

4. Graduiertentagung *4th Graduate Symposium* 24. November 2011



4. Graduiertentagung
der FH Aachen
24. November 2011

4th Graduate Symposium
FH Aachen - University
of Applied Sciences
November 24th, 2011

Beiträge / <i>Papers</i>	5
<hr/>	
Vorwort / <i>Preface</i>	
Prof. Dr. Christiane Vaeßen Prof. Dr. Michael J. Schöning	7
<hr/>	
Curriculum Vitae	
Dr. Thomas Drescher, Vorstandsvorsitzender DASGIP AG	9
<hr/>	
Curricula Vitae und Exposés	
Matthias Bäcker	10
Rasha Bassam	12
Ulrich Bohrn	14
Sebastian Börner	16
Christiano Teixeira Boura	18
Minh Tuấn Du'o'ng	20
Ralf Frotscher	22
Michael Gerhards	24
Matthias Goßmann	26
Simone Groebel	28
Daniel Heinze	30
Christina Huck	32
Patrick Kirchner	34
Silvia Kowollik	36
Nicole Lawrenz	38
Peter Lindner	40
Anuja Nagle	42
Hakan Oflaz	44
Markus Raue	46
Steffen Reisert	48
Markus Rusack	50
Johannes Schiffels	52
Nicole Schubert	54
Sebastian Schusser	56
Carl Frederik Werner	58
<hr/>	
Literatur	60
<hr/>	
Impressum	63
<hr/>	

Matthias Bäcker Chip-based enzyme sensors for monitoring of bioprocesses by flow-injection analysis	11
Rasha Bassam Micropipette aspiration of human erythrocytes in buffers of different composition	13
Ulrich Bohrn Cell-based sensor system monitoring toxic gases in air	15
Sebastian Börner Low NO_x hydrogen fuelled gas turbine	17
Christiano Teixeira Boura High temperature moving bed heat exchanger for thermal storage in granular material	19
Minh Tuấn Du'ong Constitutive modeling of hyperelastic fiber-reinforced materials in application to soft tissues	21
Ralf Frotscher Implementation of smoothed finite element methods in a large software Package	23
Michael Gerhards History-tracing XML for an actor-driven grid-enabled workflow system (HiX4AGWS)	25
Matthias Goßmann Development of a cellular 3D cardiac tissue model and characterisation of its Inotropy for functional drug and toxin screening	27
Simone Groebel Quantification of the dominance of microorganisms in the biogas process	29
Daniel Heinze Preparation of exfoliated polyvinyl acetate-layered silicate nanocomposites	31
Christina Huck Measurement of dissolved hydrogen in a liquid-to-gas transfer setup utilizing PTFE membranes	33
Patrick Kirchner Calorimetric gas sensor on micro-plates for inline monitoring of H₂O₂ concentrations	35
Silvia Kowollik The respiratory activity of cells - a fingerprinting system in cell culture fermentation	37
Nicole Lawrenz Biochemical properties of fetal membranes linked with premature birth	39
Peter Lindner HP bioforce - summary	41
Anuja Nagle A design approach for construction of an "Intelligent Car Body"	43
Hakan Oflaz A high-tech attempt to predict premature birth	45
Markus Raue ²³Na NMR study of intelligent hydrogels	47
Steffen Reisert Using a multi-sensor system to provide chemical images of sterilisation processes employing H₂O₂ vapour	49
Markus Rusack Modelling the thermodynamics of a sewage system	51
Johannes Schiffels Analysis of crucial intermediates as process indicators in the conversion of biomass to methane	53
Nicole Schubert GPU Faser Vis - GPU based visualization of nerve fibres	55
Sebastian Schusser BioMiMedics - Determination of polymer degradation by a semiconductor-based sensor system	57
Carl Frederik Werner Determination of glucose concentration by means of a microorganism-based biosensor	59

Vorwort / Preface

In diesem Jahr stellen unsere Doktorandinnen und Doktoranden zum vierten Mal im Rahmen der Graduiertentagung ihre wissenschaftlichen Arbeiten aus den verschiedenen Fachdisziplinen vor. Nach den erfolgreichen Veranstaltungen der letzten Jahre werden in diesem Jahr, neben den Posterpräsentationen zu den verschiedenen, an unserer Hochschule bearbeiteten wissenschaftlichen Fragestellungen, Vorträge von Doktorandinnen und Doktoranden zu hören sein, die ihre Promotionsarbeiten bald abschließen werden. Das Programm wird abgerundet mit einem praxisnahen Gastvortrag eines Unternehmers. Mit diesem leicht veränderten Format möchten wir an die Erfolge der letzten Jahre anknüpfen und auch in diesem Jahr eine Plattform zum Austausch zu den unterschiedlichen wissenschaftlichen Themen mit den Mitgliedern der Hochschule und unseren Gästen bieten.

Die Arbeit des Graduiertenkollegs hat im vergangenen Jahr weiter an „Fahrt gewonnen“. Unsere Graduierten erfahren in der Hochschule eine zunehmende Wahrnehmung, sie vertreten ihre Belange in den forschungsrelevanten Gremien der Hochschule und erhalten durch Bereitstellung von Rektoratsmitteln eine finanzielle Unterstützung. Erstmals haben wir in diesem Jahr ein Doktoranden-Training angeboten, in dem wir ihnen neben dem fachlichen Rüstzeug auch weitergehende Qualifikationen vermitteln, die für einen Start in eine hoffentlich erfolgreiche berufliche Karriere wichtig sind. Dieses Programm wird in den nächsten Jahren weiter ausgebaut werden, um so die Wettbewerbsfähigkeit unserer Doktorandinnen und Doktoranden um die besten Arbeitsplätze noch weiter zu erhöhen.

Die diesjährige Graduiertentagung bietet Ihnen wiederum die Möglichkeit, Ihre wissenschaftlichen Arbeitsergebnisse im intensiven Dialog mit Ihren Kolleginnen und Kollegen sowie den geladenen Gästen zu diskutieren. Wir konnten in diesem Jahr Dr. Thomas Drescher, CEO der DASGIP AG, Jülich, als Gastreferent gewinnen. Er wird über seine Erfahrungen im Bereich der wissenschaftlichen Unternehmensgründung berichten – seien Sie also gespannt!

Wir freuen uns auf einen interessanten Tag gemeinsam mit Ihnen und sind sicher, dass Sie mit Ihrem Beitrag auch in diesem Jahr die wissenschaftliche Landschaft der FH Aachen bereichern werden.

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Modulares Sensorsystem für die Zellkultur-
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Chip-based enzyme sensors for monitoring of bioprocesses by flow-injection analysis

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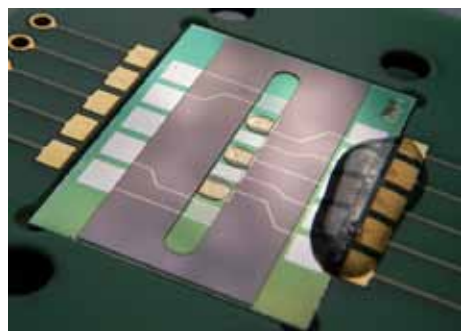
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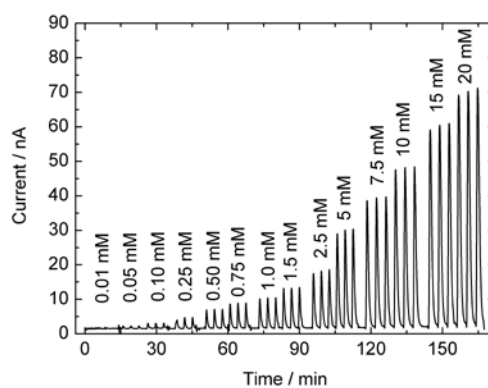
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Stringent monitoring and control of bioprocess parameters is crucial for process optimization in terms of high-quality products with a sufficiently high yield. In this context, knowledge of the concentration levels of essential nutrients such as glutamine and glucose is of particular interest. In this contribution, the sensor array presented in the last year was further refined [1]. An array of amperometric enzyme sensors was connected to a flow-injection analysis (FIA) system.

For this, a microfluidic channel was realized on the sensor chip by means of SU-8 photoresist. Glucose oxidase, glutamate oxidase and a two enzyme-system consisting of glutaminase and glutamate oxidase was then immobilized onto platinum thin-film electrodes (Fig. 1a). These different enzymes specifically react with their target molecule and produce electroactive species that can be recognized at the platinum electrodes. The developed sensors were characterized in terms of pH optimum, reproducibility, lower and upper detection limit and linear working range. By using a FIA-based differential-mode the intrinsic cross-sensitivity of the glutamine sensor towards glutamate can be reduced enabling a more precise glutamine quantification.



a)



b)

Fig. 1 | Photograph of the microfluidic chip (a) and exemplary amperometric detection measurement of glutamine in the concentration range from 0.01 to 20 mM (b).

[1] M. Bäcker, L. Delle, A. Poghossian, M. Biselli, W. Zang, P. Wagner, M.J. Schöning, *Electrochim. Acta* (2011) doi:10.1016/j.electacta.2011.04.030

Acknowledgements: The authors would like to thank the Federal Ministry of Education and Research (BMBF, project "Cellsens") for financial support.

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Micropipette aspiration of human erythrocytes in buffers of different composition

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The normal human red blood cell (RBC) has at equilibrium the shape of a flattened biconcave disc and a remarkable deformability. This deformability can be altered by a variety of chemical and physical factors. The RBC deformability in microvasculature governs the cell's ability to survive the physical demands of circulation. Interestingly, RBCs must periodically pass a deformability test by being forced to squeeze through narrow passages. Throughout RBCs life span, the mechanical integrity of RBCs degrades. Certain pathological conditions can cause changes in both the equilibrium shape and mechanics of RBCs, which impact their transport function. Thus, understanding the microrheology of RBCs is highly interesting both from a basic science and a clinical point of view.

