bubble interlinkage occurs. In a non-uniform pressure field bubble interlinkage can take place in areas where the restraint pressure is low and this leads to the formation of escape tunnels at the grain edges. Intergranular cracks which form the end of the transient when the mechanical restraint pressure is removed also provide escape routes for fission gas.

81. Withers, P.J.; **Lilholt, H.; Juul Jensen, D.**; Stobbs, W.M., An Examination of Diffusional Stress Relief in Metal Matrix Composites. In: Mechanical and Physical Behaviour of Metallic and Ceramic Composites. 9. Risø International Symposium on Metallurgy and Materials Science, Risø, 5-9 Sep 1988. Andersen, S.I.; Lilholt, H.; Pedersen, O.B. (eds.), (Risø National Laboratory, Roskilde, 1988) p. 503-510.

The temporal variation of thermal stresses in the two phases of Al/SiC metal matrix composites was investigated. In this context, the internal strains within both particulate and whisker systems were studied over extended periods of time and over a range of temperatures, and the results compared with possible mechanisms of stress relief.

2. Lectures

1. **Andersen, S.I.**, Composite Materials Research at the Metallurgy Department of Risø National Laboratory. Presented to Department of Aerospace Engineering, Indian Institute of Science and to Structures Division of National Aeronautical Laboratory, Bangalore, 6 Dec 1988.

A general overview of the work on polymer based composite materials was given, covering both basic materials research as well as materials testing and fabrication. More specifically the results from the ongoing program on fatigue of glass reinforced polyester were shown, and the stiffness change and damage mechanisms were discussed.

2. **Andersen, S.I.**, Mekanisk prøvning for bestemmelse af konstruktionsegenskaberne for anisotrope materialer (Mechanical Testing for Engineering Properties of Anisotropic Materials). Presented at XIII Polish Seminar on Experimental Mechanics, Jadwisin, Poland, 11-12 Oct 1988. To be published by Politeknika Warzawska, Poland.

The proper determination of the static and dynamic properties of strength and stiffness of composite materials are essential for the rational use of these materials for specific design purposes. Although essentially the same testing equipment and measuring technique are used as for the more conventional isotropic and seemingly homogeneous materials such as metals, the testing is normally more comprehensive and complicated to perform due to the anisotropic properties and inhomogeneous nature of the material and the often much lower strength in certain directions.
The paper will present the problems involved in the testing of fiber reinforced plastic materials (carbon/epoxy and glass/polyester) for stiffness and strength, and both static tests as well as fatigue testing is considered. The methodology applied at Risø National Laboratory for this type of testing will be outlined, and data on fatigue of unidirectional and angleplied glass/polyester presented.
The verification of the validity of data used in the design of specific components is often performed by strain gauge technique. Due to the transverse sensitivity of traditional resistance strain gauge, the anisotropic material properties may cause large errors which need to be corrected during data reduction. The importance of this correction will be outlined and examples shown for testing of components.

3. **Andersen, S.I.**, Prøvning af materialer med retningsbestemte egenskaber (Testing of Materials with Anisotropic Properties). Presented at Nordisk Materialekonference, Rønne, 31 May - 2 Jun 1988.

4. **Bentzen, J.J.**, Elektriske egenskaber af zirkoniumoxider og nogle derpå baserede anvendelser inden for energisektoren (Electrical Properties of Zirconia and Some Energy Related Applications). Presented at Dansk Metallurgisk Selskabs Vintermøde 1988, Karrebæksminde, Denmark, 4-6 Jan 1988.

5. **Bentzen, J.J.**, Ionledende keramiks anvendendelse til brændselsceller og iltmålesonder (Application of Ion Conducting Ceramics in Fuel Cells and Oxygen Sensors). Presented at Danmarks Ingeniørakademi, Lyngby, 19 Sep 1988.

6. Bilde-Sørensen, J.B., Scanningelektronmikroskopets anvendelsesmuligheder (The Scanning Electron Microscope - A Tool with Many Applications). Presented at Dansk Forening for Materialografis temadag, Lyngby, 14 Apr 1988.

The many possible applications of the scanning electron microscope were illustrated by a number of practical examples.

7. Borum, K.K., Gundtoft, H.E., Jacobsen, F., Precision Scanning with Ultrasonics with Examples from Measurements of Single Porosities in Ceramics. Presented at the Danish-Israeli Symposium on Non-Destructive Evaluation, Lyngby, 27 Jun - 1 Jul 1988. To be published as a Risø report.

A hydraulic scanning system controlled by minicomputer is described. It is a very fast and precise scanning system which gives quantitative results from automatic ultrasonic examination.
The X and Y axes are moved by hydraulic cylinders and we are working on improvement of the scanning program. We want to integrate more degrees of freedom so we get a more flexible system.
By transferring the scanning data to a PC we can use new graphic programs to show the results from the scanning.
As an example an examination of a ceramic plate is presented: We can detect the presence and the position of small spherical porosities down to 0.1 mm diameter in a ceramic plate. Several artificial defects made in the plate were used for calibration and optimisation of the technique. Areas with natural defects were viewed with a microscope. Good agreement with the predicted values from the ultrasonic examination was found.

