

Papier beschichten. Umwelt schonen.

25.04.2024 | 29. GC-Führungssymposium



## 2 Wer spricht?



### Mathias Stanzel

- 2016 M. Sc. Chemie TU Darmstadt
- 2016 – 2020 Promotion  
„Mesoporous film architectures and step gradient formation“
- 2020 – 2022 Postdoc Pioneer Fund „SiliCoat-Papier“
- 2023 Projektleiter EXIST Forschungstransfer CeraSleeve

# 3 Was ist CeraSleeve?

WASSERABWEISENDE ODER NASSFESTE PAPIERE  
DURCH BESCHICHTUNG MIT SILICA



Wir machen die Erzeugung von nassfestem und wasserabweisendem Papier  
**KREISLAUFFÄHIG & ZUKUNFTSFIT.**

# 4 Kundennutzen

## RECYCLINGFÄHIGKEIT

Durchschnittlich spart die Produktion von Recyclingpapier



Wasser



Energie



CO<sub>2</sub>  
Emissionen

### 1 VERBESSERUNG ÖKOBILANZ

Keine Schadstoffe  
Keine fossilen Rohstoffe  
Umweltverträglich

### 2 KOSTENEINSPARUNG

Abwasserabgabenlast und  
behördlicher Kontrolldruck  
sinkt drastisch

### 3 GESETZLICHEN VORGABEN EINEN SCHRITT VORAUS

SUPD, Green Deal, Verpackungs-  
richtlinie, Kreislaufwirtschaftsgesetz

### 4 EFFIZIENZSTEIGERUNG

Verringerung  
Ausschussquote & Abfallaufkommen



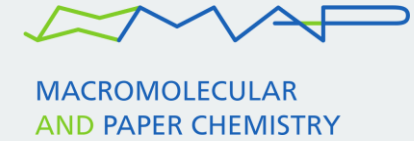
# Wo kommt's her?



Campus Lichtwiese – Standort der Chemie



# 6 Makromolekulare Chemie und Papierchemie



Prof. Dr. Markus Biesalski

"...we combine polymer science & paper chemistry, to develop innovative and sustainable materials, with fields of application progressing from coatings to construction materials and paper-based microfluidic devices."