Since RBCs main component is the hemoglobin, this molecule is mostly responsible for RBC functions as well as for its mechanical and chemical characteristics. Most of alterations occurring in the RBCs, are usually related in the Hb molecule, due to its binding with a broad class of low-molecular weight modifiers usually present in RBCs. Such molecules able of controlling Hb (and hence RBCs) function are for example adenosine triphosphate (ATP), 2, 3-diphosphoglycerate (2, 3-DPG), potassium and sodium ions, nitric oxide (NO), CO₂ and probably many others.

Micropipette aspiration technique has been used for a long time to study the mechanical properties of live RBCs. This technique provides quantitative information about the shear and bending moduli of RBC membranes in many conditions. However, knowledge of RBC mechanics is currently very limited. RBC thermal fluctuations have been studied for more than a century to better understand the interaction between the lipid bilayer and the cytoskeleton. Membrane fluctuation dynamics of RBCs can be influenced by physiological conditions. Fluctuations in phospholipid bilayer and attached spectrin network are known to be influenced by cytoskeletal defects and low-molecular weight modifiers concentration.

Previously it had been proved by G. Artmann et al. that intact RBCs undergo a sudden change from blocking to passing through 1.3 μ m micropipettes at a transition temperature (T_c) of 36.4°C and -2.3 kPa aspiration pressure. This was attributed to a change of the physical state of hemoglobin. Since low-molecular weight modifiers such as potassium and sodium ions, ATP, and NO induce conformational changes of proteins, we are studying how these molecules would affect the RBC passage through micropipettes.

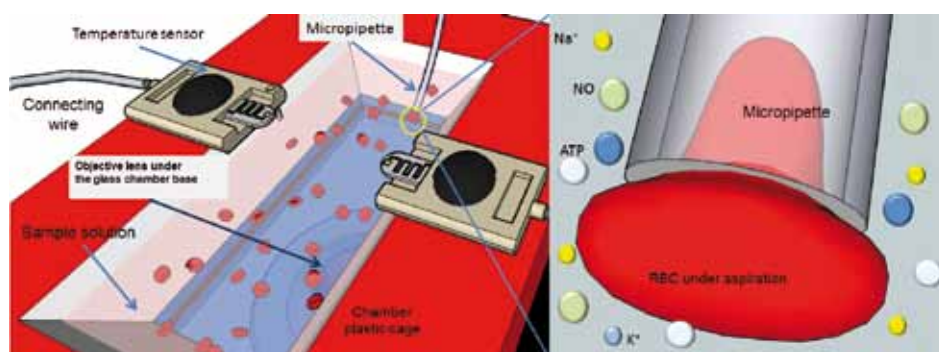


Fig. 1 | Schematics of RBCs micro-aspiration technique

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Development of real-time gas sensor system using eukaryotic cells

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Cell-based sensor system monitoring toxic gases in air

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Living eukaryotic cells represent a group of biological early warning systems (BEWS) that are characterized by easy handling and high sensitivity accompanied with low selectivity towards environmental toxins. Beside the use in the assessment of water quality, a novel field of application was opened in the last years for the monitoring of ambient air. A multiparametric sensor system, based on the measurement of three cell parameters (acidification rate, respiration rate and cell morphology) was used to distinguish between clean synthetic air and polluted air.

Toxic gases like CO, NH₃ and acetone, which are common in ambient air were successfully detected even in low concentrations.

The differences in the cellular response allow a simple clustering of the air pollutant into several classes (respiration inhibitors, metabolism inhibitors, membrane disrupting agents). The direct contact of the cells with the gaseous phase enables the measurement of water insoluble gases too. Future applications might be in the field of environmental technologies as well as in biomedical applications, e.g. for cytotoxicity identification of new respiratory drugs or inhalation narcotics.

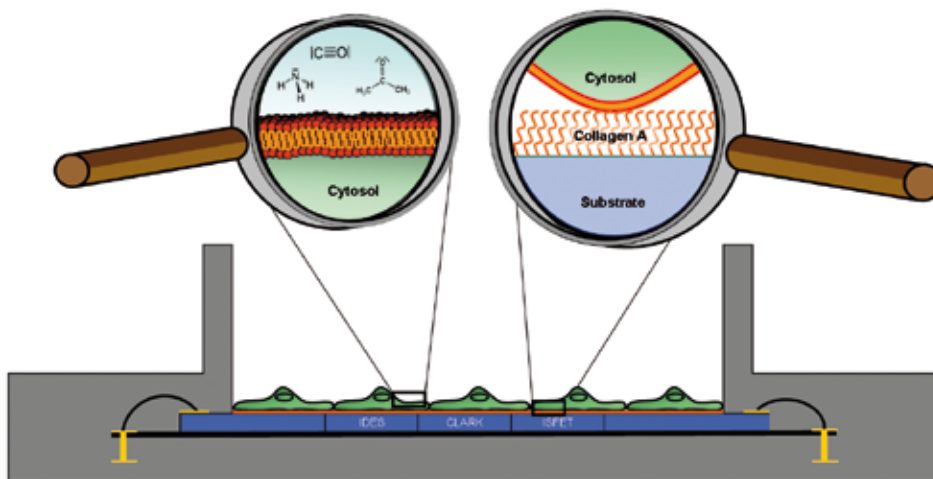


Fig. 1 | Schematic cross section of the sensor chip with living eukaryotic cells on the sensor surface. Loupes magnify the interfaces between air and cell membrane as well as cell membrane and chip surface.

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Development and Testing a Low
NO_x Hydrogen-Fuelled Gas Turbine

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Low NO_x hydrogen fuelled gas turbine

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The use of renewable discontinuous energy sources, such as wind- or solar-energy, raises the question of ensuring the continuous demand for energy. For future energy storage scenarios, hydrogen combustion systems play an important role. This offers new opportunities for alternative combustion processes with regard to efficient, safe and low NO_x-combustion of hydrogen.

For the operation of a hydrogen fuelled gas turbine two major modifications on the system gas turbine are necessary. The utilized combustion technology has to be modified to guarantee efficient, stable and low NO_x hydrogen combustion under variable operational conditions. Besides combustion technology modifications the gas turbine's control and metering system has to be adapted to ensure safe, rapid and precise changes of the engine power level. In order to evaluate and to improve controlling strategies for hydrogen fuelled gas turbines, a kerosene-driven gas turbine APU GTCP 36-300 (Fig 1a) is modified into hydrogen fuelled gas turbine. As far as possible the operational characteristic of the hydrogen gas turbine should be similar to the kerosene fuelled engine.

Against the background to evolve a secure and low NO_x combustion of hydrogen the micromix burning principle is developed for years at ACUAS and was first investigated for the use in aircraft jet engines to significantly reduce NO_x-emissions. This combustion principle is based on cross-flow mixing of air and gaseous hydrogen and burns in multiple miniaturized diffusion-type flames (Fig 1b). The two advantages of this principle is the inherent safety against flash back and the low NO_x-emissions due to a very short residence time of reactants in the flame region of the micro-flames.

The aim of the current research activities is the further improvement of combustor and metering technology. The work objectives comprehend the deeper analyzing of the combustion principle's main geometric influencing parameters and their influence on NO_x-formation. In addition the investigation of a further up scaling to higher energy densities with regard to industrial gas turbine applications is of major interest. Besides optimization of the combustion principle's resultant NO_x-emissions the combustion chamber design and manufacturing will be further optimized. Manufacturing complexity and costs will be reduced while the aspect of scalability of the design concept will be extended.



a)



b)

Fig. 1 | Hydrogen fuelled APU GTCP 36-300 (a) and Micromix test burner (b)

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Development of a high temperature
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High temperature moving bed heat exchanger for thermal storage in granular material

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This Abstract summarizes research activities that analyse the thermodynamic behaviour of an Air-Sand Heat Exchanger, developed by Solar-Institut Jülich (SIJ) and the German Aerospace Centre (DLR). The numerical 3-D model, new results and a model validation of this particular cross-flow heat exchanger are presented. The simulation was validated with a new 15 kW prototype unit. Ansys, including Ansys-CFX, is used as modelling and simulation platform. Validation is made using a new test rig system. The geometry of numerical model is equal to the inner geometry of the test rig. Furthermore, the 3-D geometry between the air entrance and exit cross section area are considered and simulated within the new numerical model (fig. 1, left). The bulk material is modelled by a porous solid medium without structural dynamic interaction between fluid and solid phase. A constant velocity is imprinted on the bulk velocity field. Material parameter, e.g. permeability, porosity and bulk density, were gained on the one hand from literature and on the other hand from measured results. Thus all thermodynamic medium properties depend on temperature. For bulk material pressure drop model from Ergun is used. The model parameters are the permeability, the porosity, the Sauter diameter and the Forchheimer coefficient. The parameters were validated and fitted with measured values of a separate pressure drop test rig. The validation was done with quartz sand. Furthermore a material library was also gained for bulk material with 1-2 mm diameter, i.e. for basalt and spherical ceramic balls.

Validation was made with the 15 KW test facility shown in fig. 1 (right). A quartz glass plate is installed for analysing the bulk flow behaviour and temperature profile inside the heat exchanger, near the pane. Thus the temperature profile can be visualised with an infrared camera. Pressure drop validation shows an accuracy of $\pm 2\%$. In fig. 2 (left) the result of the simulated air streamlines through the MBHE are shown. Inside the HE the air uses a larger cross section area than the filter walls on the inlet and outlet.