8. Domanus, J.C., Neutron Radiography. Techniques and Application. Presented at the Danish-Israeli Symposium on Non-Destructive Evaluation, Lyngby, 27 Jun - 1 Jul 1988. Also presented as a poster. To be published in NDT-International.

After describing the principles of the »in pool« and »dry« installations, techniques used in neutron radiography are reviewed. Use of converter foils with silver halide films for the direct and transfer methods is described.
Advantages of the use of nitrocellulose film for radiographing radioactive objects are discussed. Dynamic imaging is shortly reviewed. Standardization in the field of neutron radiography (ASTM and Euratom Neutron Radiography Working Group) is described.
The paper reviews main fields of use of neutron radiography. Possibilities of use of neutron radiography at research reactors in various scientific, industrial and other fields are mentioned.
Examples are given of application of neutron radiography in industry and the nuclear field.

9. Eldrup, M.; Mackenzie, I.K.; McKee, B.T A.; Segers, D., Open Discussion on Experimental Techniques and Data Analysis (For Bulk Systems). Presented at the Eighth International Conference on Positron Annihilation, Gent, 29 Aug - 3 Sep 1988. Proceedings to be published.

During ICPA-8 a 2 hour open discussion was arranged about experimental techniques and data analysis used in positron annihilation studies of bulk systems. The discussion was structured in five parts: 2D Angular Correlation measurements, *Analysis of 1D Angular Correlation curves, Analysis of Doppler Broadening curves, Lifetime Spectrometry, and Analysis of Lifetime spectra. This paper is an edited compilation of the discussion.*

10. Foreman, A.J.E.; **Singh, B.N.**, The Role of Collision Cascades and Helium Atoms in Cavity Nucleation. Presented at Workshop on the Effects of Recoil Spectrum and Nuclear Transmutations on the Evolution of the Microstructure, Lugano, 24-29 Mar 1988. To appear in Radiation Effects.

The simultaneous production of cascades and helium atoms during irradiation may give rise to enhanced cavity nucleation. However, this would occur only if a sufficient number of helium atoms is present to prevent the collapse and to stabilize the vacancy aggregates against thermal evaporation. The number of helium atoms needed to prevent the collapse of cascades is estimated. The number of helium atoms required is unlikely to be achieved even at high helium production rate.
The cascades that fail to collapse will have a thermal annealing lifetime. The lifetimes of isolated cascades and a group of subcascades are estimated. This is followed by the calculation of the probability of helium atoms reaching the cascade by diffusion during these lifetimes. The effect of collision cascades on cavity nucleation is found to depend on sensitivity on the stability against collapse, size and structure of the cascades and the mobility of the gas atoms.

11. **Gundtoft, H.E.**, Automatisk ultralydkontrol af materialer belyst ved eksempler (Automatic Ultrasonic Examination of Materials illustrated by Examples). Presented at Dansk Svejseteknisk Landsforenings Tyndpladeseminar, Randers, 15 Mar 1988.

12. **Gundtoft, H.E.**, Eksempler på kvantitative NDT-ultralydmetoder (Examples of Quantitative NDT-Ultrasonic Methods). Presented at Svejsecentralen i Esbjerg, Esbjerg, 26 May 1988.

13. **Gundtoft, H.E.**, Eksempler på kvantitative NDT-ultralydmetoder til udvikling af plastkompositter (Examples of Quantitative NDT-Ultrasonic Methods for Development of Plast Composites). Presented to Dansk Selskab for Materialeprøvning og -forskning, Lyngby, 23 Mar 1988.

14. Gunnarson, G.; Westmann, A.-K.; Mäntylä, T.; **Toft Sørensen, O.**, Production of Zirconia Powders by Hydrothermal Methods and Supercritical Drying and Their Properties. Presented at the 2nd International Conference on Ceramic Powder Processing Science and Technology, Berchtesgarten, FRG, 10-14 Oct 1988. Also presented as a poster. Proceedings to be published.

15. **Hansen, N., Barker, I.**, Ralph, B., **Juul Jensen, D.**, Deformation Textures and Structures of Deformed FCC Metals. Presented at ICSMA 8, Tampere, Finland, 22 Aug 1988.

16. **Hansen, N.**, Microstructure and Creep Strength of Aluminium Composites Reinforced with SiC-Fibers. Presented at Light Metals Center, University of Virginia, Charlottesville, 4 Oct 1988.

The recrystallization behavior and the creep properties will be discussed for SiC reinforced aluminum composites containing small Al_2O_3 particles. The recrystallization behavior of these materials is strongly affected both by the presence of SiC fibers *and of Al_2O_3 particles. The SiC fibers tend to accelerate the nucleation whereas the Al_2O_3 particles have the opposite effect. Therefore the recrystallized microstructure depends on the relative concentration of the SiC and Al_2O_3. The creep strength of the composites has been studied at 673 K in the extruded and in the recrystallized state. It is shown that the creep strength is significantly enhanced by recrystallization and this effect is discussed on the basis of previous results for aluminum containing a fine dispersion of Al_2O_3.*

17. **Hansen, N.**, Microstructure, Texture and Mechanical Properties After Large Deformations. Presented at ETH and to Schweizische Verband für Materialtechnik, Zürich, 13 Jan 1988.