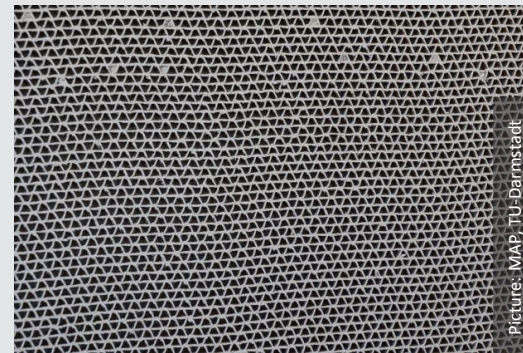
Picture: MAP, TU-Darmstadt

Biogenic Polymers



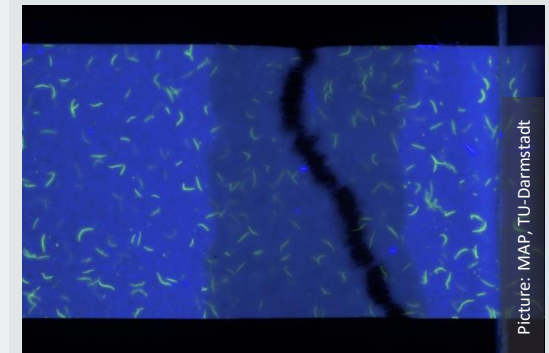
Picture: MAP, TU-Darmstadt

Functional Surfaces



Picture: MAP, TU-Darmstadt

Construction Papers



Picture: MAP, TU-Darmstadt

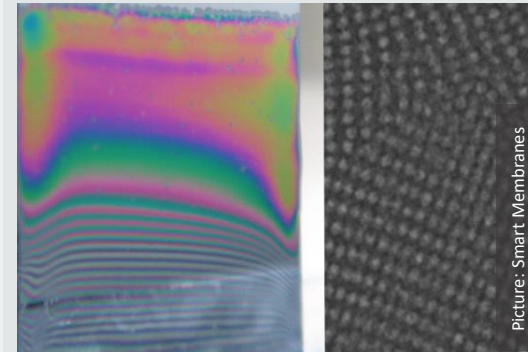
Paper Dynamics

# 7 Smart Membranes

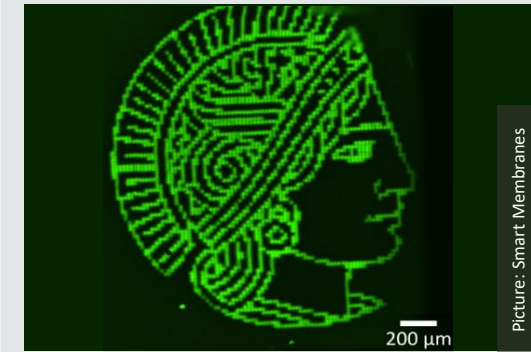
Prof. Dr. Annette  
Andrieu-Brunsen



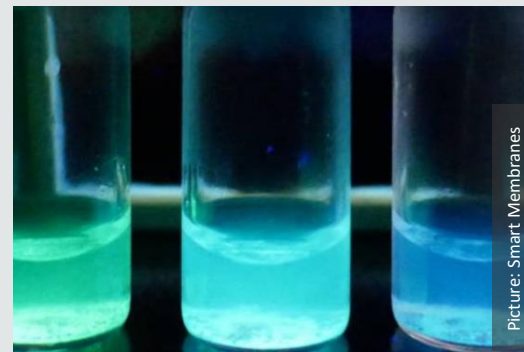
"...searching for new nanoporous materials, manufacturing methods and transport processes with benefits in the areas of water, sensor technology and energy conversion."



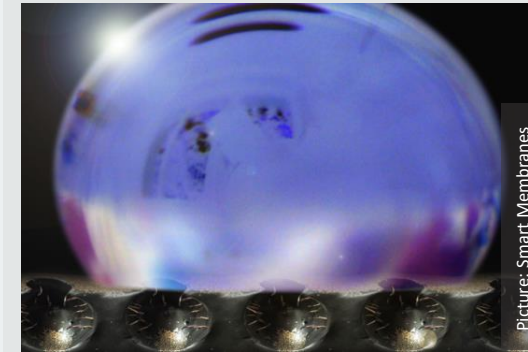
Nanopore &  
Membrane Design



Nanopore  
Functionalization



Sensing &  
Monitoring

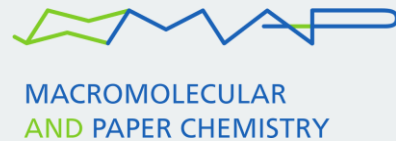


Transport Design



Hydrogel Matrices

# 8 Kombination der Forschungsexpertisen



## LANGMUIR

Article

pubs.acs.org/Langmuir

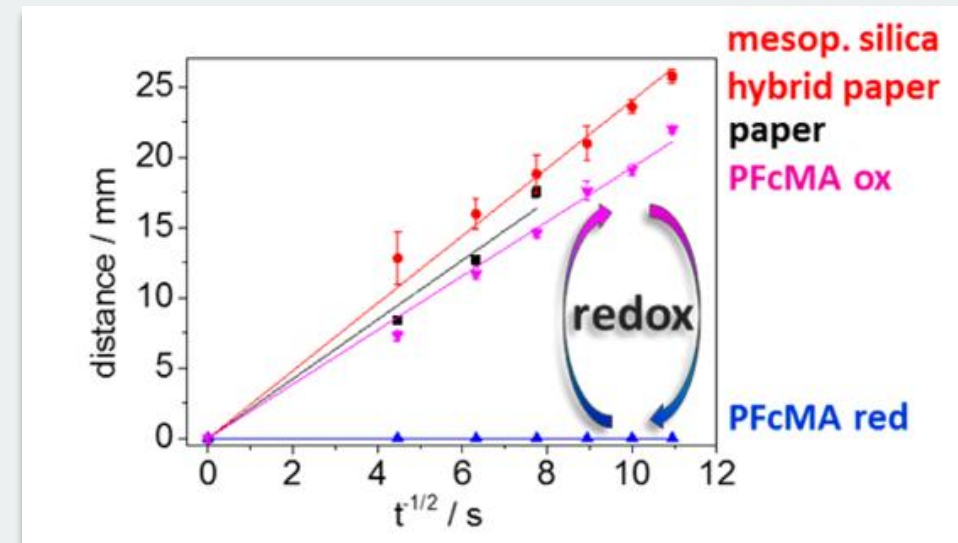
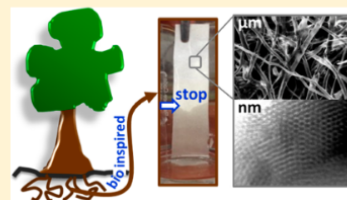
### Fluid Flow Programming in Paper-Derived Silica–Polymer Hybrids

