NEWSLETTER

BioSmart Trainee
Training in Bio-Inspired Design of Smart Adhesive Materials

No. 4/ Sept 2017

Dear All,
we are approaching the first half of our BioSmartTrainee project by the end of September 2017. Our young researchers already started to present their results during the renowned *INTERNATIONAL CONFERENCES* such as EPF 2017 in Lyon, ECOF 2017 in Dresden, GRS and GRC 2017 in USA/MA. We are very proud to announce that within the ECOF 2017, the first poster price was awarded to our young researcher from INM - Vaishali Chopra, who was presenting the first results on her project related to adhesion testing under an electric field between soft and rough surfaces. Congratulations Vaishali! We already prepared our *MID-TERM REPORT,* which was also sent to our International Advisory Board (IAB) for an internal evaluation and suggestions. We received a very positive feedback on the scientific and training program of the BioSmartTrainee and valuable suggestions. I would like to take the chance and say many thanks to our IAB members for their important and worthy input and support.
Our project will be evaluated by the European Commission during the Mid-Term Meeting on September 12th. During the *MID-TERM MEETING* the consortium partners and young researchers will show the progress in the implementation of the results and cooperation started within secondments. The steps necessary to prepare a successful meeting are already under progress.
The BioSmartTrainee *3rd TRAINING SCHOOL* will be held immediately after the Mid-Term Meeting from September 13th to 15th 2017. This school will mainly focus on the testing and evaluation of adhesive properties of developed materials in general and in immersed conditions specifically. Especially, the aspects on the surface functionalization and characterzation, adhesion: fundamentals and applications, fundamentals of molecular simulations, viscoelasticity in adhesion as well as soft skills such entrepreneurship, writing of research proposals and understanding of funding schemes will be in focus. Moreover, the early stage researches ESRs will be practically trained in the characterization of adhesive properties with the probe tack technique. The *4th TRAINING SCHOOL* will take place at the BASF, Ludwigshafen, Germany from 6th - 8th March 2018 with the main industrial focus on technology transfer from research into innovative products. I would like to take the chance to warmly welcome Ugo G. Sidoli to the BioSmartTrainee network as a new fellow working at the Leibniz-Institut für Polymerforschung Dresden e.V.
Finally, I would like to deeply thank all our BioSmartTrainee members for the great work together, excellent networking, fruitful discussions and results. I am sure we will have a very interesting and productive next part of our project as well as a lot of fun! With my best wishes, Alla Synytska

Outlook:

TRAINING SCHOOL 3 at CNRS/ESPCI, Paris, 13 - 15 Sept 2017

The Training School 3 as originally planned will mainly focussed on the measurement of adhesive properties in general and specifically in immersed conditions.

The early stage researches ESRs will be trained in the characterization of adhesive properties with the probe tack technique as well as in soft skills such as writing a research proposal and understanding funding schemes.

The training school takes place over three days. On day 1 we will focus on adhesion fundamentals, day2 will have some ore specific topics and day 3 will be dedicated to soft skills. graphic search methods.

Ca. 30 participants will attend the TS 3 incl. 4 project external PhDs.

TS3-AGENDA at NEWSLETTER Page No.6

NEWS

BioSmartTrainee-Poster update (page no. 5)

EVENTS

- PROJECT MEETINGS -

- 11 - 12 Sep 2017 Mid Term Meeting, CNRS/ESPCI, Paris
- Dec 2017 Telco

- TRAINING COURSES -

- 6 - 8 March 2018 **Training School 4** at BASF Ludwigshafen

Further information are available at:

www.biosmarttrainee.eu

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BioSmart Trainee

ESR PROJECTS

We would like to welcome our new fellow:

ESR 1:
UGO G. SIDOLI

Ugo is working on the fellow project: **Responsive polymeric surfaces with controllable underwater adhesion properties.** He is hosted at the Leibniz-Institute for Polymer Research Dresden e.V. in Germany.

In this and the upcoming next 2 newsletter we would like to summarize the research work in WP 1 (POLYMER SCIENCE), WP 2 (ADHESION), WP 3 (FLUID) biomechanics and Modelling.