18. **Hansen, N.**, Recrystallization and High Temperature Strength of Aluminium Composites Reinforced with SiC-Fibers. Presented at the Metallurgical Engineering and Materials Science Department, Carnegie Mellon University, Pittsburgh, 10 Oct 1988.

The recrystallization behavior and the high temperature strengths will be discussed for SiC reinforced aluminum composites containing small Al_2O_3 particles. The recrystallization behavior of these materials is strongly affected both by the presence of SiC fibers and of Al_2O_3 particles. The SiC fibers tend to accelerate the nucleation whereas the Al_2O_3 particles have the opposite effect. Therefore the recrystallized microstructure depends on the relative concentration of the SiC and Al_2O_3.
The high temperature strength of the composites has been studied by creep testing at 673 K in the extruded and in the recrystallized state. It is shown that the creep strength is significantly enhanced by recrystallization and this effect is related to previous results for aluminum containing a fine dispersion of Al_2O_3. Finally addition strengthening of fibers and small particles is discussed.

19. Jensen, K.O.; Nieminen, R.M.; **Eldrup, M.; Singh, B.N.**; Evans, J.H., Gas Densities in Noble Gas Bubbles and Positron Annihilation Characteristics. Presented at the International Positron Workshop 1988, Munich, 25-27 Aug 1988.

A survey of recent theoretical and experimental work on the relationship between positron annihilation parameters and gas densities in noble gas bubbles in metals is given.
The state of positrons trapped at Al-He and Cu-Kr interfaces has been studied theoretically. The distribution of gas atoms across the interfaces was calculated by the molecular dynamics technique. The influence of the gas on a positron trapped in the image potential well at the metal surface was determined in the corrugated mirror model. The annihilation rate of an interface-trapped positron is increased compared to the clean surface due to annihilation with gas atom electrons. This allows relationship between positron lifetimes and gas densities to be established for the systems studied.
Positron lifetime measurements were made for Al samples which contain He bubbles as a result of being irradiated with 600 MeV protons. Helium density values determined from the positron lifetimes using the theoretical results agree well with independent, albeit uncertain, estimates based on Transmission Electron Microscopy (TEM) data. In addition, one-dimensional angular correlation curves for He bubbles as a function of He density were determined.
Similarly, lifetime measurements were made for Cu and Ni containing high concentrations of Kr. Estimates of Kr densities in bubbles containing solid Kr in as-prepared material based on positron lifetime results are in good agreement with density

determinations by electron diffraction. The positron Kr density results in an isochronal annealing study correlate well with TEM data on similar material.

20. **Juul Jensen, D.**, Fast Texture Measurements by Neutron Diffraction Used in the Study of Recrystallization. Presented at ETH, Zürich, 22 Feb 1988.

A fast technique for texture determination based on neutron diffraction has been developed. A variable wavelength neutron spectrometer was modified to incorporate a linear position sensitive detector and a fully automatic Euler goniometer. With this spectrometer a complete texture analysis required 15 to 45 minutes measuring time depending on the sample material. With standard X-ray spectrometers this time is about 4 to 10 hours. For relative slow processes, the neutron technique enables accurate in-situ kinetic investigations based on the complete texture description. The kinetics of faster processes can be followed by measurements that focus on selected texture components. Thereby, a time resolution in the order of seconds is obtained.
The potential of the neutron texture technique is illustrated by an in-situ kinetic investigation of recrystallization of aluminium. By comparing results obtained by the neutron technique and other more traditional methods it is shown that the neutron technique has several advantages in describing accurately recrystallization kinetics, and that the neutron-kinetic data can be used to validate recrystallization models.

21. **Juul Jensen, D.**, Neutron Diffraction for Applied Materials Research at Risø National Laboratory, Presented at ENEA, Bologna, 20 May 1988.

Experimental neutron diffraction techniques for texture measurements, internal stress determination, small angle neutron scattering and phase transformations are described. Special emphasis is on the measurements of textures and internal stresses as new precise, and fast experimental techniques have been developed at Risø for these type of measurements. Examples of the ongoing research with the different techniques are discussed.

22. **Juul Jensen, D.**, Neutron Diffraktion til NDT (Neutron Diffraction Used for NDT). Presented to Dansk Selskab for Materialprøvning og -forskning, Lyngby, 23 Mar 1988.

Neutron diffraction can be used as a non-destructive testing technique for the determination of internal stresses. The experimental technique and set-up are described. The potential of the technique is demonstrated via measurements of internal stresses in a CTS specimen and in a metal matrix composite material.

23. **Leffers, T.**, Measurement of Internal Stresses by Neutron Diffraction with Reference to SOFC Structures. Presented at Contractor's Meeting on Solid Oxide Fuel Cells, European Communities, Bruxelles, 18 Jan 1988.

The potential application of neutron diffraction for measurement of internal stresses in solid-oxide fuel-cell structures and SOFC materials is discussed with special reference to the equipment built up at Risø.

