## **IUPAC-** Polymer Division IV

# Subcommittee on Structure and Properties of Commercial Polymers

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CHAIR : Yongfeng Men Western European Chair: Iakovos Vittorias Eastern Asian Chair: Koh-hei Nitta

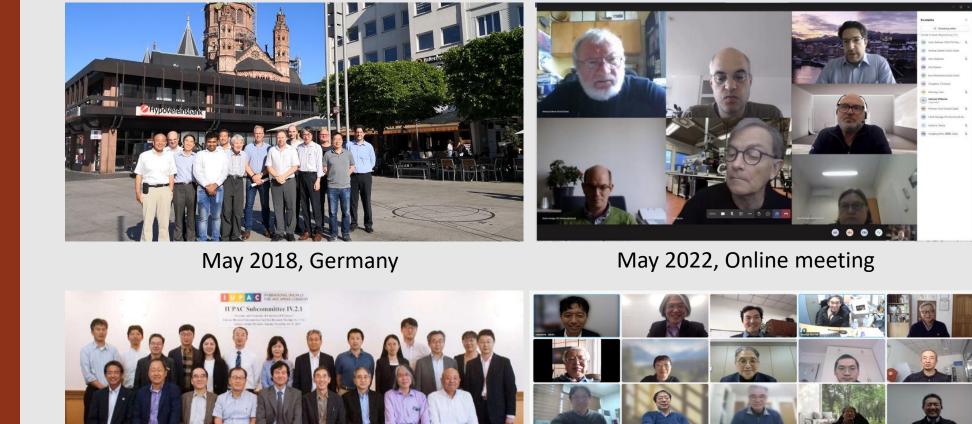
SECRETARY: Yujing Tang Dietmar Auhl Kenji Urayama





INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY

#### Past group meetings



## INTRODUCTION

The aim of the Subcommittee is to operate an international network of scientists whose interests lie within the broad field of structure and properties of **commercial polymers**. Drivers of this activity are its members and their motivation to obtain value (to them and their business) from participation in the group. The group meets at least once per year and defines projects on which at least a significant part of the members agrees to work on and to commit resources.

The balanced membership base from industry and academy works in a manner to ensure that the projects are structured in such a way as to accommodate value in application, need and scientific novelty. Membership

The projects have a particular scientific target and have been mainly experimental in nature. Coordinators guide the projects to the final publication(s). The projects conducted by the Subcommittee are funded by the participants and in turn their organizations. Participation in a project is voluntary but to maintain membership in the Subcommittee it is mandatory to participate in at least one project and to attend meetings (at least every two years). Its members enjoy the opportunity of working with like-minded scientist albeit that they come from often competitive organizations.

in the Sub-committee offers a platform for collaboration on a global basis. It enables contacts and networks that would be difficult to establish by other means. In addition, the value that is generated from a joint scientific project where an individual (or his/her organization) is funding only a fraction of the cost can be considerable.

Due to geographical constraints, the Subcommittee runs two research meetings in parallel: one in western Europe (WE) including members from US and Canada and another in eastern Asia (EA) including China, Japan and Korea. Both WE and EA meetings have their chairs and secretaries elected by corresponding members.

Nov. 2019, Japan

Dec. 2022, Online meeting

# PROJECTS

### **RESEARCH TOPICS**

- Rubber modified polymer
- LLDPE
- PAN-based carbon fibers
- PVDF
- **PVA**
- UHMWPE
- Ageing
- EDAM copolymer
- PLC fibers
- COC
- Long-chain branching PC
- PA6 and PA66 clay nanocomposites

2010-019-1-400- Characterization, rheology and mechanical properties of high and ultra-high molecular weight polyethylene

Pure Appl. Chem. 2020: 92(9): 1485-150

## Task Group Chair: Prof. Clive Bucknall

### **OUTPUT**

- Characterizing molecular weight , *PAC*. 2020
- Crystallinity and supra molecular structure, PAC. 2020
- Deformation, wear and fracture, PAC. 2020
- Sporadic fatigue crack propagation, PAC. 2020