This newsletter starts with the description of WP 1:

The objective of this WP 1 is the progress in knowledge and scientific development in the field of bioinspired adhesive polymers. During the reported period, we have achieved the following specific and training objectives:

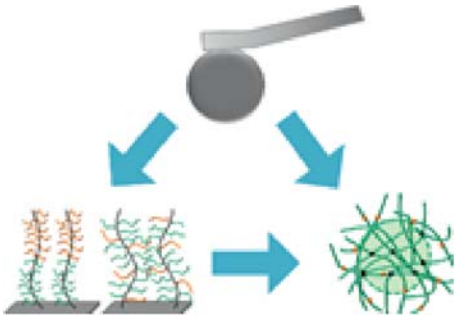
i) Training of young students in polymer synthesis, surface micro- and nanostructuration and the synthesis of responsive materials with improved adhesive properties, in particular for applications underwater. The students have attended the two training schools (TS) as planned in the program, along with in-house training provided by the hosting Institutions, attendance to scientific and technology seminars, individual training in labs.

ii) Reinforcement of European network and enhancement of European visibility in bioadhesives. All students have exchanged knowledge and discussed their research topics in the specific sessions during TSs and via shared on-line communication. The ESR3, ESR7, ESR9, ESR11 have already carried out part of their secondments in another partner Institution.

iii) Joint academia and industrial efforts in bioadhesion which will accelerate translation of biological adhesive principles into high-tech commercial products. Industrial partners (BASF, AkzoNobel-ICI and URGO) have participated in the TSs and discussed with the students, showcasing industrial

WP1/Task 1.1 (ESR1/IPF Dresden)

Adhesive surfaces from responsive polymer brushes:
"Responsive polymeric surfaces with controllable underwater adhesion properties"



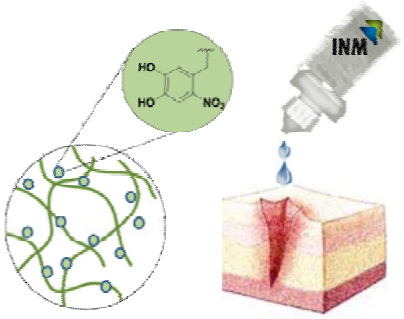
The synthesis of model thin films based on thermo- and pH-responsive bi-component brushes formedy thermoresponsive poly-(–isopropylacrylamide)(PNIPAAm) with inclusions of adhesive/charged framents of poly-(2-dimethylaminoethyl methacrylate) (PDMAEMA) using ATRP approach was carried out. PNIPAm provides switching of conformation of polymer chains, while PDMAEMA provides adhesion based on electrostatic interactions, combining both strength and reversibility of binding. Controlled variation in surface chemical composition (100%; 50%; 5%, 1% and 0.1% of PDMAEMA units), architecture (statistical random and block copolymer), grafting density and responsiveness (pH, T, ionic strength) was established. The influence of such parameters over swelling, surface charge properties and underwater adhesion to negatively charged substrates (colloid probe modified with poly acrylic acid brush) depending on pH, salt concentration and T via AFM colloid probe technique has been evaluated. We demonstrated that strongest adhesion to PAA-CP is achieved at high (50-100%) fraction of charged/adhesive PDMAEMA groups below and higher LCST temperatures. Contrary to this, the most pronounced switching of adhesion under water is achieved at lowest fraction (between 0.1% and 1%) of charged/adhesive groups. The fraction of the lowest portion of charged/adhesive groups is that low (1 group per few polymer chains) that can be easily achieved by designing of statistical random copolymers and not by block copolymers.

Next steps: In the next future, the adhesive properties between the PNIPAAm/PDMAEMA brush systems and gels both in dry and wet environment, will be examined in collaboration with ESR4 and ESR5 at ESPCI in Paris. Furthermore, the strategies for further modification of brush system with catechol containing units are developed. The adhesion properties of these systems to negatively and positively charge substrates and its reversibility will be studied using AFM colloidal probe technique and tack testing.

Networking: Collaboration with ESR 3 (WU) on the responsive gels is ongoing. Thin grafted films from polymer brushes are model systems and prototypes of building blocks for coaservates synthesized in the WU group. Collaboration with ESR 4 (ESPCI) on adhesion tack measurements between thin brush films and gels under water is ongoing.