24. **Leffers, T.**, Neutron Diffraction in Materials Science: Measurement of Textures and Residual Stresses. Presented to Department Metaalkunde en Togepaste Materiaalkunde, Katholieke Universiteit Leuven, Leuven, Belgium, 16 Mar 1988.

A general description is given of the application of neutron diffraction in materials science. The set-ups for measurement of textures and internal stresses developed at Risø are described in detail together with some applications.

25. **Leffers, T.**, Quantitative Simulation of the Microstructural Development During Plastic Deformation. Presented to Institut für Werkstoffe, Technische Unversität Braunschweig, Braunschweig, FRG, 1 Dec 1988.

It is described how quantitative microstructural simulations may widen the experimental basis for the evaluation of models for plastic deformation. The application of microstructural simulation (simulation of aspects for mechanical twinning) in an investigation of the deformation pattern during rolling of brass is quoted as an illustration of the potential of microstructural simulation.

26. **Leffers, T.**, Quantitative Simulation of Microstructural Evolutions. Presented at Department of Materials Science and Engineering, Northwestern University, Evanston, Illinois, 23 Sep 1988.

Initially the application of microstructural simulation is described in general (on recrystallization, grain growth and plastic deformation). Then some specific new applications are discussed: simulation of various aspects of mechanical twinning during rolling of brass.

27. **Leffers, T.**, Real and Simulated Microstructure and Anisotropic Mechanical Properties of Rolled Brass. Presented at Symposium on Modelling of Anisotropic Materials Behaviour, Chicago, 28 Sep 1988.

Thin lamellae of mechanical twins are predominant features in the microstructure of rolled brass (in the present work brass with 15% Zn). The twin lamellae appear in bundles making up special microbands in which the shear is concentrated. Simulation shows that the orientation distribution of the twin lamellae reflects a modified-Sachs type of deformation pattern rather than a Taylor type (in agareement with the texture). The effect of the anisotropic orientation distribution of the twin lamellae on mechanical anisotropy is investigated by simulation with a simple model.

28. **Leffers, T.**, Simulation of the Microstructural Evolution During Deformation. Presented to Department of Materials Engineering, Drexel University, Philadelphia, 4 Oct 1988.

The application of microstructural simulation to problems within plastic deformation is discussed with reference to some specific simulations of aspects of mechanical twinning in rolled brass. Simulation of deformed microstructures is compared with simulation of annealed microstructures.

29. **Lilholt, H.**, Creep Behaviour and Strengthening Effects in Metals Reinforced with Ceramic Fibres. Presented at Development in Composite Materials, Chalmers University of Technology, Gothenburg, 15-16 Mar 1988.

The incorporation of ceramic fibres in metals normally improves the creep strength of the resulting composite material. The strengthening effects of fibres are discussed and constitutive equations and diagrams are established for some simple cases; the fibres may stay elastic (i.e. non-creeping) or they may creep themselves. The creep curve *(strain versus time) of the fibrous composite has several stages and possible strengthening and weakening mechanisms will be discussed, to illustrate the complex interaction of microstructure and internal stresses in fibrous composite materials.*

30. Lilholt, H., Fibre Reinforcement of Polymers, Metals and Ceramics. Presented at Lecture Series on Materials, Technical University of Denmark, Lyngby, 8 Nov 1988.

The general principles for fibre reinforcement are described; special properties and phenomena in polymers, metals and ceramics, respectively, are presented.

31. Lorentzen, T., Non-Destructive Evaluation of Residual Stresses by Neutron Diffraction. Presented at Danish-Israeli Symposium on Non-Destructive Evaluation, Lyngby, 27 Jun - 1 Jul 1988. To be published in NDT-International.

A technique for non-destructive determination of residual stresses using neutron diffraction is described. The basic principles are explained, and two experimental set-ups for the determination of type-1 and type-2 stresses are presented. Problems concerning texture and anisotropic effects are discussed and the potential of the technique is illustrated by examples related to non-destructive evaluation (NDE) of structural components.

32. Lystrup, Aa., Fiberarmeret Plast - Et holdbart materiale til vindmøllevinger (Fibre-Reinforced Materials - A Strong Material for Wing Blades for Wind Mills). Presented to Danmarks Ingeniørakademi, Kemiafdelingen, Lyngby, 21 Nov 1988.

33. Lystrup, Aa., Fremstilling af fiberforstærket plast; teknik og maskiner (Filament Winding of Fibre Composites; Techniques and Machinery). Presented to Danmarks Ingeniørakademi, Maskinafdelingen, Lyngby, 19 Aug 1988.

The basic principles of filament winding of fibre reinforced composite materials were explained and different types of filament winding machines were discussed.

34. Mogensen, M., Brændselsceller (Fuel Cells). Presented to Dansk Elektrokemisk Forening, Lyngby, 26 May 1988.

After a brief overview of the fuel cells history a general description of the state of the art of fuel cell technology was given. Emphasis was put on the types which are believed to be of major importance in large scale electricity production in the future, i.e. phosphoric acid, molten carbonate and solid oxide fuel cells. Finally, the magnitude of the efforts put into the development of the various fuel cell types by the major countries were given.