Christelle Dubois,<sup>†</sup> Nicole Herzog,<sup>†</sup> Christian Rüttiger,<sup>†</sup> Andreas Geißler,<sup>†</sup> Eléonor Grange,<sup>†</sup> Ulrike Kunz,<sup>‡</sup> Hans-Joachim Kleebe,<sup>‡</sup> Markus Biesalski,<sup>†</sup> Tobias Meckel,<sup>§</sup> Torsten Gutmann,<sup>§</sup> Markus Gallei,<sup>†</sup> and Annette Andrieu-Brunsen<sup>\*,†</sup>

<sup>†</sup>Ernst-Berl Institut für Technische und Makromolekulare Chemie, <sup>‡</sup>Institut für Angewandte Geowissenschaften, Fachgebiet Geomaterialwissenschaft, and <sup>§</sup>Eduard-Zintl Institut für Anorganische und Physikalische Chemie, Technische Universität Darmstadt, D-64287 Darmstadt, Germany

Supporting Information

**ABSTRACT:** In paper-based devices, capillary fluid flow is based on length-scale selective functional control within a hierarchical porous system. The fluid flow can be tuned by altering the paper preparation process, which controls parameters such as the paper grammage. Interestingly, the fiber morphology and nanoporosity are often neglected. In this work, porous voids are incorporated into paper by the combination of dense or mesoporous ceramic silica coatings with hierarchically porous cotton linter paper. Varying the silica coating leads to significant changes in the fluid flow characteristics, up to the complete water exclusion without any further fiber surface hydrophobization, providing new approaches to control fluid flow. Additionally, functionalization with redox-responsive polymers leads to reversible, dynamic gating of fluid flow in these hybrid paper materials, demonstrating the potential of length scale specific, dynamic, and external transport control.





# 9 Wer hat's entdeckt?



Dr. Nicole Rath

Erfinderin der Grundtechnologie CeraSleeve®

## Methods Towards Asymmetric Functionalization in Porous Systems

Rath, Nicole  
(2020)

DOI (TUprints):

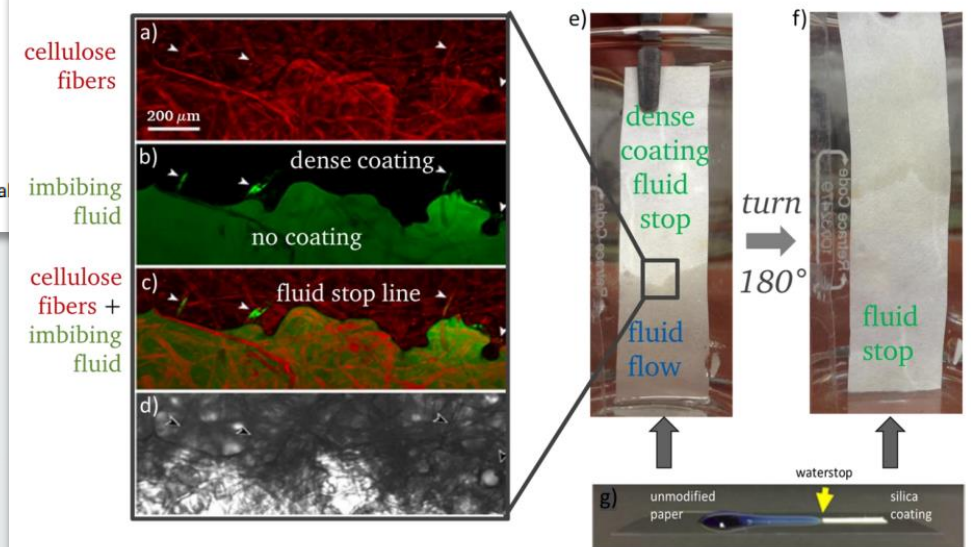
<https://doi.org/10.25534/tuprints-00013337>