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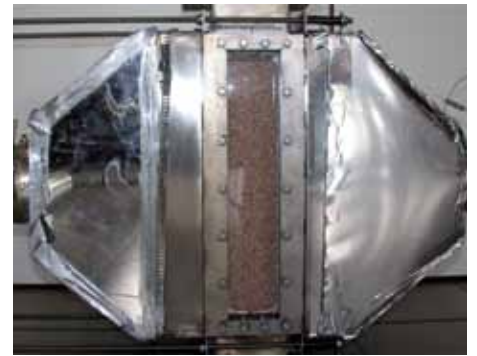
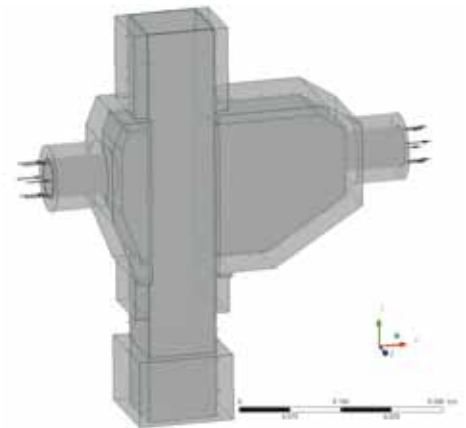


Fig. 1 | 3-D model of MBHE (above), test facility (below)

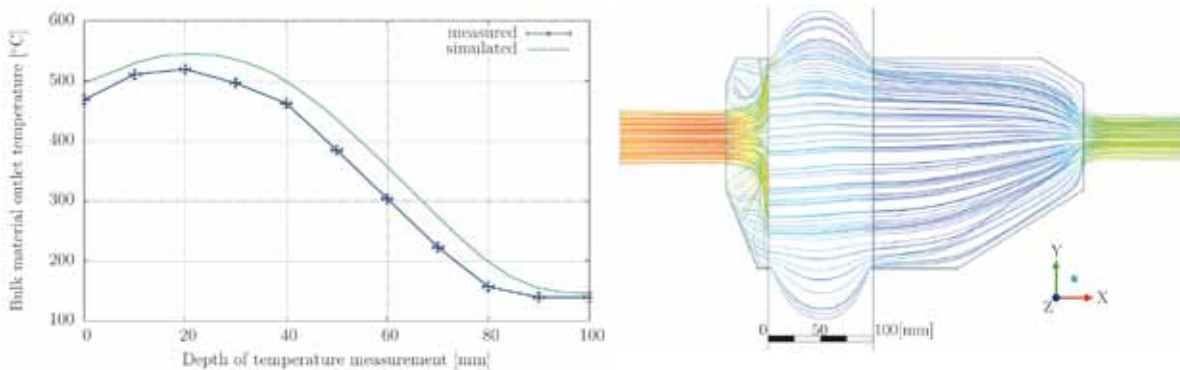


Fig. 2 | Air streamline through heat exchanger (left), Sand outlet temperature profile (right)

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Constitutive modeling of a hyperelastic
model for fiber-reinforced materials in
application to soft tissues

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Messung mechanischer Grundspannungen
und Schlagamplituden von Monolayern
stammzellbasierter Kardiomyozyten für
die funktionelle Medikamenten- und Tox-
inforschung – Ein Bio-Medical-Engineering
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Implementation of smoothed finite element methods in a large software package

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In the project CardiaKytos it is the aim to measure cell stresses of cardiomyocytes (heart muscle cells) on monolayers. One part of the project is to simulate these measurements with the Finite Element Method (FEM) and examine the computed stresses. Cardiomyocytes are soft tissues that undergo large deformations and are incompressible. Additionally the material of the heart muscle is highly nonlinear with a complex constitutive equation. To avoid common problems that occur within simulations of soft tissues we want to use the so-called Smoothed FEM (S-FEM) instead of the standard FEM and implement it in the large FEM software Code_Aster from the French electric power company EDF. This method has been developed since 2005 by G.R. Liu and Nguyen Thoi Trung and is not yet available in a large software package. Also to the authors knowledge it has been applied to nonlinear materials only on a very limited scale.

During the deformation of soft tissues a main problem often is that the FE meshes become highly distorted so that a solution is no longer attainable due to numerical problems. The S-FEM in all its different types overcomes this problem naturally without consuming more computation time than the standard FEM (maybe even less). This is done by smoothing of the strains to compute over smoothing domains that are part of or consist of parts of elements (c.f. Figure 1).

Also all S-FEM types are applicable for nonlinear materials and can avoid the problems depending on the incompressibility of soft tissues. For the examination of cardiomyocytes on monolayers at least the (ES-FEM) Edge-based and the (FS-FEM) Face-based S-FEM shall become implemented in this project to facilitate the simulations. Especially its application to the nonlinear materials will reveal new insights into the S-FEM. The implementation in a large FEM software like Code_Aster that has a lot of capabilities will also be very useful in other projects that deal with soft tissues.

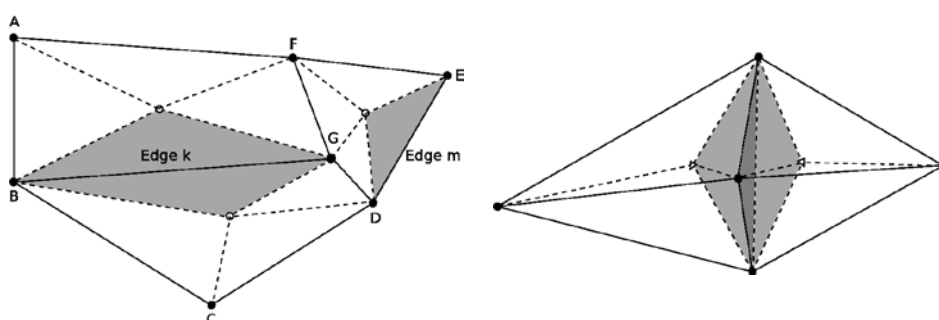


Figure 1 | a) In the ES-FEM the strains become smoothed over smoothing domains around edges. This figure shows 3 elements that are used to create 9 smoothing domains.

b) The FS-FEM is the 3D equivalent of ES-FEM thus the smoothing domains are based on faces of elements.

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OG A66

History-tracing XML for an Actor-driven
Grid-enabled Workflow System
(HiX4AGWS)

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History-tracing XML for an actor-driven grid-enabled workflow system (HiX4AGWS)

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Complex processes are often modeled as workflows. A workflow consists of several tasks which can depend on each other. Each task describes an atomic piece of work. Workflows are illustrated as directed graphs with tasks as nodes [squares] and dependencies as edges [arrows] [Figure 1]. Control flow patterns [grey] are used to route the execution of the individual tasks on the base of decisions.

The ubiquity of IT-based solutions is an indicator for a scenario in which tasks were executed by software components. In such a scenario, a user can automate the processing of a particular process. He composes predefined software components, i.e. tasks and control flow patterns, to model a particular workflow. Thereafter, he submits it to a workflow management system that automates its execution based on the dependencies and the progress of the individual tasks in the workflow.

One crucial requirement during the execution of workflows is the validation of the generated results and the traceability of the experiments execution path. In the domain of workflows this demand is reflected by the term provenance. Several provenance model specifications already exist but a special challenge arises when workflow tasks are mapped to components that were provided by different organizations. These scenarios exist in the domain of Grid- and Cloud-Computing. The contribution of different organizations in the 'partial' execution of the tasks within a workflow execution has to be determined in a convincing way that in some cases even has to be liable.

At the end of 2010 we designed an own new provenance model to support a unique layer structure which enables the liable digital signature of individual workflow tasks. Within the scope of the HiX4AGWS project we created a provenance framework prototype to support our own provenance model. This framework creates a separate provenance file for each workflow execution and updates this file during the runtime of the workflow with the produced data of each active task. After the whole workflow execution has finished, the provenance file enables the user to validate the outcome of the workflow. However, retrieving the related information out of provenance files in their raw format is rather complex. That is why the storage, distribution, and user representation of such provenance files were the new challenges for 2011.

In order to provide an easy access to the complete provenance files, a repository has been developed which stores all provenance files of finished workflow executions in a data base and provides globally available web based access to them. A Meta-information catalogue guides the user to query and select the desired provenance files. To simplify the analysis of a selected provenance file, a graphical browser was developed to hide the complexity of a raw provenance file. By using this browser the user can intuitively reengineer the workflow graph out of the provenance file and check the sanity of its execution. The representation and the verification of digital signatures in the special layer structure of our own provenance model will become a future challenge.

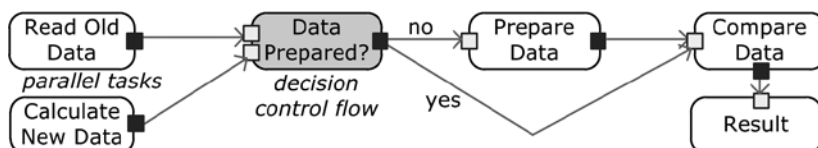


Figure 1 | Workflow

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Entwicklung eines zellulären dreidi-
mensionalen Herzmuskelmodells und
Charakterisierung seiner Inotropie für die
funktionellen Medikamenten- und Toxin-
forschung

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Development of a cellular 3D cardiac tissue model and characterisation of its inotropy for functional drug and toxin screening

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Almost one in two deaths in Germany is due to a disease of the cardiovascular system like hypertonia, cardiac infarction and others. For in-vitro studies of the mechanical properties of cardiovascular cells, organ explants from animal donors are still the best available technology. Regarding the problems of limited reproducibility, costly application and not least the ethical concerns, a cell based in-vitro model for the evaluation of mechanical data from beating cardiomyocytes is established.