35. Mogensen, M., Brændselscelleforskningen på Risø (Fuel Cell Research at Risø National Laboratory). Presented to Dansk Ingeniørforening - Brændsels- og Fyringsteknisk Selskab, Ingeniørhuset, Copenhagen, 26 Feb 1988.

Work on the characterization of ceramic materials for solid oxide fuel cells (SOFC) has been carried out at Risø during a number of years. Now also methods for the manufacturing of SOFC components are being developed at the Risø Metallurgy

Department. Furthermore a study of electrocatalytic effects of ceramic electrodes with mixed ionic and electronic conduction has been initiated. Examples of the obtained results were given.

36. **Mogensen, M.**, C.T. Walker, Concerning the Development of Grain Face Bubbles and Fission Gas Release in UO_2 Fuel. Presented at the Enlarged Halden Meeting, Loen, 8 - 13 May 1988.

A series of scanning electron micrographs showing the development of gas bubbles on the grain faces in a transient tested BWR fuel are presented. The observations indicate that gas bubbles nucleate on metallic precipitate particles and that bubble migration is prevented by the precipitates. X-ray fluorescence and electron probe microanalysis results show an accumulation of Xe on the grain boundaries at intermediate radial positions and an increasing »in grain« retention towards the centre of the fuel. These findings are ascribed to the presence of high compressive forces in the fuel and an increase in the rate of thermal resolution with increase in temperature. Under transient conditions the magnitude of the local mechanical restraint and the existence of macroscopic pressure gradients are important in determining the behaviour of grain face bubbles and thus fission gas release. In high pressure fields both the bubbles and precipitates grow by Ostwald Ripening. The bubble growth is impeded so that no bubble coalescence occurs. In a non-uniform pressure field bubble coalescence can take place on grain boundaries with low restraint pressure. This leads to gas escape tunnels at grain edges. Intergranular cracks which form when the mechanical restraint is removed at the end of the transient may provide further escape paths for fission gas.

37. **Singh, B.N.**, Consequences of Concurrently Produced Helium Atoms and Lattice Defects by Fast and Fusion Neutrons. Presented at Materials Science Laboratory, Indira Gandhi Centre for Atomic Research, Kalpakkam, India, 28 Jan 1988.

While evaluating the consequences of helium atoms generated via nuclear reactions induced by fast and fusion neutrons, it is essential to consider some of the basic interactions between helium atoms and lattice defects or/and defect clusters (e.g. cascades and sub-cascades). These interactions are expected to affect both helium mobility and cascade stability. This implies that the evolution of cavity as well as dislocation microstructure is likely to be influenced by the presence of helium atoms. The sensitivity of the microstructural evolution to helium generation rate and the recoil energy spectrum will be discussed. The mechanisms of helium transport to and diffusion through grain boundaries will be analysed. Finally, the factors controlling the magnitude of helium flux to grain boundaries will be briefly discussed.

38. **Singh, B.N.**, Irradiation Effects in Copper and Copper Alloys. Presented at ITER Specialists Meeting on Materials Data Base, Garching, FRG, 22-26 Aug 1988.

39. **Singh, B.N.**, Foreman, A.J.E., Nucleation of Helium Bubbles at Grain Boundaries During Irradiation. Presented at Fourteenth International Symposium on the Effects of Radiation on Materials, Andover, USA, 27-29 Jun 1988. To appear in the ASTM STP.

Experimental results are used to determine the dependence of bubble density at grain boundaries as well as within the grains on irradiation temperature and helium generation rate. The measured flux of helium to grain boundaries is then related to

helium generation rate. Finally, the dependence of the grain boundary bubble density on helium flux is obtained. These dependencies point to a possibility that under irradiation the diffusion kinetics of helium during the bubble nucleation phase may be material independent.
Analytical calculations are made to determine these dependencies. In these calculations, the nucleation at the boundary and within the grains is considered to be coupled. The comparison of the calculated and experimental results shows that the dependence of the average flux of helium on the helium generation rate can be predicted reasonably accurately within the framework of the diatomic type nucleation. The nucleation behaviour at grain boundaries has been calculated using diatomic and multi-atomic type mechanisms. Dependencies calculated in terms of the multi-atomic type nucleation are found to be consistent with the observed nucleation behaviour at grain boundaries.

40. Sommer, W.F.; Borden, M.J.; Allen, J.P.; Sommer, S.C.; Chavez, R.M.; Taylor, I.K.; Montoya, T.R.; Mueller, C.M.; **Horsewell, A.**, Temperature Regulation at the Los Alamos Spallation Radiation Effects Facility. Presented at 14th International Symposium on Effects of Radiation on Materials, ASTM, Andover, USA, 27-29 Jun 1988.

Temperature calculation and control using beam heating helium gap cooling combined with interactive direct heating is described. Experiments which take advantage of dose rate, temperature and fluence variations arising from gaussian accelerator beams are described.

41. **Toft, P.; Borring, J.; Adolph, E.**, LEU Fuel Element Production Plant at Risø National Laboratory. Presented at the 1988 International Meeting on Reduced Enrichment for Research and Test Reactors, San Diego, 19-22 Sep 1988. Proceedings to be published.