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**Task Group Members:** Volker Altstädt, Dietmar Auhl, Paul Buckley, Dirk Dijkstra, Andrzej Galeski, Christoph Gögelein, Ulrich A. Handge, Jiasong He, Chen-Yang Liu, Goerg Michler, Ewa Piorkowska, Miroslav Slouf, Iakovos, Vittorias and Jun Jie Wu

DE GRUYTER

IUPAC	Technical	Report	

DE GRUYTER

Clive Bucknall\*, Volker Altstädt, Dietmar Auhl, Paul Buckley, Dirk Dijkstra, Andrzej Galeski, Christoph Gögelein, Ulrich A. Handge, Jiasong He, Chen-Yang Liu, Goerg Michler, Ewa Piorkowska, Miroslav Slouf, lakovos Vittorias and Jun Jie Wu Structure, processing and performance of ultra-high molecular weight polyethylene (IUPAC Technical Report). Part 1: characterizing molecular weight

Pure Appl. Chem. 2020; 92(9): 1469-1483

https://doi.org/10.1515/pac-2019-040 Received April 6, 2019: accepted March 20, 2020

Pure Appl. Chem. 2020 | Volume 92 | Issue 9

Abstract: The aim of this project was to study the efficacy of current methods of quality control and quality assurance for ultra-high molecular weight polyethylene (UHMWPE) products, and find improvements where possible. Intrinsic viscosity (IV) tests were performed on three grades of polyethylene with weight average relative molar masses  $\overline{M}_w$  of about  $6 \times 10^5$ ,  $5.0 \times 10^6$  and  $9.0 \times 10^6$ . Results from three laboratories showed substantial scatter, probably because different methods were used to make and test solutions. Tensile tests were carried out to 600 % extension at 150 °C under both constant applied load and constant Hencky strain rate, on ompression mouldings made by a leading manufacturer of ultra-high molecular weight polyethylene. They gave low values of  $\overline{M}_{w}$ , suggesting incomplete entanglement at 'grain boundaries' between powder particles. Results from conventional melt-rheology tests are presented, and their relevance to quality control and assurance is discussed. Attempts to calculate molecular weights from these data met with limited success because of extended relaxation times. Suggestions are made for improving international standards for IV testing of UHMWPE, by rious factors that can cause significant errors, and by introducing methods for checking the

#### **IUPAC Technical Report** Clive Bucknall\*, Volker Altstädt, Dietmar Auhl, Paul Buckley, Dirk Dijkstra, Andrzej Galeski, Christoph Gögelein, Ulrich A. Handge, Jiasong He, Chen-Yang Liu, Goerg Michler, Ewa Piorkowska, Miroslav Slouf, lakovos Vittorias and Jun Jie Wu Structure, processing and performance of ultra-high molecular weight polyethylene (IUPAC Technical Report). Part 2: crystallinity

and supra molecular structure

nttps://doi.org/10.1515/pac-2019-0403 Received April 5, 2019; accepted March 20, 202

DE GRUYTER

Abstract: Test methods including OM, SEM, TEM, DSC, SAXS, WAXS, and IR were used to characterise supra-molecular structure in three batches of polyethylene (PE), which had weight-average relative molar masses  $\overline{M}_{\rm w}$  of approximately  $0.6 \times 10^6$ ,  $5 \times 10^6$ , and  $9 \times 10^6$ . They were applied to compression mouldings made by the polymer manufacturer. Electron microscopy showed that powders formed in the polymeri zation reactor consisted of irregularly shaped grains between 50 and 250 µm in diameter. Higher magnif cation revealed that each grain was an aggregate, composed of particles between 0.4 and 0.8 µm in diameter, which were connected by long, thin fibrils. In compression mouldings, lamellar thicknesses ranged from 7 to 23 nm. Crystallinity varied between 70 and 75 % in reactor powder, but was lower in ompression mouldings. Melting peak temperatures ranged from 138 to 145 °C, depending on processing history. DMTA showed that the glass transition temperature  $\theta_{\sigma}$  was -120 °C for all three grades of polyethylene. IR spectroscopy found negligibly small levels of oxidation and thermal degradation in mouldings.