Lizenz:

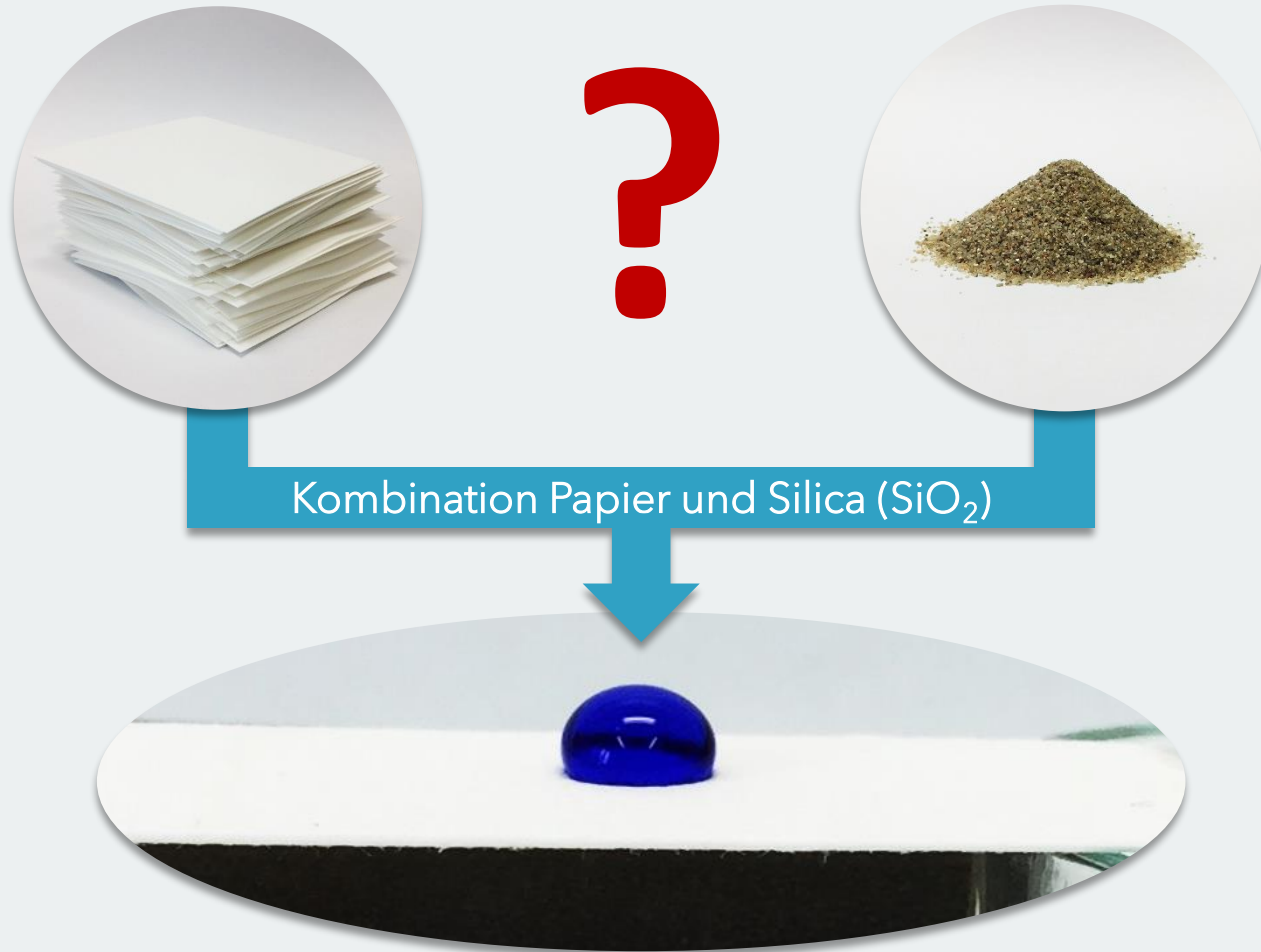
Publikationstyp:

Fachbereich:

Quelle des Originals:



# 10 „Das kann nicht stimmen...“



„2018 durfte ich auf einer Fachkonferenz in den USA unsere Technologie das erste Mal vorstellen. Im Anschluss daran wurde ich von drei unterschiedlichen **Teilnehmern aus der Industrie** gefragt, ob wir diese bereits **patentiert haben**. Damit wurde mir schnell klar: Wir sind hier auf etwas mit **vielversprechendem Kommerzialisierungspotenzial** gestoßen.“



# Was braucht's? ...

## ...Schutzrecht!



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**D04H 1/413** (2012.01)

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(56) Ermittelter Stand der Technik:

DUBOIS, Christelle [et al.]: Fluid flow programming in paper-derived silica-polymer hybrids. In: Langmuir, Vol. 33, 2017, No. 1, S. 332–339. - ISSN 0743-7463 (P), 1520-5827 (E). DOI: 10.1021/acs.langmuir.6b03839. URL: <https://pubs.acs.org/doi/pdf/10.1021/acs.langmuir.6b03839> [abgerufen am 2019-02-19]

Rechercheantrag gemäß § 43 PatG ist gestellt.

Die folgenden Angaben sind den vom Anmelder eingereichten Unterlagen entnommen.

(54) Bezeichnung: Faservliese mit asymmetrischer Silica-Imprägnierung und Verfahren zur Herstellung der Vliese sowie deren Verwendungen

### FULL PAPER

Hybrid Paper Membrane

ADVANCED  
MATERIALS  
INTERFACES  
[www.advmatinterfaces.de](http://www.advmatinterfaces.de)