A production plant for fabrication of LEU silicide fuel elements has been established at Risø National Laboratory. The first eight elements for the Danish reactor DR3 have been fabricated, based on 19.77% enriched U_3Si_2 powder. The set-up of the production plant and the fuel element fabrication has been carried out without any major problems.

42. **Toft Sørensen, O.**, Anvendelse af avanceret teknisk keramik som konstruktionsmateriale i maskinkonstruktioner (Application of Advanced Technical Ceramics as Construction Materials in Machine Constructions). Presented at Ålborg Universitetscenter, Ålborg, 4 May 1988.

43. **Toft Sørensen, O.**, Application of Computer Controlled Thermal Analysis Techniques in Materials Research on Advanced Ceramic Materials. Presented at the 9th International Conference on Thermal Analysis and Calorimetry, Jerusalem, 22-26 Aug 1988.

44. **Toft Sørensen, O.**, Application of Computer Controlled Thermal Analysis Techniques in Materials Research on Advanced Ceramic Materials. Presented at 11th Nordic Symposium on Thermal Analysis and Calorimetry, Oulu, Finland, 20-22 Jun 1988. Also presented as a poster.

45. **Toft Sørensen, O.**, Introduktion til teknisk keramik (Introduction to Technical Ceramics). Presented at Teknologisk Institut, Taastrup, 13 Apr 1988.

46. Toft Sørensen, O., Orientering om termiske analysemetoder (Introduction to Thermal Analysis Techniques). Presented at Dansensor Seminar, Vipperød, Denmark, 20 Sep 1988.

47. Toft Sørensen, O., Research and Development in Advanced Ceramic Materials at Risø National Laboratory. Presented at Manchester University, Manchester, UK, 29 Nov 1988.

48. Toft Sørensen, O., Sintring (Sintering). Presented at Teknologisk Institut, Taastrup, 14 Apr 1988.

49. Toft Sørensen, O., Thermodynamic and Structural Evidence for the Presence of Defect Complexes in Some Non-Stoichiometric Oxides. Presented at the NATO-Workshop: Non-Stoichiometric Compounds - Surfaces, Grain Boundaries and Structural Defects, Rottach Egern, FRG, 4-8 Jul 1988. Proceedings to be published.

50. Walker, C.T.; Lassmann, K.; Coquerelle, M.; Mogensen, M., The D-COM Blind Problem on Fission Gas Release: Further Experimental Results and Calculations with TRANSURANUS. Presented at the IAEA Technical Committee Meeting on Water Reactor Fuel Element Computer Modelling in Steady-State, Transient and Accident Conditions, Preston, England, 18-22 Sep 1988. To be published by IAEA.

The concentration of retained xenon, the percentage of porosity and the grain size have been measured as a function of radial position in the base irradiated rod AG11-8 and the transient tested rod AG11-10. The results show that in the base irradiation, densification of the fuel took place, no detectable gas release occurred and that slight grain growth occurred at the pellet centre. During the transient test, 15-20% of the xenon inventory was released from the fuel grains. Gas release was accompanied in the central region of the fuel by an increase in the porosity from 4.7% to 6-8%.
These findings are compared with predictions made by the fuel performance code TRANSURANUS. The code predictions are in good agreement with the experimental observations.

3. Posters

1. **Andersen, S.I.; Lilholt, H.**, Fatigue of Glass Polyester Composite Materials for Wing Blades. Presented to Euroforum New Energies, Saarbrücken, FRG, 24-28 Oct 1988. To be published by the Commission of the European Communities.

Glassfibre reinforced polyester is consider a load bearing material for wingblades. The long time fatigue properties (up to 10^8 cycles) are under investigation. Well defined materials are used, with volume fractions of 50% fibres and fibre orientations of 0°, ~10°, ~45°, ~60° and 0°/~45°; the latter represents typical practical materials for wingblades. Fatigue data are produced for tension-tension loading (R - 0.1), compression loading (R - 10), and for tension-compression loading (R - -1). The fatigue results, the change in stiffness during fatigue and the damage (i.e. cracks, delamination) are discussed and related to possible design limits.

2. **Andersen, S.I.; Lilholt, H.**, Fatigue of Glass/Polyester Composite Materials for Wing Blades. Presented at the European Community Wind Energy Conference 1988, Herning, 6-10 Jun 1988.

Glassfibre reinforced polyester is considered a load bearing material for wingblades. The long time fatigue properties (up to 10^8 cycles) are under investigation. Well defined materials are used, with volume fractions of 50% fibres and fibre orientations of 0°, ~10°, ~45°, ~60° and combinations. Results on some of these materials will be discussed in relation to fatigue curves, change in stiffness during fatigue, models for the damage development and property changes, and the possible design considerations which can be derived from these results.

3. Foreman, A.J.E.; **Singh, B.N.**, Diffusion of Helium Along Grain Boundaries During Irradiation. Presented at the International Meeting on Diffusion in Metals and Alloys, DIMETA- 88, Balatonfured, Hungary, 5-9 Sep 1988. To appear in »DIMETA- 88«.