The CellDrum™ System developed in the Laboratory for Cellbiophysics at the University of Applied Sciences Aachen provides a sophisticated environment for the measurement of the mechanical properties of cellular monolayers and thin tissue constructs based on collagen matrices. This unique technology offers the possibility to measure and compare the three different concepts of contraction known in medical applications:

- a) Isometric contraction
- b) Isotonic contraction
- c) Auxotonic contraction

Cell-seeded collagen gels are very weak and only grow stronger slowly in culture. For this reason, a simple but highly effective way of plastically compressing seeded collagen gels (external mechanical loading and capillary fluid flow) was developed at the Tissue Regeneration & Engineering Centre at the University College London.

A crucial prerequisite for the measurement of the tension of cell seeded compressed collagen gels is with the CellDrum® system is a tight mechanical coherence of the silicone membrane and the collagen gel.

At present a protocol for the chemical binding of the two layers is developed, including physical and chemical modification of the silicone surface and covalent binding the collagen gel to the membrane.

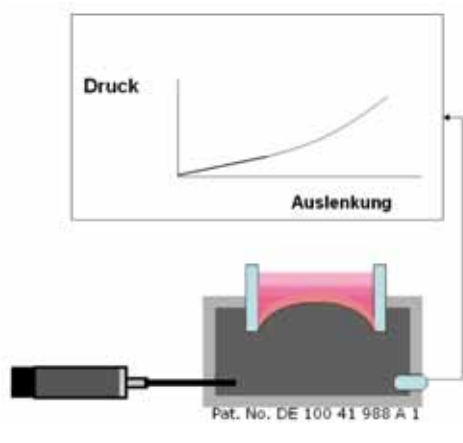


Fig. 2 | The CellDrum Principle

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„Bio-LAPS“ Optimierung des Betriebs eines
Biogasfermenters mit Hilfe eines Feldef-
fekt Biosensors auf der Basis eines lichtad-
ressierbaren potentiometrischen Sensors
(LAPS)

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Quantification of the dominance of microorganisms in the biogas process

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Facing the shortage of fossil energy sources and the contribution of its use to climate change, the utilization of renewable energy sources is including biomass, wind, water and sun energy gaining recently increasing public attention.

The conversion of biomass to methane (biogas) is a complex anoxic process, which involves a syntrophic interaction of various microbial species. These organisms belong to two large groups, which either degrade biomass polymers to acetate, hydrogen and carbon-dioxide (called bacteria). In order to optimise the biogas process it is necessary to know the organisms involved in the process. Most of the organisms cannot be cultivated in the laboratory and are, therefore, still unknown. Thus, molecular biological techniques are employed in order to identify these organisms.

Using these techniques, the most abundance organisms (OTU=operational transcription units) of both groups in a cattle manure-based laboratory biogas fermenter were identified (figure 1).

According to these results, some experiments regarding quantification of the process-relevant organisms have been realised including real time PCR and Fluorescence in situ hybridisation (FISH). First results indicate significant differences in the abundances of the organisms depending on the food mix of the plants.

Bacteria		
phylum		frequency
Bacteroidetes	<i>Bacteroides</i>	3,87%
	<i>Bacteroidetes</i>	0,32%
	<i>unclassified</i>	0,55%
Firmicutes	<i>Mollicutes</i>	1,74%
	<i>Bacilli</i>	1,28%
Spirochaetas	<i>sp.</i>	0,39%
Chloroflexi	<i>Anaerolineae</i>	0,32%
Fibrobacteres	<i>sp.</i>	0,32%
Candidatus Cloacamonas	<i>sp.</i>	5,61%
unclassified bacteria		0,32%

Archaea		
phylum		frequency
Euryarchaeota	<i>Methanomicrobiales/</i> <i>Methanosarcinales</i>	11,65%
	<i>Methanobacteriales</i>	4,13%
	<i>unclassified</i>	14,56%
Crenarchaeota	<i>sp.</i>	58,25%

Fig. 1 | Overview of the phyla of the predominance organisms in the laboratory biogas plant. Only 15 % of all analysed organisms are allowed to classify into OTU.

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OG A 41

Preparation of exfoliated polyvinyl
acetate-layered silicate nanocomposites

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Preparation of exfoliated polyvinyl acetate-layered silicate nanocomposites

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Polymer nanocomposites based on layered silicates have attracted great interest in recent years because they exhibit an improvement of physical and chemical properties compared to the neat polymer matrix. In these composites, the layers are dispersed at nanoscale level in the matrix and thus they are used as nanofillers resulting in an improvement of the properties compared to those of composites filled with macro- or microscopic fillers. The layered silicates present phyllosilicates whose negatively charged layers are counterbalanced by cations residing in the gallery between the layers. These cations can be replaced by organic cations changing the normally hydrophilic silicate surface hydrophobic in order to improve the compatibility between polymer and silicate particles. For an improvement of the properties, the silicate layers have to be exfoliated, i.e. the polymer chains intercalate into the gallery accompanied by a delamination of the layers. Consequently, they are dispersed homogeneously as individual layers in the matrix. A good exfoliation corresponds to strong interactions between polymer and organic cation. The exfoliation of polymer-layered silicate nanocomposites can be prepared by three main methods: the intercalation of the polymers from (aqueous) solution, the polymerisation of the polymer between the layers, and the melt-intercalation.

In order to obtain exfoliated polyvinyl acetate-layered silicate films, we develop a new method of the melt intercalation, called masterbatch-method. First, the layered silicates were melt-mixed with low molecular polymers such as polyvinyl acetate or polyvinyl stearate which were synthesized by transfer reactions. These polymers improve the exfoliation since they diffuse easily into the gallery of the layers caused by their low molecular weight and melt viscosity. Moreover, the interactions between the short polymer chains and the alkyl chains grafted on the layered silicates are better than with high molecular polymers. In the second step, the masterbatch consisting of layered silicate and low molecular polymer was melt-mixed with the polymer matrix polyvinyl acetate to give the film. Additionally, the use of the low molecular weight polyvinyl acetate effects a plasticization of the brittle polyvinyl acetate. Hence, it should be possible to create flexible polyvinyl acetate films featuring low gas permeability and transparent appearance which will be the aim of the work for the next year. Moreover, it is planned to prepare exfoliated polyvinyl acetate films by mixing the silicate layers with aqueous polymer solutions in glass flasks and to compare this technique with the masterbatch-method.

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EMSiG - Entwicklung eines Multisensorsystems in Siliziumtechnik zur Beurteilung der Gärbiologie eines Anaerobfermenters in der Flüssigphase

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Measurement of dissolved hydrogen in a liquid-to-gas transfer setup utilizing PTFE membranes

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Biogas production has the potential to replace some of the limited fossil fuels. In order to realize its full potential, real-time and reliable monitoring of the biogas process is crucial for a stable and efficient operation of the biogas production. One of the most important parameters for an early warning of process disturbances is the concentration of dissolved hydrogen. It is a key factor in the intricate balance between microbial species involved in the multistep degradation during anaerobic digestion.

This contribution explores the feasibility of hydrophobic tetrafluorethylene (PTFE) membranes for liquid-to-gas transfer in order to utilize conventional gas sensors for the detection of dissolved hydrogen. For this, a micromechanical thermal conductivity sensor was applied to investigate different PTFE membranes in terms of permeation of hydrogen. The membranes varied in pore size (non-porous, 0.05 μm , 0.2 μm , 0.45 μm) and membrane thickness (10-200 μm).

Hydrogen gas was dissolved in deionized water and the response of the sensor, which was separated from the liquid was recorded. A schematic representation of the measuring cell is depicted in Fig. 1a). In addition, the membranes were physically characterized by atomic force microscopy (AFM) and scanning electron microscopy (SEM). The obtained results were compared with theoretical permeabilities of the membranes.

Acknowledgements: The authors thank the Bundesministerium für Bildung und Forschung (BMBF, Germany) for financial support of the project "EMSiG".

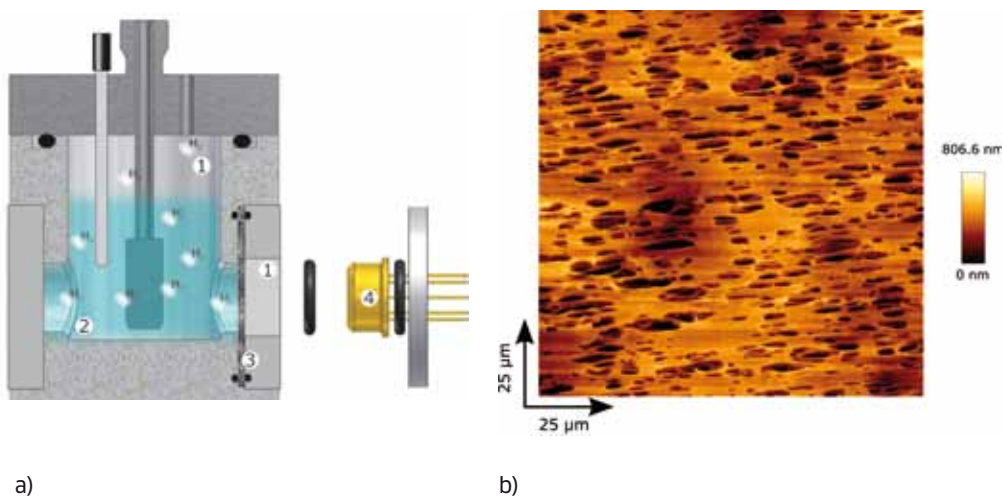


Fig. 1 | Sketch of the setup for the investigation of the membranes (1: gas phase; 2: liquid phase; 3: membrane; 4: thermal conductivity sensor) (a) and exemplary AFM height image of a PTFE membrane with a pore size of 0.2 μm and a thickness of 65 μm (b)