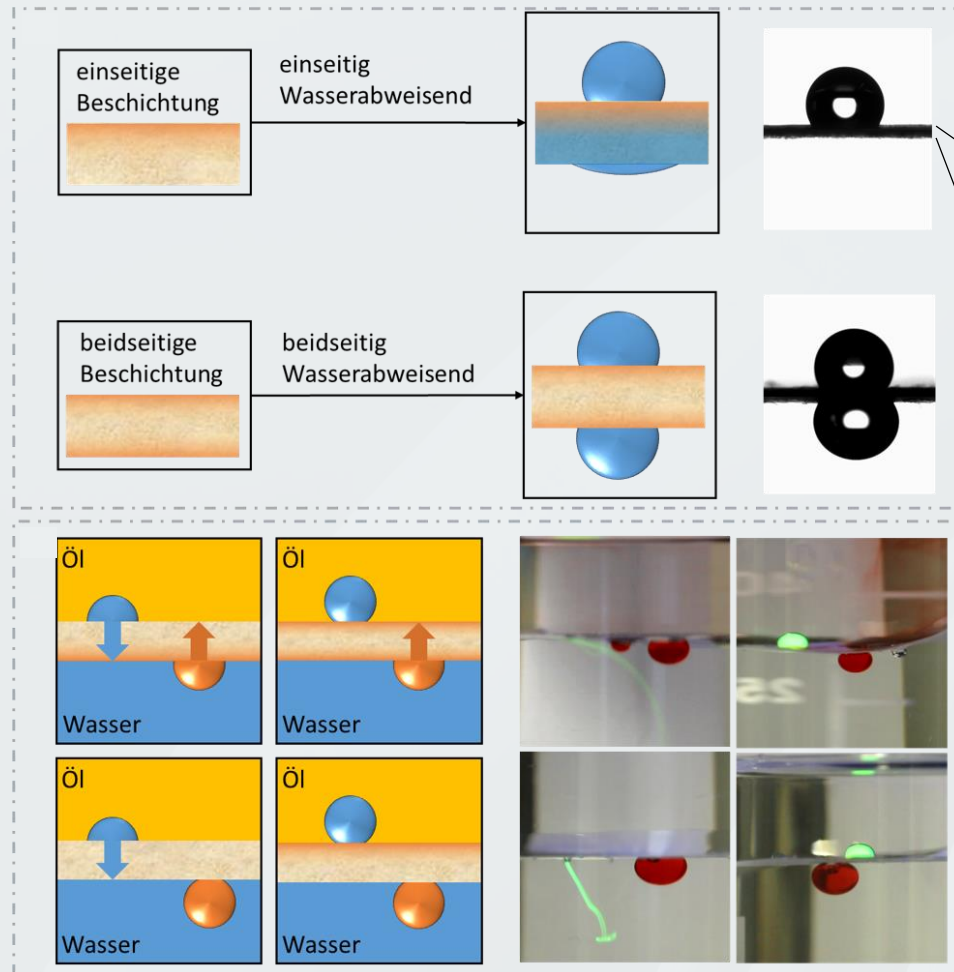
## Janus-Type Hybrid Paper Membranes

Maximilian Nau, Nicole Herzog, Johannes Schmidt, Tobias Meckel,  
Annette Andrieu-Brunsen,\* and Markus Biesalski\*

Functional paper-based materials and devices have been increasingly attractive to scientists in the recent past. In particular, the possibility to functionalize the surface of paper fibers with tailor-made coatings has broadened a possible scope of emerging application considerably. This work introduces novel functional paper membranes with adjustable gradient and Janus-type wettability based on gradient and Janus-type silica coating distribution along the paper cross-section. Correlation of CLSM (distribution), thermogravimetric analysis (silica amount), and Kr-BET (surface area; BET: Brunauer–Emmett–Teller) reveals an extremely low coating thickness, in the range of just a few nanometers, being sufficient to fully inverse paper wettability from hydrophilic to very hydrophobic excluding water. This asymmetric wettability, originating from an asymmetric silica distribution along the paper cross-section, is established by synchronizing silane hydrolysis and condensation reaction rates with silane transport rates in paper within a simple and scalable one-step drying process after having immersed a paper sheet into a tetraethoxysilane-containing precursor solution. As silica by itself, like paper, is a hydrophilic material, the observed hydrophobicity is related to a reduction in cellulose fiber nanoscale porosity controlling water imbibition. While being relevant in manifold applications, these ultrathin, Janus-type hybrid paper membranes are demonstrated to show directed gating and selective oil–water separation.

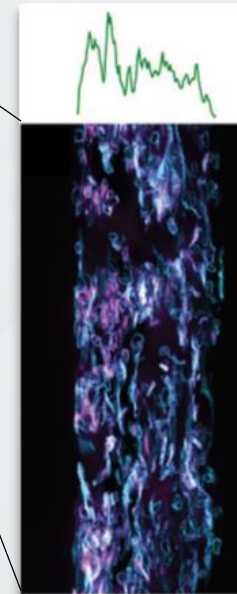
asymmetric chemical properties, both in bulk and in surface-confined coatings.<sup>[1–5]</sup> Referencing their two-faced nature, such asymmetric material properties are often named after the Roman god Janus. In particular, the behavior of membranes, particles, rods, or micelles with two orthogonal sides shows high potential for different applications, such as oil/water separation, droplet manipulation, fog collection, unidirectional water flow design, bubble aeration, ion gating, and energy harvesting.<sup>[6–12]</sup> In particular, asymmetrically designed membranes show strong potential for improved transport design and thus improved application performance. Directed oil–water transport in the context of oil–water separation and directed gas–water transport in the context of fuel cell gas diffusion layers are two specific application examples.<sup>[13,14]</sup> Therefore, enhancing control of material design and reducing the amount of material needed to achieve asymmetric material characteristics such as wettability are still an ongoing challenge. To make this