An indirect procedure is employed to study the diffusional behaviour of helium atoms through grain boundaries under irradiation conditions. The theory of homogeneous nucleation is used to determine the relationship between the diffusion kinetics of helium and the density of helium bubbles. The calculation of dependencies of the bubble density at grain boundaries on helium generation rate and helium flux to grain boundaries and their comparison with experimental results are used to identify the nucleation mechanism. Finally, the effective rate of helium transport through the boundary is determined numerically from the experimental results on bubble density at the grain boundaries.

4. Gunnarson, G.; Tjernlund, A.-K.; Mäntylä, T.; **Toft Sørensen, O.; Bentzen, J.**, Properties of Zirconia Powders Produced by Hydrothermal Methods and Supercritical Drying. The First Results of a Nordic Research Project on Oxide Ceramics. Presented at Ceramic Materials '88, Gothenburg, 31 May - 1 Jun 1988.

Zirconia powders have been produced by two methods, hydrothermal synthesis and supercritical drying, at the Technological Institute of Iceland (ITI) (1). At ABB Cerama AB the powders are processed, densified by HIPing and mechanically tested

tested to some extent. Mechanical measurements on HIPed material and fracture analysis are performed at Tampere University of Technology. The sintering properties of the powders and mechanical testing on sintered materials are performed at Risø National Laboratory.
The results show that zirconia powders produced by supercritical drying have better sintering properties than those produced only by the hydrothermal method. The bend strength (3-p) for zirconia with 3 m/o zirconia densified by HIPing at 1300 °C was 1050 MPa for a ITI-produced powder compared to 800 MPa for a commercial powder. Some results on other materials will also be presented.

5. Jensen, K.O.; Eldrup, M.; Linderoth, S.; Evans, J.H., Kr Physisorption on Internal Cu Surfaces Observed by PAT. Presented at the Eighth International Conference on Positron Annihilation, Gent, 29 Aug - 3 Sep 1988. Proceedings to be published.

Copper samples that initially contain percentage concentrations of krypton will on annealing release most of the krypton, but at high temperatures the remaining Kr fraction (~100 ppm) will stabilize large (i.e. micron size) Kr-filled cavities (Kr bubbles). The detailed annealing behaviour is discussed in Ref. 1. At room temperature the Kr is gaseous inside the cavities (p ~ 1-10 atm.), but at low temperatures it adsorbs at the bubble surfaces. If positrons are trapped at the bubble surface, the trapped-positron lifetime is expected to be influenced by the Kr adsorption. This influence was studied theoretically in ref. 2. In the present work, positron lifetime measurements were carried out in the temperature range 10-550 K. A longlived component (τ_2,I_2) (I_2~6%) ascribed to positrons trapped in the bubbles was observed. The lifetime is constant $\tau_2 = 470 \pm 10$ ps at temperatures above approx. 275 K, but below 275 K decreases almost linearly with temperature to reach 300 ± 20 ps at 10 K, the lifetime expected for a physisorbed Kr monolayer (or thicker layers) on a Cu surface[2]. Thus, the results give a direct indication that positrons do get trapped at the surfaces of the bubbles. More detailed calculations of the temperature dependence of τ_2 (taking into account the Kr density distribution and temperature dependence of the adsorption) gives fair but not complete agreement with the measurements. Interestingly, the intensity I_2 decreases only slightly with temperature (7 to 5.5%); this variation is much smaller than expected for diffusion limited trapping into large cavities.
1. K.O. Jensen, M. Eldrup, N.J. Pedersen, and J.H. Evans: Annealing behaviour of Cu and Ni containing high concentrations of krypton studied by positron annihilation and other techniques. J. Phys. F (in press).
2. K.O. Jensen and R.M. Nieminen: Noble-gas bubbles in metals: Molecular-dynamics simulations and positron states. Phys. Rev. B 36. 8219 (1987).

6. Kirkegaard, P.; Pedersen, N.J.; Eldrup, M, PC-PATFIT: A Program Package for Fitting Positron Annihilation Spectra on Personal Computers. Presented at the Eighth International Conference on Positron Annihilation, Gent, 29 Aug - 3 Sep 1988. Proceedings to be published.

The programs in the PATFIT program package[1] has been used for several years by a number of groups to fit positron lifetime and angular correlation spectra on mainframe computers. The rapid increase in the use of Personal Computers (PCs) has raised a need for computer programs which ca.. carry out analysis of positron annihilation data on a PC. The PC-PATFIT package has been developed to meet this need (but can still be used on mainframe computers). PC-PATFIT consists of the 3 fitting programs: POSITRONFIT (for the extraction of lifetimes and intensities from lifetime spectra), RESOLUTION (for

the determination of the lifetime spectrometer time resolution function from measured lifetime spectra), and ACARFIT (for fitting angular correlation spectra as sums of Gaussians and parabolas (convoluted with Gaussians)). The two lifetime programs are very similar to the previous mainframe versions, while the ACARFIT combines the features of the previous two programs (Paacfit and Parafit).
In order to make the programs more »user friendly« three separate interactive programs were developed. With each of these programs one can easily generate and edit the input data to one of the fitting programs. The programs are called POSEDIT, RESEDIT and ACAREDIT.
The programs are written in Fortran 77. They have been developed on an Olivetti PC M24SP with 640 kbytes memory, a 20 Mbytes hard disc, and using the MS-DOS operating system. The programs can be used on any IBM-compatible PC.
Finally, in addition a graphics program was developed which makes possible the display of measured and fitted spectra on the screen with hard-copies on a matrix printer.
1. P. Kirkegaard, M. Eldrup, O.E. Mogensen, and N.J. Pedersen, Comp. Phys. Commun. 23 307-335 (1981).