#### **IUPAC Technical Report**

Clive Bucknall\*, Volker Altstädt, Dietmar Auhl, Paul Buckley, Dirk Dijkstra, Andrzej Galeski, Christoph Gögelein, Ulrich A. Handge, Jiasong He, Chen-Yang Liu, Goerg Michler, Ewa Piorkowska, Miroslav Slouf, Jakovos Vittorias and Jun Jie Wu Structure, processing and performance of ultra-high molecular weight polyethylene (IUPAC Technical Report). Part 3: deformation, wear and fracture

**Abstract:** Three grades of polyethylene, with weight-average relative molar masses,  $\overline{M}_{W}$ , of approximately  $0.6 \times 10^6$ ,  $5 \times 10^6$ , and  $9 \times 10^6$ , were supplied as compression mouldings by a leading manufacturer of ultra-high molecular weight polyethylene (UHMWPE). They were code-named PE06. PE5. and PE9. respectively. Specmens cut from these mouldings were subjected to a wide range of mechanical tests at 23 °C. In tensile tests deformation was initially elastic and dominated by crystallinity, which was highest in PE06. Beyond the yield point, entanglement density became the dominant factor, and at 40 % strain, the rising stress-strain curves for PE5 and PE9 crossed the falling PE06 curve. Fracture occurred at strains above 150 %. Differences in stressstrain behaviour between PE5 and PE9 were relatively small. A similar pattern of behaviour was observed in wear tests; wear resistance showed a marked increase when  $\overline{M}_{W}$  was raised from  $0.6 \times 10^{6}$  to  $5 \times 10^{6}$ , but there was no further increase when it was raised to  $9 \times 10^6$ . It is concluded that the unexpected similarity in behaviour between PE5 and PE9 was due to incomplete consolidation during moulding, which led to deficiencies in entanglement at grain boundaries; they were clearly visible on the surfaces of both tensile and wear speci

Pure Appl. Chem. 2020; 92(9): 1521–1536

**IUPAC Technical Report** 

DE GRUYTER

Pure Appl. Chem. 2020; 92(9): 1503-1519

Clive Bucknall\*, Volker Altstädt, Dietmar Auhl, Paul Buckley, Dirk Dijkstra, Andrzej Galeski, Christoph Gögelein, Ulrich A. Handge, Jiasong He, Chen-Yang Liu, Goerg Michler, Ewa Piorkowska, Miroslav Slouf, Jakovos Vittorias and Jun Jie Wu Structure, processing and performance of ultra-high molecular weight polyethylene (IUPAC Technical Report). Part 4: sporadic fatigue crack propagation

#### https://doi.org/10.1515/pac-2019-0408 Received April 16, 2019: accepted March 20, 2020

Abstract: Fatigue tests were carried out on compression mouldings supplied by a leading polymer manu facturer. They were made from three batches of ultra-high molecular weight polyethylene (UHMWPE) with veight-average relative molar masses,  $\overline{M}_{
m W}$ , of about 0.6 imes 10 $^6$ , 5 imes 10 $^6$  and 9 imes 10 $^6$ . In 10 mm thick compac tension specimens, crack propagation was so erratic that it was impossible to follow standard procedure, where crack-tip stress intensity amplitude,  $\Delta K$ , is raised incrementally, and the resulting crack propagation rate, da/dN, increases, following the Paris equation, where a is crack length and N is number of cycles. Instead nost of the tests were conducted at fixed high values of  $\Delta K$ . Typically, d*a*/d*N* then started at a high level, but decreased irregularly during the test. Micrographs of fracture surfaces showed that crack propagation was sporadic in these specimens. In one test, at  $\Delta K = 2.3$  MPa m<sup>0.5</sup>, there were crack-arrest marks at intervals  $\Delta a$  of about 2 µm, while the number of cycles between individual growth steps increased from 1 to more than 1000 and the fracture surface showed increasing evidence of plastic deformation. It is concluded that sporadic crack propagation was caused by energy-dissipating crazing, which was initiated close to the crack tip under plane

- PTFE in PP
- TLCP blends
- ΡE
- G-resin (Polypropylene)
- Polyketone
- Biopolymers
- . . . . . .