## 12 Janus-Papiere



Adv. Mater. Interfaces 2019, 1900892

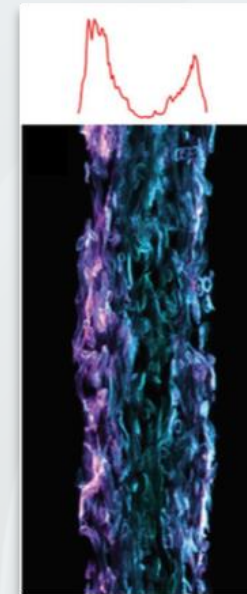
homogen



einseitig

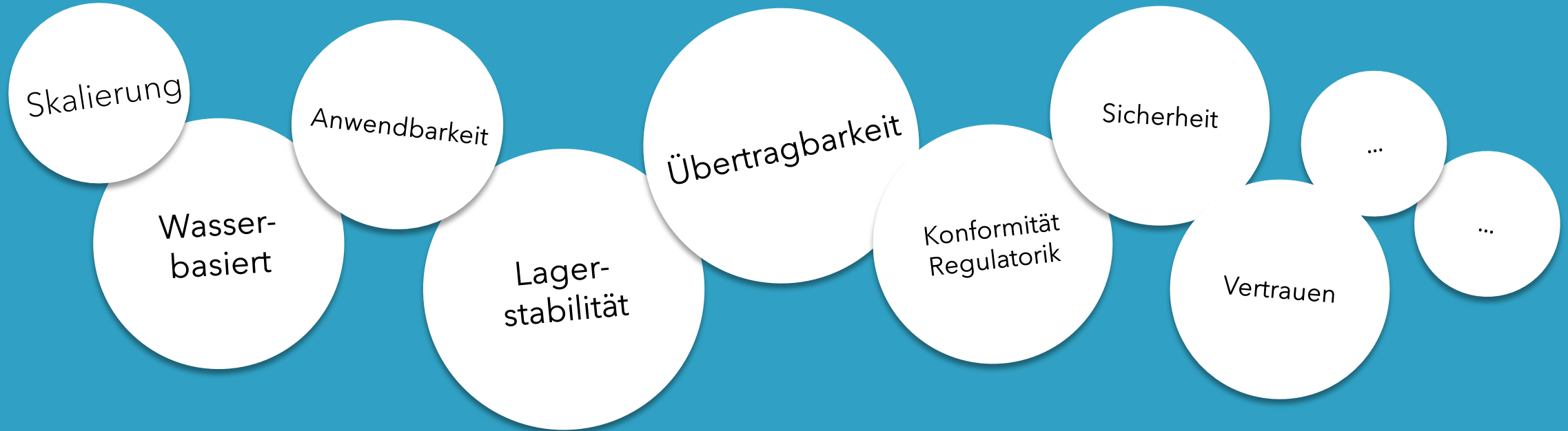


beidseitig





# Was braucht's für die Industrie?





Dr. Nicole Rath

Chemikerin,  
BetriebswirtinSpezialisierung:  
Biobasierte  
Beschichtungen

Augustin Coreth, MBA

Betriebswirt,  
ProjektmanagerSpezialisierung:  
Zirkuläre  
Geschäftsmodelle

Dr. Mathias Stanzel

Chemiker

Spezialisierung:  
Oberflächen-  
beschichtung

## BERATENDE

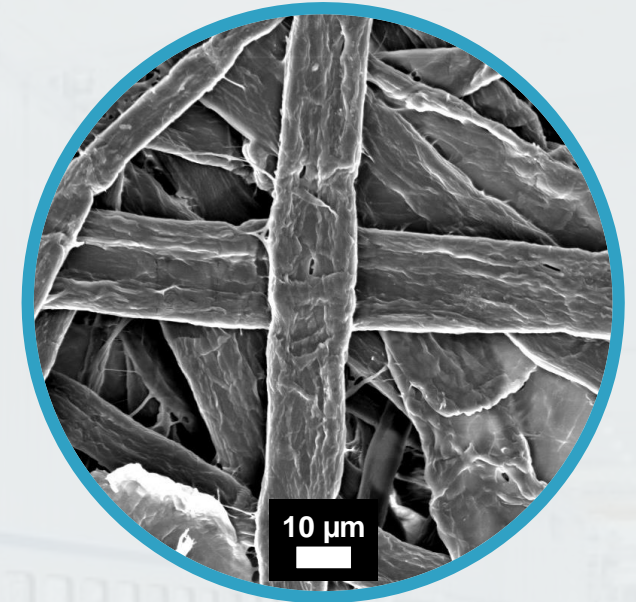
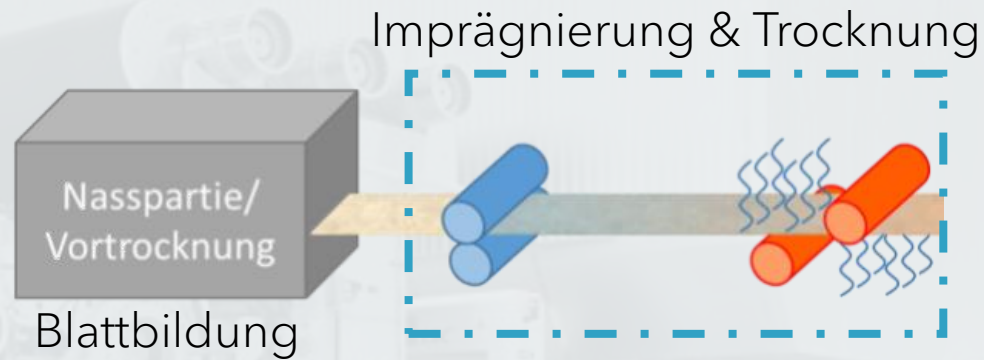
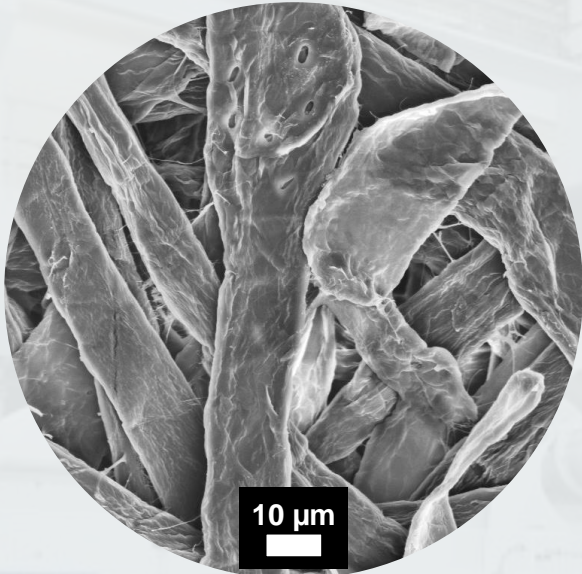
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Andrieu-Brunsen  
Lehrstuhl Smart  
MembranesProf. Dr. Markus  
Biesalski  
