UNIVERSITÄT BAYREUTH

Medienmitteilung

No 65 / 2013 // 9th April 2013

Aktuelle Presseinformationen aus der Universität Bayreuth

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Particles Changing Angle:

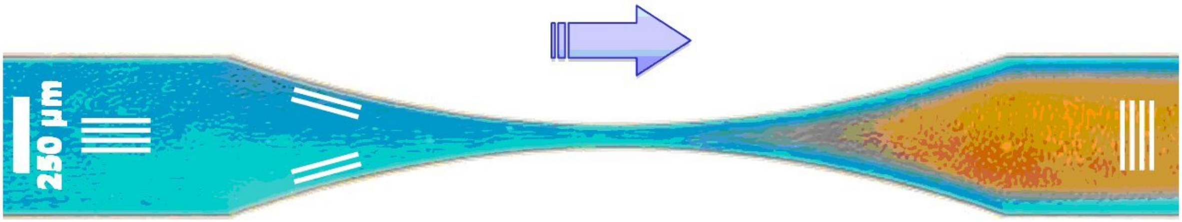
Unexpected Orientation in Capillaries

When small particles flow through thin capillaries, they display an extremely unusual orientation behaviour. This has recently been discovered by a research team led by Prof. Stephan Förster and Prof. Walter Zimmermann (University of Bayreuth). The participating scientists of Bayreuth University, the Radboud University Nijmegen, the research centre DESY in Hamburg, and the Max Planck Institute for Dynamics and Self-Organization in Göttingen report their new findings in the scientific journal PNAS. The discovery is of major importance for spinning processes designed for the production of synthetic fibres, and the understanding of vascular stenosis.

X-ray experiments make the flow behaviour visible

Rod- or plate-like particles flowing through thin capillaries, usually orientate themselves parallel in relation to the flow direction. Should a capillary display a constriction, this alignment does not change until the particles have reached the narrowest location. As soon as the capillary expands again however, the particles align themselves perpendicular to the flow direction, having changed angle. Not only have scientists in Bayreuth, Hamburg, Nijmegen and Göttingen discovered this surprising phenomenon, they have also found an explanation. After establishing theoretical calculations, they were then able to show that within the dilating capillary segment, strong dilating forces appear perpendicular to the flow direction. Such dilating effects a realignment of the particles.

The theoretical calculations were confirmed using micro x-ray experiments at the German Electron Synchrotron (DESY). Here, using modern x-ray optical techniques and the radiation source PETRA III, highly intensive x-rays were produced measuring merely a few micrometers in diameter. By this means it was possible for the first time to observe the



Microscopic image of a constricted capillary and a subsequent dilated section. Within the blue area, the particles orientate themselves parallel to the flow direction and in the orange area, perpendicular to the flow orientation.

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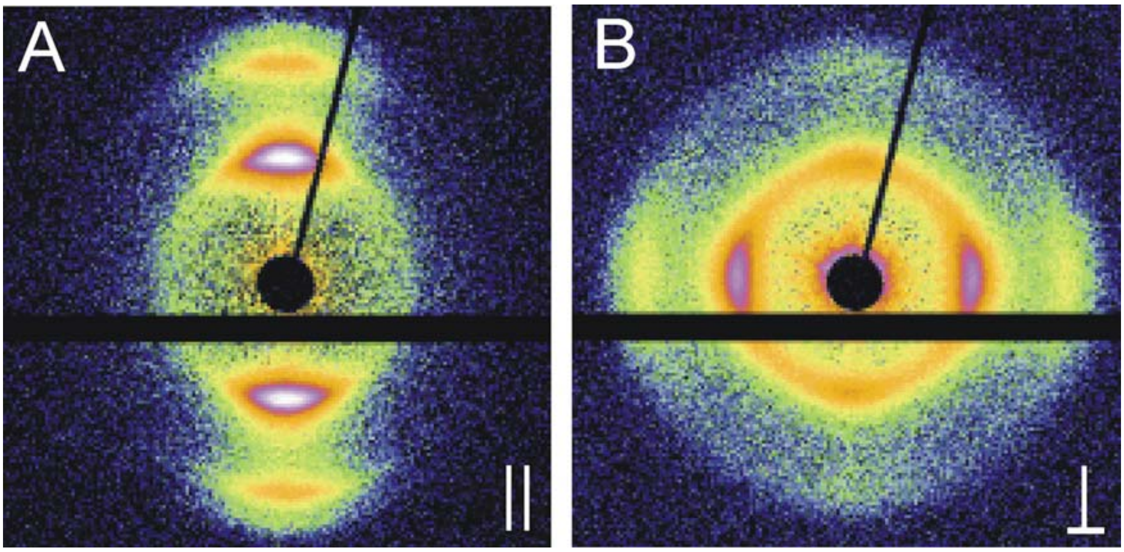
streaming behaviour in particularly thin capillaries. The scientists were able to precisely determine the alignment of particles flowing through a constricted capillary. The perpendicular orientation which is taken on after passing the narrowest point remains stable, not changing in the further course of the capillary.

New applications first in the production of high-performance fibres and second with regard to the onset of vascular diseases

The realignment of particles when flowing through narrow points of capillaries is crucial to the understanding of many biological and technical flow processes. One example is the process of spinning, whereby solutions of macromolecules and particles are pressed through fine spinning nozzles. In order to produce fibres characterised by high tear strength and other significant mechanical properties, it is vital that the macromolecules and particles orientate themselves parallel to the flow direction. As recently discovered however, they are aligned perpendicular to the flow direction when leaving the nozzle. This explains why, as has been known for a long time, that spun fibres have to be stretched. This stretching ensures the macromolecules and particles (the fibres' building blocks) reassume the desired parallel alignment. The findings recently published in the PNAS make it possible to predict the flow orientation of such building blocks and control it precisely by means of an appropriate design of capillaries and nozzles.



Scatter diagrams, originating from micro-X-ray experiments. A) Parallel orientation to the flow direction prior to the narrowing B) Perpendicular orientation to the flow direction after narrowing in the capillary.

A further area of application is in the field of medicine, insofar as cells and proteins flow through very fine blood vessels. When they realign themselves due to vascular stenosis, agglomeration may occur, resulting in thrombosis or vascular occlusion. The international team of researchers have possibly discovered an important sub-process which contributes significantly to the onset of vascular disease.

International research co-operation

Among the authors of this report published in the PNAS are Prof. Stephan Förster and his team from the Physical Chemistry I department as well as Prof. Walter Zimmermann of the Theoretical Physics I department of the University of Bayreuth, Dr. Julian Thiele (Radboud University Nijmegen), Dr. Jan Perlich, Dr. Adeline Buffet and Dr. Stephan V. Roth (DESY, Hamburg), and Dr. Dagmar Steinhauser (Max Planck Institute for Dynamics and Self-Organization, Göttingen, and German Institute of Rubber Technology, Hannover). The project has been realised within the framework of one of the most prestigious funding programmes of the European Union: in 2012, Prof. Stephan Förster was awarded an ERC Advanced

Grant. The research received additional funding from the German Ministry of Science and Education (Bundesministerium für Bildung und Forschung, BMBF).

Publication:

Martin Trebbin, Dagmar Steinhauser, Jan Perlich, Adeline Buffet, Stephan V. Roth, Walter Zimmermann, Julian Thiele, Stephan Förster,

Anisotropic particles align perpendicular to the flow-direction in narrow microchannels

in: PNAS (Proceedings of the National Academy of Sciences of the United States of America) Early Online Edition, April 8, 2013;

DOI: 10.1073/pnas.1219340110

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(released for publication when references are included)

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