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RFID-basiertes Sensorsystem zur
Realisierung intelligenter
Verpackungen, "Intellipack"

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Calorimetric gas sensor on micro-plates for inline monitoring of H_2O_2 concentrations

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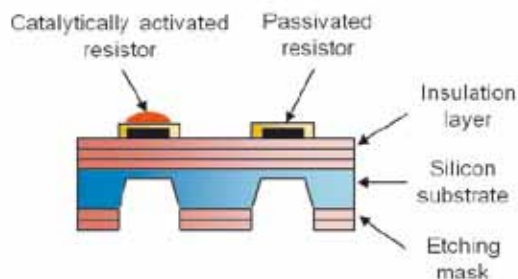
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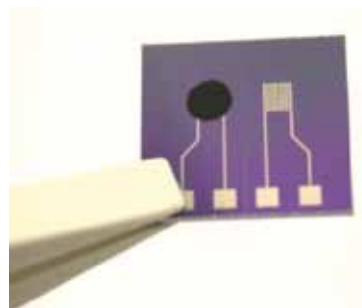
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In aseptic filling processes, gaseous hydrogen peroxide in combination with heat has become one of the most significant sterilisation agents for beverage packages (for milk and juice) due to its strong oxidising effect and the spontaneous decomposition in environment-friendly products, namely water vapour and oxygen. In this process, the microbicidal efficiency of the sterilisation agent depends particularly on the present H_2O_2 concentration that varies from 4 to 10% v/v and should be homogeneously distributed inside of the beverage package. This fact points out the need of a gas sensor for inline monitoring of the H_2O_2 concentration in aseptic filling processes.

In this work, a calorimetric gas sensor as a differential set-up of a catalytically activated and a passivated temperature-sensitive thin-film resistor has been built up on micro-plates in form of silicon-membrane structures (see Fig. 1). These membrane structures are an intrinsic feature of the novel sensor in order to reduce the thermal mass for each resistor (active/passive) resulting in an improved response time and to thermally isolate both resistors from each other to increase the sensors' sensitivity. In H_2O_2 atmosphere, the sensor has shown an elevated sensitivity and a low response time that demonstrates the adequate usability for inline monitoring of H_2O_2 concentration in sterilisation processes.



a)



b)

Fig. 1 | Calorimetric gas sensor on micro-plates, schematic side view (a) and front side of the sensor (b).

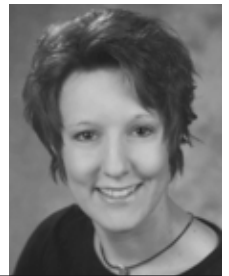
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Relevance of the respiratory quotient in
mammalian cell culture fermentation

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The respiratory activity of cells – a fingerprinting system in cell culture fermentation

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The production of monoclonal antibodies and recombinant proteins, called bio-pharmaceuticals, take place in large scale cell culture fermentation processes. Human and animal cells are used caused by their characteristic quality to build up medical active ingredients like EPO (Erythropoietin, Roche) or Factor VIII (Bayer Healthcare).

To achieve high cell densities and high production yields, ideal cultivation conditions (temperature, pH, DO, nutrient supply) are necessary. Therefore, the monitoring of the fermentation process is very important. Usually, industrial processes are controlled by measuring the oxygen uptake rate (OUR)[Ruffieux et al., 1998] and the concentrations of substrates, products and cell density. Except of the OUR, all other determinations need an interference in the ongoing cultivation process, which is connected to a high risk of contamination.

The fully automatically detection of the respiratory activity with the HiSense™ precise exhaust gas analyser (developed in cooperation with Hitec Zang GmbH), which includes the determination of the oxygen uptake rates (OUR), the carbon dioxide evolution rate (CER), the carbon dioxide transfer rate (CTR), the respiratory quotient (RQ) and the transfer rate (TQ)[Royce, 1992], enables to collect data non-invasive from the current process.

Every cell line has its own cell specific pattern dependent on the used media formulation (fig. a and fig. b). A cell line specific fingerprint occurs. Once, variations in this pattern appear during the fermentation, a clear indication for a change (e.g. character of the cell line, media composition, cultivation conditions) in the cultivation system is given.

This system allows the non-invasive controlling of an industrial production process only by the comparison of the fingerprints of the used cell line.

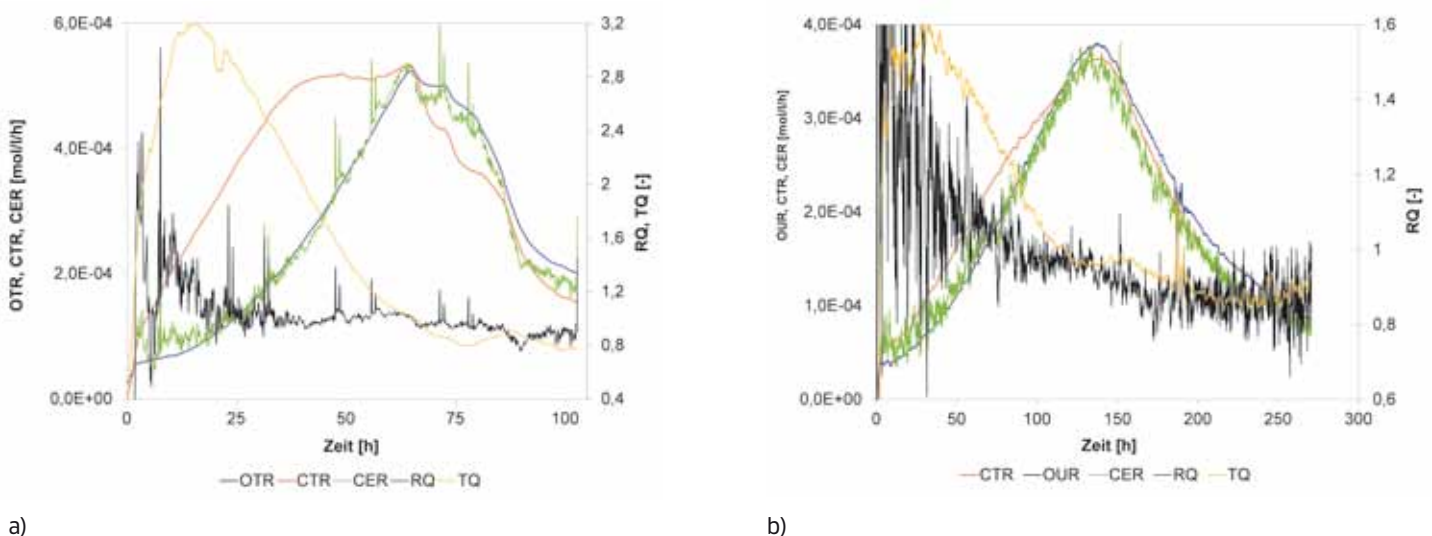


Fig. 1 | OUR, CER, CTR, RQ and TQ of two batch fermentations with the hybridoma cell line CF10-H5 in standard DMEM/ Ham's F12 media without any additional ingredients (a) and in commercial ProCHO4 media (Lonza AG) (b) are shown. During this cultivation processes, pH and DO were not controlled.

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Biomarker zur Prognose von Frühgeburten

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Biochemical properties of fetal membranes linked with premature birth

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Human fetal membranes hold the amniotic fluid and protect the developing embryo from outside influences. When the membranes rupture amniotic fluid drains off and birth is initiated.

Normally, the membranes rupture due to the mechanical forces of labour. When the membranes rupture before onset of labour it is called premature rupture of membranes (PROM). Furthermore, if this early ripening occurs before achievement of the 37th week of gestation it is called preterm premature rupture of membranes (PPROM). PPRM is critical as it is the main reason for a preterm birth. Preterm births in turn are crucial, because the neonatal death rate is substantially due to premature infants. Besides serious medical problems the medical care of premature babies imply immense costs for the health care system.

To date there is no satisfying tool to predict an upcoming preterm birth.

The aim of this study is to find the linkage between biochemical properties of fetal membranes and PPRM in order to predict a preterm premature rupture of membranes and therefore a preterm birth.

Before measuring biochemical properties, the maximal bursting pressure of the membranes were determined which makes a correlation between stability and biochemical parameters possible.

The main idea for these biochemical in vitro measurements is to find markers for an upcoming PPRM. Moreover, it has to be ensured that these markers can be measured in vivo (in pregnant women) in order to predict a preterm premature rupture of membranes. For this reason the determination of glycosaminoglycans like hyaluronan, collagen and water content were chosen.

Collagen is assumed to be the main component for the stability of fetal membranes. Hyaluronan is a glycosaminoglycan which is able to accumulate large amounts of water. This is the reason for the suggestion, that increased water content makes the fetal membranes less stable and could promote the ripening of fetal membranes.

There was a positive correlation between collagen content and maximal bursting pressure of term births ($r = 0.559$; $p = 0.002$) and of PROM births ($r = 0.539$; $p = 0.005$). These results suggest that the stability of fetal membranes are due to the collagen content. No correlation was found between maximal bursting pressure and PPRM births. It is believed that PPRM tissues loose stability caused by water retention. This assumption is enhanced by the finding of a negative correlation between water content and maximal bursting pressure ($r = -0.31$; $p = 0.046$).

These results show that not only the content of the mentioned biochemical factors are of importance, but especially the interplay between each other. Consequently knowing the linkage between biochemical properties and stability of fetal membranes could allow the prediction of an upcoming PPRM.