7. Lorentzen, T.; Leffers, T.; Juul Jensen, D., Demonstration of a New Instrument for Fast Neutron Diffraction Strain Measurements. Presented at the International Conference on Residual Stresses ICRS-2, Nancy, France, 23-25 Nov 1988. Proceedings to be published.

A technique for fast determination of residual stress profiles by neutron diffraction is described. The instrument is a variable wave length neutron spectrometer modified to incorporate a linear position sensitive detector and a fully automatic sample robot. The necessary measuring time for a typical strain profile is reduced by a factor of 3 - 10 compared with measurements performed on a standard triple axis spectrometer. The experimental set-up is described in the present paper and the performance is discussed. Finally, the application of the technique is demonstrated by measurements of strain profiles around a fatigue crack in a CTS-specimen.

8. Poulsen, F.W., Electrochemical Properties of Composite Materials. Presented at the 9th Risø International Symposium on Metallurgy and Materials Science, Risø National Laboratory, 5-9 Sep 1988.

Useful electrochemical properties of solid materials are often obtained by mixing two or more components. Examples from the field of composite electrodes, composite electrolytes and composite ceramic bodies are given. Suitable mechanical, electrical and chemical properties for battery and fuel cell use are obtained.

9. Schrøder Pedersen, A.; Larsen, B., The Storage of Industrially Pure Hydrogen in Magnesium. Presented at 7. World Hydrogen Energy Conference, Moscow, 25-29 Sep 1988.

The effect of impurities on the hydrogen storage capacity of magnesium was studied. The metal used was a mechanically produced magnesium powder with a mean particle diameter of 30 μm. The foreign gases considered were oxygen, nitrogen, carbon dioxide and carbon monoxide, in concentrations of 0.5% in pure hydrogen, except for carbon dioxide which was 2%. The effects described were observed by absorbing and desorbing once in a microbalance and by performing the storage cycle about 100 times using pure and then switching to impure hydrogen observing the change in absorption behaviour. The effects of the four gases were different. Oxygen reacted heavily with the metal but still allowed the formation of hydride at a reduced *rate. Nitrogen caused a slow-down in absorption speed but left the metal powder almost unchanged after desorption. Carbon monoxide practically prevented hydrogen uptake. Finally carbon dioxide in a concentration of 2% totally prevented hydrogen uptake. The results are discussed and explanations for the observations are given.*

10. Theilgaard, N.; Christiansen, N.; Vågø, F.; **Toft Sørensen, O.; Bentzen, J.**; Grahl-Madsen, L.; Engell, J., Strength of Alumina Ceramics - A Comparison of As Prepared Samples Shaped by CIP, Slipcasting and Injection Moulding. Presented at Ceramic Materials '88, Gothenburg, 31 May - 1 Jun 1988.

The purpose of the present contribution was to investigate the influence of the shaping process on the fracture strength of alumina ceramics. The ceramics studied were made from Alcoa alumina powder CT 3000 SG by cold isostatic (CIP), slip casting and injection moulding. Different powder preparation schedules were used for the different shaping methods. Spray dried powders with an average particle size of 72 μm was used in the CIP-process. An aqueous suspension containing 50 vol% of alumina dispersed with Darvan C was used for the slip casting. For the injection moulding several different binder systems and concentrations have been investigated. All samples were sintered to 1550 °C for 3 hours using the same furnace and firing schedule. The fracture strength was measured by the 4-point bending technique. One aim of this work was to study the effects of the shaping process on the surface finish of the samples. Thus the ceramics have been tested as prepared.

11. Toft Sørensen, O.; Klitholm, C, Application of Computer Controlled Thermoanalytical Techniques in Materials Research on Advanced Ceramics. Presented at Ceramic Materials '88, Gothenburg, 31 May - 1 Jun 1988.

12. Toft Sørensen, O.; El Sayed Ali, M.; **Strauss, T.**, Effect of Cutting on Fracture Strength of YPSZ. Presented at Ceramic Materials '88, Gothenburg, 31 - 1 Jun 1988.

13. Toft Sørensen, O.; Jensen, H., Udvikling af keramiske iltsensorer på Risø (Development of Ceramic Oxygen Sensors at Risø National Laboratory). Presented at the symposium Nye materialer fra forskning til erhvervsliv, Symbion, Copenhagen, 19 May 1988.

14. Toft Sørensen, O., Udvikling af teknisk konstruktionskeramik på Risø (Development of Engineering Ceramics at Risø National Laboratory). Presented at the symposium Nye materialer fra forskning til erhvervsliv, Symbion, Copenhagen, 19 May 1988.

4. Subject Index to »Publications«

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