Vorstand Zellcheming  
Lehrstuhl PapierchemieDr. Roland  
Pelzer  
40+ Jahre Erfahrung in  
Papierindustrie

Gefördert durch:

Bundesministerium  
für Wirtschaft  
und KlimaschutzTECHNISCHE  
UNIVERSITÄT  
DARMSTADTaufgrund eines Beschlusses  
des Deutschen Bundestages



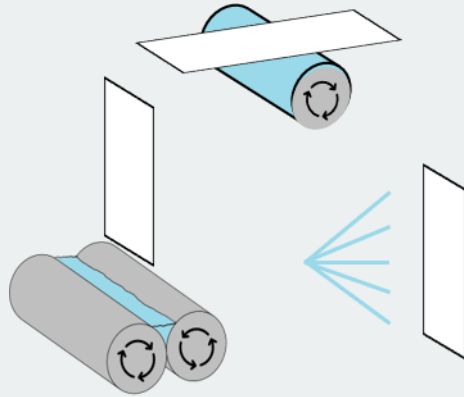
# Die Technologie



Technologielinie 1) wasserabweisende Papiere, lösemittelbasierte Beschichtung

Technologielinie 2) nassfeste Papiere, wasserbasierte Beschichtung

# Die Technologie



## FLEXIBEL APPLIZIERBAR

Industrierelevante  
Beschichtungsmethoden

## HOHE ANWENDUNGSBREITE

Papiere unterschiedlichster  
Faserzusammensetzung



# Was braucht's? ...

...den richtigen Zeitpunkt!



# CeraSleeve®



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