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HP bioforce

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HP bioforce – Summary

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To find and characterize new molecules in drug development for pharmaceutical industry, it is a necessary tool to perform mechanical (functional) measurements on isolated cells or thin 3D tissue equivalents, respectively. For cardiovascular systems contractility measurements of cardiomyocytes and vascular muscle cells play an important role. But how can such forces be examined in extremely thin cell layers or shown to be improved by drugs?

The answer to this was given by the project HPBioforce: Inside an incubator a fully automated system is measuring the forces exerted by cells growing in layers of only a few μm thickness. All steps – including all cell culture processes, drug application and measurements – can be controlled from the outside without opening the incubator. This is important, as slight environmental changes like variations in the temperature have a direct effect on the cell behaviour. The force measurement is based on the CellDrum™ technology, which is suitable to fulfil all the requirements for this fully automated system to work in high throughput. In the past the system was continuously optimized and it is now – due to the possibility to analyse a bigger number of samples in a relatively short time – ready to attract the interest of industrial customers. In order to satisfy the needs of the industry, in this last phase of the project HP Bioforce the approval of all integrated processes has to be performed. This does not just include the validation of the measurements, but also the quality of the cell culture procedures. As the use of disposables is not practical in this closed environment cleaning procedures for the liquid handling components have to be optimized to avoid any cross-contamination with drugs between the different experimental groups. Additionally the results of the measurements were compared to those from manually performed experiments to prove the working principle and to show the advantages of this automated cell force measurements.

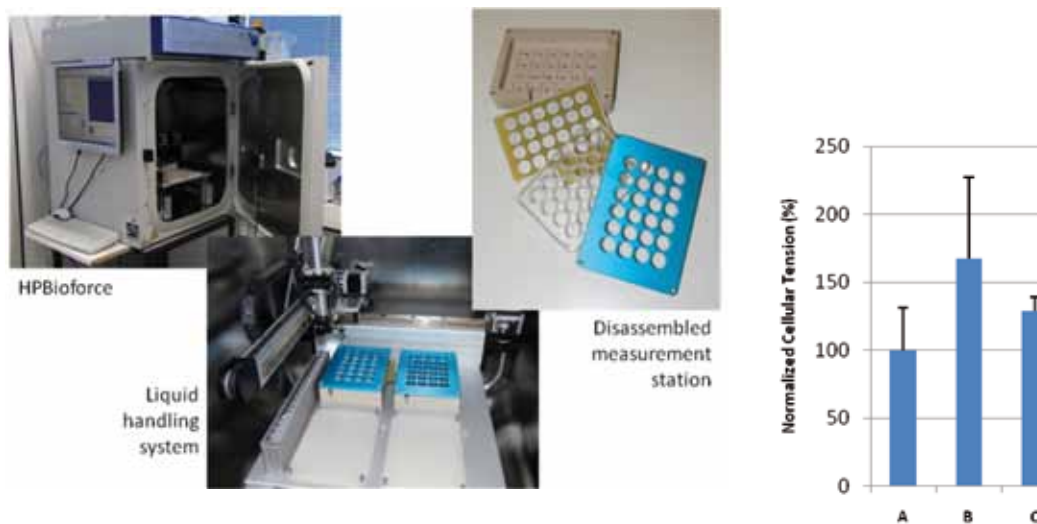


Figure 1 | On the left hand the different components of HP Bioforce are shown. On the right hand some results from measurements of NHDF monolayers are presented (n=4): A is the control group, B samples were intrinsically damaged, C samples were damaged but recovered due to drug application

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A design approach for construction of an
"Intelligent Car Body"

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A design approach for construction of an "Intelligent Car Body"

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Design and development of a car body is one of the challenging fields in automotive design. The design is driven by various requirements imposed by safety regulations and ever increasing performance demands. The level of information available for design in the initial stages of the design process is considerably low. Hence a car body goes through many time-consuming optimization loops till its final design. The current project aims at developing a guideline for the design of a car body which will help in reducing these optimization loops and hence create a "structurally intelligent car body" using modern CAD/CAE tools.

The proposed approach consists of four steps as summarized in the figure below. First step deals with setting up performance requirements for the car body and its various beams in different crash scenarios. Second step involves a detail study of behaviour of the beams in case of crash for deciding their preferred mode of deformation. In the next step various analytical models which determine the performance of beams in different modes of deformations are validated using testing, CAE simulations and statistical sensitivity analysis techniques. These analytical models are then used to evaluate different beams, differing in their shape, size and material and a suitable beam is chosen which matches the initially set target performance values. This approach hopes to reduce the further optimization required of the car body as the components are designed by taking into account the loads acting on them quite early in the design stage.

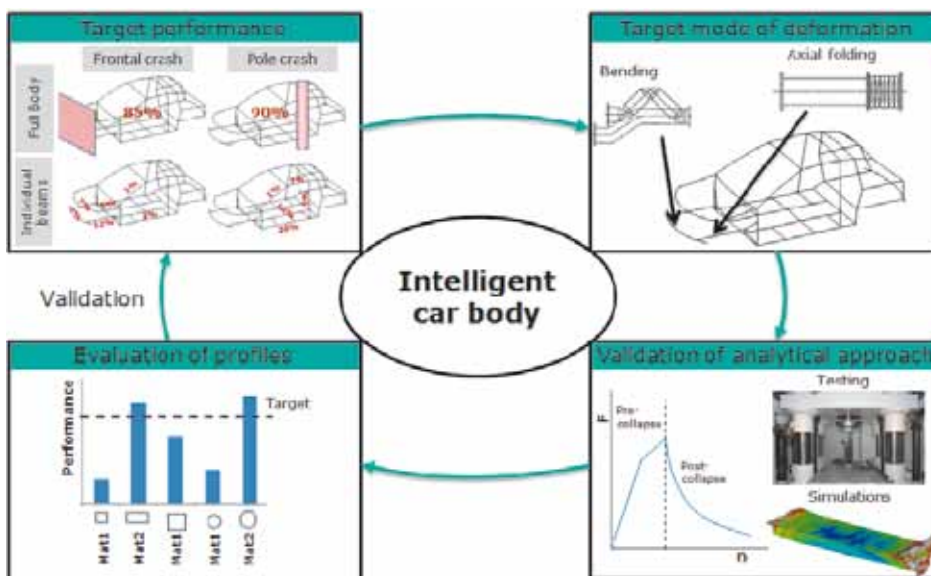


Figure 1 | Proposed approach for design of an "intelligent car body"

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Mechanics and structure of amniotic sac
tissue as potential information to predict
premature birth

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A high-tech attempt to predict premature birth

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Premature birth is one of the main problems of modern obstetrics, which affects 6 % of the annual deliveries in Germany, causing parental suffering, increased perinatal morbidity and mortality of newborn children and extended costs for the German health care system. Biophysicists at the University of Applied Science Aachen and gynecologists at the University Hospital of Cologne developed new investigation methods and instruments to understand the structural integrity of the amniotic sac and to predict premature birth.

In an extensive in-vitro-study carried out by both universities, amniotic sac tissue samples were collected and investigated with the “advanced device to investigate the mechanical properties of amniotic sac tissue” (DIMPAST).

DIMPAST is capable of measuring thickness, bursting pressure and deflection value under air flow as it is in eye pressure measurement technique to provide appropriate biomechanical data for any type of soft tissue membranes. Using Spectral radar OCT, the thickness were able to be measured and the thickness values were measured at the relaxation state and the stiff state.

In this study, measurement groups were designed as normal (NB), preterm (PRB), premature rupture of membrane births (PROMB) and preterm premature rupture of membrane births (PPROMB) and histological techniques were used in parallel with mechanical evaluation. The histological thickness of the fetal membranes was examined using periodic acid Schiff stain (PAS). Average of the fetal membranes` thickness was found to be $383.8 \pm 19.2 \mu\text{m}$ (NB), $324.6 \pm 14.4 \mu\text{m}$ (PRB), $343.1 \pm 21.2 \mu\text{m}$ (PROMB)(PAS staining) and $313.892 \pm 72.243 \mu\text{m}$ (NB), $270.231 \pm 66.083 \mu\text{m}$ (PRB), 266.64 ± 49.571 (PROMB) μm (OCT). Differences between the NB and the other groups were statistically significant (Mann Whitney U, $p < 0.05$). These results show that although the gestation duration was almost equal in the NB and the PROMB, the corresponding membrane thicknesses were different. This seems to be in accordance with previously reported water accumulation in tissue at the onset of the NB. OCT results were encouraging for the future clinical applications aimed to predict PRB and PROMB.

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DFG SPP 1259 "Intelligente Hydrogele"

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^{23}Na NMR study of intelligent hydrogels

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Hydrogels are three-dimensional polymer networks which have the ability to absorb high amounts of water. Due to this property they are used as diapers, contact lenses, sealing materials, ameliorates, drug delivery systems, sensor and actuators. In response to an external stimulus such as pH, ion concentration, or temperature, hydrogels can reversibly change their shape. Depending on their chemistry, they may swell or shrink upon external stimulation. (Figure 1)

Different kinds of hydrogels are presented based on acrylic acid and maleic acid for a high charge density and on vinylphosphonic acid for a high ionic strength.

The particular chemical composition also influences the mechanical properties and the swelling behaviour. The new types of hydrogels could be employed as sensors, actuators, and switchable porous media. The mobility of sodium ions is investigated by NMR interns of the ^{23}Na self-diffusion coefficient and the relaxation times T_1 and T_2 for a better understanding of the swelling and the switching processes.

Furthermore the ion dynamics of thermo sensitive copolymers on N-isopropylacrylamide and sodium acrylate were investigated by ^{23}Na relaxometry as a function of temperature.