Contents	overs mechanical properties, and Part 4 focuses on the sporadic crack propagation behaviour ree grades of UHMWPE in fatigue tests on 10 mm thick compact tension specimens.	methods that can detect less obvious fusion defects.
Clive Bucknall, Volker Altstädt, Dietmar Auhl, Paul Buckley, Dirk Dijkstra, Andrzej Galeski, Christoph Gögelein, Ulrich A. Handge, Jiasong He, Chen-Yang Liu, Goerg Michler, Ewa Piorkowska, Miroslav Slouf, Iakovos Vittorias and Jun Jie Wu Structure, processing and performance of ultra-high molecular weight polyethylene (IUPAC Technical Report). Part 1: characterizing molecular weight — 1469	ring body: IUPAC Polymer Division: see more details on page 1482. Ior: Clive Bucknall, B 61 School of Aerospace, Transport & Manufacturing, Cranfield University, Bedford, MK43 :bucknall@aol.com	Article note: Sponsoring body: IUPAC Polymer Division: see more details on page 1500. *Corresponding author: Clive Bucknall, School of Aerospace, Transport & Manufacturing B 61, Cranfield University, Bedford, MK
Clive Bucknall, Volker Altstädt, Dietmar Auhl, Paul Buckley, Dirk Dijkstra, Andrzej Galeski, Christoph Gögelein, Ulrich A. Handge, Jiasong He, Chen-Yang Liu, Goerg Michler, Ewa Piorkowska, Miroslav Slouf, lakovos Vittorias and Jun Jie Wu <b>Structure, processing and performance of ultra-high molecular weight polyethylene (IUPAC Technical</b> <b>Report). Part 2: crystallinity and supra molecular structure — 1485</b>	artment of Polymer Engineering, Universität Bayreuth, Bayreuth, Germany ät III - Werkstoffwissenschaft Technische Universität Berlin, Berlin, D-10623, Germany ment of Engineering Science, University of Oxford, Oxford, OX1 3P), UK ro Deutschland AG, Leverkusen, Germany <b>Ewa Piorkowska:</b> Centre for Molecular and Macromolecular Sciences, Polish Academy of Sciences, Lodz,	OAL, UK, e-mail: clivebucknall@aol.com Volker Altstädt: Department of Polymer Engineering, Universität Bayreuth, Bayreuth, Germany Dietmar Auhl: Fakultät III – Werkstoffwissenschaft Technische Universität Berlin, D-10623, Berlin, Germany Paul Buckley: Department of Engineering Science, University of Oxford, OX1 3PJ, Oxford, UK Dirk Dijkstra: Covestro Deutschland AG, Leverkusen, Germany Andrzej Galeski and Ewa Piorkowska: Centre for Molecular and Macromolecular Sciences, Polish Academy of Sciences, Lodz,
Clive Bucknall, Volker Altstädt, Dietmar Auhl, Paul Buckley, Dirk Dijkstra, Andrzej Galeski, Christoph Gögelein, Ulrich A. Handge, Jiasong He, Chen-Yang Liu, Goerg Michler, Ewa Piorkowska, Miroslav Slouf, Iakovos Vittorias and Jun Jie Wu	Arlanxeo Deutschland GmbH, Dormagen, Germany stitute of Polymer Research, Helmholtz-Zentrum Geesthacht, Max-Planck-Strasse 1, Geesthacht, 21502,	Poland Christoph Gögelein: Arlanxeo Deutschland GmbH, Dormagen, Germany Ulrich A. Handge: Institute of Polymer Research, Helmholtz-Zentrum Geesthacht, Max-Planck-Strasse 1, 21502, Geesthacht,
Structure, processing and performance of ultra-high molecular weight polyethylene (IUPAC Technical Report). Part 3: deformation, wear and fracture — 1503	-Yang Liu: Chinese Academy of Sciences, Laboratory of Polymer Science and Materials, Beijing, 100190, China in-Luther-Universität Halle-Wittenberg, Halle, Germany	Germany Jiasong He and Chen-Yang Liu: Chinese Academy of Sciences, Laboratory of Polymer Science and Materials, Beijing, 100190, Ch
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Report). Part 4: sporadic fatigue crack propagation — 1521	UPAC & De Gruyter. This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 or more information, please visit: http://creativecommons.org/licenses/by-nc-nd/4.0/	С рукисир © 2020 Walter de Gruyter GmbH.

thence validity) of the solutions tested. Part 2 addresses characterization of crystallinity and relatively weak defects can be characterized using optical microscopy, but there is a need for improved that it forms the basis for a separate report - Part 4 in this series. Keywords: consolidation; fatigue; fracture; IUPAC Polymer Division; UHMWPE; wear; yielding.