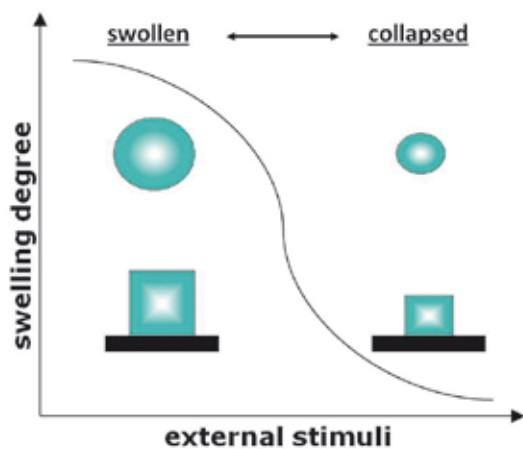


Fig. 1 | Intelligent hydrogels

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Entwicklung eines Sensorsystems zur
Erfassung der Sterilisationswirkung von
gasförmigem Wasserstoffperoxid

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Using a multi-sensor system to provide chemical images of sterilisation processes employing H₂O₂ vapour

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Hydrogen peroxide vapour (HPV) is used as sterilising agent in aseptic processes. It has a high potential of bacterial and sporicidal inactivation. The food processing industry is using purposely contaminated test packages with spores of e.g., *Bacillus atrophaeus* by means of a microbiological challenge test. Thereby, the logarithmic reduction of viable spores (log-rate) is a measure for the process sterility.

In this work, six different gas sensors (four different MOX, λ -probe and H₂O₂ sensor) have been used in order to obtain chemical images of the sterilising agent at different hydrogen peroxide concentrations. At the same time, microbiological tests have been carried out in order to determine the sterilisation efficacy at different hydrogen peroxide concentrations.

Figure 1 depicts the chemical images (radar plots) of the six sensors for each gas composition. For each plot, the achieved log-rate during the microbiological tests is given. It can be seen, that there is a differentiation between the patterns obtained for the different compositions of the sterilisation agent and resulting log-rates. It follows, that changing of a process parameter, in this case the hydrogen peroxide concentration, equally affects the response of each of the sensors in test. Also, discrete patterns could be obtained for the achieved log-rates. The described sensor system may be used for the real-time evaluation of aseptic sterilisation processes employing HPV.

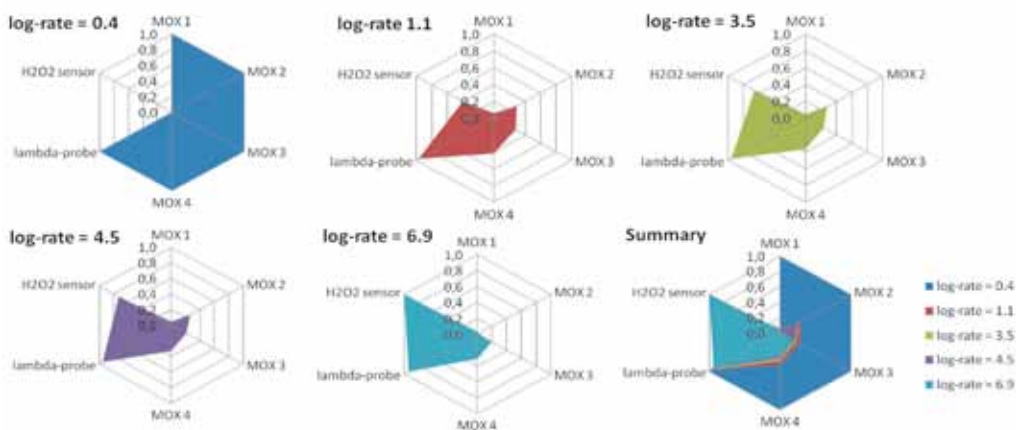


Fig. 1 | Chemical images of a sterilisation process employing hydrogen peroxide vapour at different H₂O₂ concentrations and resulting log-rates, obtained from a multi-sensor system containing six gas sensors.

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Development and Testing of Hydrogen-
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Modelling the thermo-dynamics of a sewage system

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A mathematical model is built up, which enables the simulation of a sewage-heat recovery system. The concept of the heat recovery system was developed within the framework of the research project "Exairgie" at the "Solar-Institut Jülich" (SIJ) of the Aachen University of Applied Sciences. The project was funded by the BMBF. The sewage is an ideal heat source for supplying heat pumps, since it is relatively constant during the course of a day and also a year. The developed system is adopted for supplying domestic hot water in one-family houses and for heating. It is installed as a pilot plant and operational-test measurements took place.

The concept affords to draw air through the sewage system by a ventilator. Therefore the existing internal sewer of the one-family house is used, so that cost-intensive earth moving is not necessary.

The air, used as the heat transfer medium, enters the sewage system through the manholes outside in the street and streams over the surface of the sewage. Thereby a combined heat- and mass transfer (water vapour) from the sewage to the cold air takes place. Simultaneously the system works as an air/earth-heat exchanger, so that there is an additional heat input from the surrounding soil. With a gas/liquid heat exchanger inside the house, the sensitive and the latent heat of the humid air can be transferred into the heat pump circuit. After cooling down, the air is led back into the sewage system and into the ambient respectively.

The heat pump has a heating power of 4.8 kW. The flow temperature for supplying domestic hot water is 52 °C, the flow temperature for heating is 40 °C. With the actual configuration, an average coefficient of performance of the system (COP) of 2.6 can be reached.

Amongst others, the simulations should give information about the ideal configuration of the sewer, e.g. its discharges, temperatures, diameter and depth. The developed model enables the user to change several input parameters to parameterise the sewage channel.

The model is based on a finite difference method, which divides the sewer into small "slices". For every single element, the heat- and mass transfer inside the sewer, as well as the heat conduction in the surrounding soil is calculated. Appropriate boundary conditions are chosen. Currently, the model works with a fixed time step.

The program is structured into four sub models. First, the discharge of the sewage and the temperature are calculated. In a second step, the calculated fluid level in the sewer is used to determine the flow cross-section of the air. A pressure drop calculation results in the flow rate inside every single element. The third sub model calculates the heat and mass transfer inside the sewer. In the last step, the heat conduction in the surrounding soil is determined. As data output, the temperature of the drawn air at the inlet of the ventilator, the relative humidity and the volumetric flow are generated for every time step.

The characteristic of the above mentioned pilot plant is determined since the end of 2008. At the present, the obtained data is used to verify the simulation model.

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Analysis of crucial intermediates as process indicators in the conversion of biomass to methane

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The conversion of complex substrates like facial slurries or manure to methane requires the interdependent activities of different syntrophic microbial communities. In order to shuttle metabolic intermediates between the organisms, the microbial consortia are believed to grow in tight associations, allowing interspecies-metabolite-transfers and directed metabolic fluxes. Since the individual participating microbes generally prefer different environmental conditions for growth, the strictly anoxic biogas fermenter content forms a compromise allowing growth of the participants under tolerable conditions. However, a single organism among a biogas forming community can cause the metabolic flux to shut down as soon as its environmental demands drop below the minimal individual growth requirements.

In the light of this context, process (im)balance of biogas processes can be monitored in time by analyzing crucial intermediates such as individual short-chain fatty acids (SCFA) or alcohols present inside the fermenter slurry. Eminent conclusions regarding the process stability can be drawn by accumulation or degradation of such individual compounds over time, especially in combination with a set of state-of-the-art monitoring technologies including data for pH, redox potential and buffer capacity as well as the amount and quality of the produced biogas that have to be taken into account.

In this project, a method for analyzing and quantifying individual short-chain fatty acids in complex suspensions like fermenter contents by high-performance liquid chromatography (HPLC) was developed. Using a three-step preparation, the SCFA are initially extracted from the aqueous matrix using diethyl ether, subsequently converted cleanly to the respective acyl chlorides and finally labelled using 4-nitrophenol. By taking advantage of the presented sample preparation in combination with HPLC analysis of the resulting 4-nitrophenyl esters, routine analytical monitoring of our lab scale biogas fermenters was achieved. Moreover, the development of an analogous analytical set-up for analyzing and quantifying individual alcohols is planned in order to gain combined knowledge about the process state of our laboratory fermenters especially when the communities are artificially stressed by feeding different compounds.

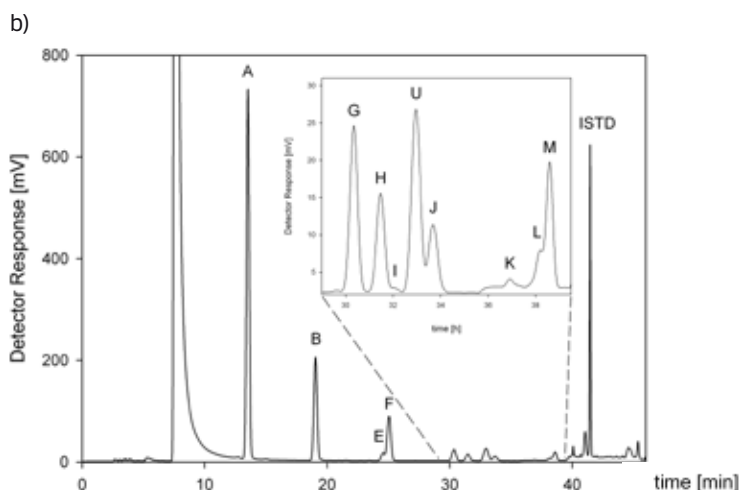
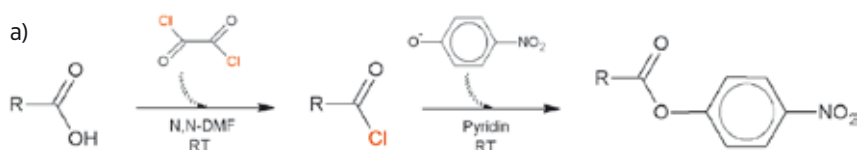


Fig. 1. a) Simplified reaction scheme of the SCFA derivatization using the applied protocol and b) chromatogram of a sample from a balanced lab-scale biogas fermenter with a selective detection of the 4-nitrophenyl esters using a UV detector at 295 nm wavelength. (The analytes are marked A - M; ISTD = internal standard; U = unknown compound)

Reference: J. Schiffels, M. E. Baumann and T. Selmer (2011). "Facile Analysis of Short-Chain Fatty Acids as 4-Nitrophenyl Esters in Complex Anaerobic Fermentation Samples by High Performance Liquid Chromatography." *J Chromatogr A* 1218(34): 5848-51.