Article note: Sponsoring body: IUPAC Polymer Division: see more details on page 1518

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thick specimens followed the Paris equation approximately. The results from all four reports on this project are reviewed, and the possibility of using fatigue testing as a quality assurance procedure for melt-processed UHMWPE is discussed.

Article note: Sponsoring body: IUPAC Polymer Division: see more details on page 1536. \*Corresponding author: Clive Bucknall, B 61 School of Aerospace, Transport & Manufacturing, Cranfield University, Bedford, MK43 OAL, UK, e-mail: clivebucknall@aol.com Volker Altstädt: Department of Polymer Engineering, Universität Bayreuth, Bayreuth, Germany Dietmar Auhl: Fakultät III – Werkstoffwissenschaft Technische, Universität Berlin, D-10623, Berlin, Germany Paul Buckley: Department of Engineering Science, University of Oxford, Oxford, OX1 3PJ, UK Dirk Dijkstra: Covestro Deutschland AG, Leverkusen, Germany Andrzej Galeski and Ewa Piorkowska: Centre for Molecular and Macrom

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2016-028-1-400 - Structure and Properties of Transparent Polypropylene with Very Low Solubility

Task Group Chair: Profe. Jinliang Qiao

Task Group Members: Yongfeng Men, Chang-Sik Ha, Koh-hei Nitta, Katsuhisa Tokumitsu, Iakovos Vittorias, Wenbing Hu, Liangshi Wang, Meifang Guo, Yujing Tang, Hongwei Shi

PROJECT **AIM:** Investigation on the relationship between the micro-structure and the properties of polymer with very low soluble contents

<u>NEW PROJECT PROPOSAL</u> - Thermoplastic starchbased materials: properties and characterization.

Miroslav Slouf (coordinator) Elvira Vidovic (co-coordinator)

### Task group members:

Miroslav Slouf; Veronika Gajdosova; Saffana Kouka; Zdenek Stary; Magdalena Konefal; Elvira Vidovic; Dajana Kucic Grgic; Vesna Ocelic Bulatovic; Iakovos Vittorias; Iakovos; Dietmar Auhl; Sven Henning; Ulrich Handge; Maria Laura Di Lorenzo; Yongfeng Men

## **FEASIBILITY STUDIES**

Anti-bacterial and anti mildew PP resin.

- Polyketone New Green Polymeric Material.
- Structure and properties of PLA.
- Recycling of mixed Polyolefins even PVAc, etc. using compatibilizer (also Rubber with CaCO3, Kaolin, fumed Silica as fillers)
- 3D-print vulcanisates, TPU, TPE, soft rubber materials, series of materials with

The task group has 5 publications, including 3 publications in *Polymer*, 1 in *European Polymer Journal* and 1 in J Therm Anal Calorim

#### **OBJECTIVES:**

Optimization of starch plasticization, and deeper understanding relationships between structure and properties of starch-containing materials.

thermoplastic content, x-linking, fillers

PC/SAN BayBlend: compatibility studies

# PERSPECTIVES

The subcommittee on structure and properties of commercial polymers welcomes scientists from both industry and academia to work on topics of mutual interests.

The key words of this subcommittee are "commercial polymers" and "structure and properties". These together with the fact of participation of multiple competitive companies define our research projects being applied fundamental in nature.

Over the past 60 years since its establishment, the subcommittee continuously operating smoothly via running projects that address common concerns of competing partners. Making knowledge useful via participating in a project attracts also researchers from academia.

In the future, we are looking forward to building stronger network among members and creating opportunities for joint efforts beyond IUPAC.

## JOIN US IN OUR NEXT EVENT!

**In-person EA research meeting** & Workshop on Structure and **Properties of Commercial Polymers** 

14-17 December 2023 Danzhou, Hainan, China

#### **ORGANIZERS:**

- Koh-hei Nitta
- Yongfeng Men
- Kenji Urayama
- Ying Lu



Supported by: Chinese Chemical Society, Changchun Institute of Applied Chemistry, SINOPEC

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