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127

GPU Faser Vis - GPU based visualization of
nerve fibers from polarized high-resolu-
tion brain data

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GPU Faser Vis – GPU based visualization of nerve fibres

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The aim of the project GPUFaserVis is real-time visualization of high resolution nerve fibres of the human brain in context to their anatomy (Figure 1). With these visualizations we expect new knowledge of neurodegenerative diseases.

Nerve fibre data sets of our project partner FZJ contain sample points along a nerve fibre. To visualize these points a suited algorithm is necessary to approximate the shape of the fibres. Therefore a dynamic and parallel algorithm was implemented that allows the representation of the fibres with different shapes with help of rectangles: Lines has 0, ribbon 1 and tubes 8 rectangles (Figure 2). The number of calculated vertices to specify the shape depends on the number of rectangles.

The data set can have a size of several gigabytes and then the calculation on the Central Processing Unit (CPU) is slow. To speed up the calculation it is executed on the Graphics Processing Unit (GPU). The advantage of computing of the GPU is its high degree of parallelism, so the GPUs have more computing power.

The algorithm has been implemented and tested on a graphics workstation with the Intel Core i7 920 processor with 2.67 GHz and Nvidia Quadro FX 5800 graphics card.

In table 1 are results of the measurement of time of the calculation on one CPU (serial), 8 CPUs (parallel) and one GPU (parallel). The nerve fibre data set, that we consider, has 1.838 nerve fibres and 1.5 million points. The visualization results are shown in figure 3.

The results show that a speedup of more than 2.8 is given from CPU to GPU. The representation as lines is the fastest, but the visualization is not clearly. The calculation of ribbons is slower, but the visualization is more sorted. The calculation of the tubes takes the longest time, but the relations between the fibres are clearly recognizable. For details the tube representation is better, for a general survey of the fibres the line representation is adequate.

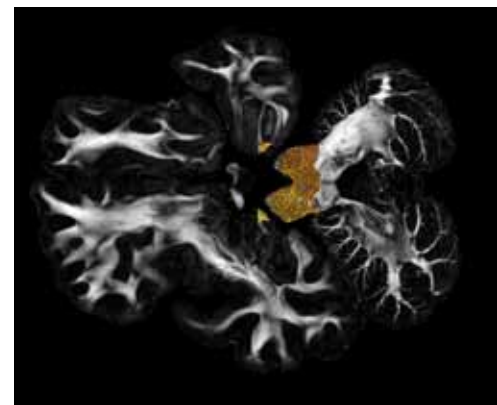


Fig. 1 | Human brain with nerve fibre data (yellow)



Fig. 3 | The figure shows a subarea of a nerve fibre data set with different forms of representation: lines (left), ribbons (middle) and tubes (right).

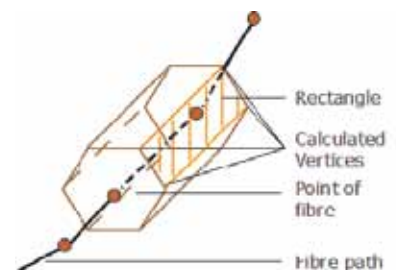


Fig. 2 | Approximation scheme

Representation	Number of vertices (in million)	Time 1 CPU (in sec)	Time 8 CPUs (in sec)	Time 1 GPU (in sec)
Lines	1.5	0.03	0.03	0.01
Ribbons	12.1	2.63	0.66	0.23
Tubes	30.1	7.90	1.71	0.66

Tab. 1 | The results of measurement of time for the different representation shapes and single or parallel execution of the calculation.

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BioMiMedics - Determination of polymer
degradation by a semiconductor-based
sensor system

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BioMiMedics – Determination of polymer degradation by a semiconductor-based sensor system

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Today, polymers play a major role in medical application and their chemical composition is as diverse as their application fields. One group of high interest is that of biodegrading polymers. These polymers feature a limited life time due to decomposition effects taking place inside the human body, e.g. hydrolysis or enzymatic reactions. The field of applications includes wound dressing, stitching materials and drug delivery systems but also implants with limited life time are conceivable.

Designing devices or developing novel polymers requires a lot of information about their degradation behaviour. Hence, a numerousness of parameters needs to get investigated and, consequently, there is a great demand for high throughput and online measurement techniques.

As part of the BioMiMedics project, which has the aim of developing novel biodegrading biopolymers for clinical use, a new sensor system, comprising different types of sensors, should be developed for giving on-line information of the degradation behaviour of polymers. In detail (see Fig. 1):

- > Tracing changes in bulk composition,
- > determination of erosion type (surface or bulk erosion).

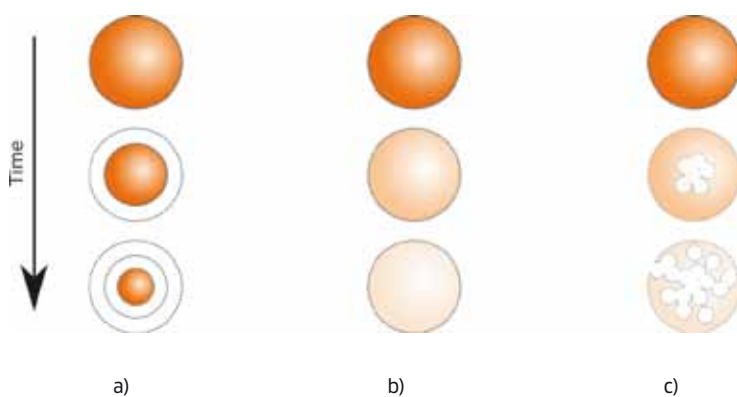


Fig. 1 | Types of biodegradation and resulting erosion (loss of mass) of a polymer sphere. (a) In case of heterogeneous erosion, only the surface of the sphere degrades, thus, the sphere diameter shrinks over time. (b) In contrast, during homogeneous erosion, the shape retains its original form and loses mechanical stability. (c) If degradation products inside the sphere cannot diffuse out fast enough, they affect the pH significantly. As a consequence, the degradation speed inside the sphere gets accelerated due to autocatalytic reactions.

This project is co-financed by the European Union (ERDF). "The commission, investing in your future".



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OG A 51

„Bio-LAPS“ Optimierung des Betriebs eines
Biogasfermenters mit Hilfe eines Feldef-
fekt-Biosensors auf Basis eines lichtad-
ressierbaren potentiometrischen Sensors
(LAPS)

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Determination of glucose concentration by means of a microorganism-based biosensor

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The light-addressable potentiometric sensor (LAPS) is a semiconductor-based chemical sensor with the advantage to detect chemical species on the sensor surface in a spatially resolved manner (Fig. 1a). In this work, a LAPS platform has been established in order to determine the response of microbes to variable environmental conditions on the chip surface. Thereby, the extracellular acidification in consequence to the metabolic activity of the microbes has been detected. This sensor principle might be useful to analyse metabolic activities as well as the nutrient concentration of microorganisms in biotechnical processes, e.g. for monitoring of the biogas process.

The easy to handle organism *Escherichia coli* was immobilised as a model organism on the sensor surface. The bacteria were immobilised by embedding them into a polyacrylamide gel (Fig. 1b). During growth, *E. coli* produces organic acids, like acetic and lactic acid. The acid production results in local pH shifts, which change the local potential of the LAPS surface. With this LAPS set-up is it possible to determine the metabolic activity as well as the glucose concentration in the fermentation medium.

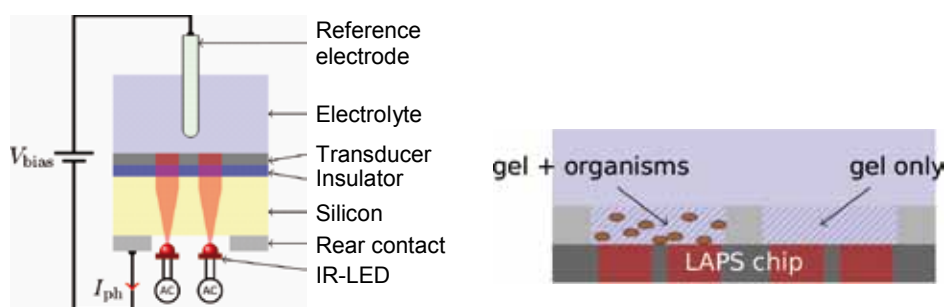


Fig. 1 | a) Principle of a LAPS, b) Layout of the "on chip" differential set-up.

Acknowledgements: The authors thank the Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz (BMELV) and FNR for financial support of this work (Bio-LAPS).

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Impressum / Imprint

Tagungsband der 4. Graduiertentagung
der FH Aachen am 24. November 2011

Proceedings from the 4th Graduate Symposium,
FH Aachen, Germany, November 24th, 2011

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Druck | Print | Druckverlag Kettler GmbH, Bönen

Auflage | Circulation | 100 Stück

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Foto Deckblatt | FH Aachen, Jeanne Niermann

Aachen, November 2011



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