WP1/Task1.2 (ESR2/INM Saarbrücken)

Reversible wet adhesives based on catechol chemistry:
"Bioinspired Medical Adhesives"



During this period, novel nitro-catechol derivatives with improved photodegradation properties vs. previous reports were synthesized. Such derivatives also contain lateral groups for biorthogonal conjugation to polymer scaffolds. The 3D printability of catechol-containing polymers was

evaluated. The polymers were crosslinked with an oxidant agent, and the obtained material was 3D printed at different time points during crosslinking. The effect of different experimental parameters over printing fidelity of the material was assessed. Biocompatibility of the material was evaluated by culturing cells on 2D thin film hydrogel samples.
Viability of cells embedded on such hydrogels (3D culture) was also investigated, to assess the effect of the different parameters (e.g. polymer and oxidant concentration) over cell survival.

Next steps: The photocleavable unit will be incorporated into polymer scaffolds and photo-degradable hydrogels will be prepared. Depolymerization of the material will be carried out by light exposure, at determined wavelengths and irradiation doses.
Rheological studies on hydrogels will be conducted to determine curing kinetics and final mechanical properties. Evaluation of the adhesive performance and responsiveness on different tissue types is planned.

Networking: Collaboration with the organization industrial partner URGO towards the potential translation of adhesive hydrogels into products for the biomedical industry is ongoing

WP1/Task1.3 (ESR3/WU,Wageningen)

Responsive gels using complex coacervation:
"Bioinspired underwater adhesives using complex coacervation"

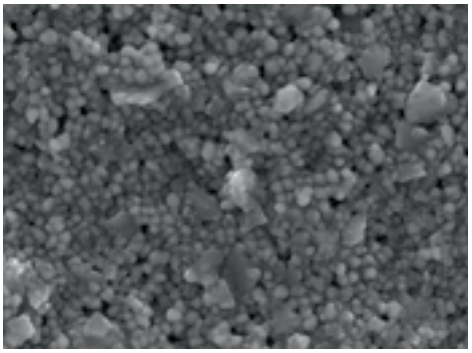
The demand for new adhesives for soft tissue repair and wound closure that could substitute traditional repairing techniques is hugely increasing. Synthetic adhesives that could work effectively in wet conditions (such as inside the human body) can be developed finding inspiration in nature. A phenomenon which is believed to play a fundamental role in the adhesion mechanism of many aquatic organisms (sandcastle worm, caddisfly larva and mussel) is complex coacervation. When oppositely charged polyelectrolyte solutions are mixed, associative phase separation can take place, resulting in a formation of a dilute phase and of a dense polymer-rich phase, generally known as coacervate. Coacervate based materials gained popularity as underwater adhesives since they could solve common issues such as insolubility in water and surface wetting. In addition to that, an adhesive, in order to work properly, after contact with a surface has been made, needs to be able to sustain a certain amount of stress upon debonding: for this reason, a reinforcing mechanism is generally introduced so that a transition from the liquid to the solid state can occur after establishing molecular contact. In this work, the synthesis of different sets of oppositely charged copolymers has been carried out with different techniques. Successful complex coacervation between the two synthesized copolymers was observed upon mixing water solutions of the mentioned polyelectrolytes, having the same concentration of charged groups in the final material. The mechanical properties of the coacervate phase have been evaluated using rheology. The adhesive properties have been determined underwater using a probe-tack test in collaboration with ESR4 at ESPCI in Paris. The rheological and adhesive properties can be tuned by varying several parameters. In conclusion, we were able to use complex coacervation to design a material which can display good mechanical and underwater adhesive properties. These results match our expectations and show that this material can be a promising candidate for the development of an underwater adhesive for soft tissue repair.

Next steps: In the next future, the adhesive properties of the developed coacervate will be examined in more detail in collaboration with ESR4 and ESR5 at ESPCI in Paris. Furthermore, a new setup for the measurements of the adhesive properties underwater is currently being developed at Wageningen University. At the same time, the structure of the material and the mechanism of adhesion will be studied using scattering techniques. New chemistries will be evaluated in order to improve both the adhesion and the cohesion in wet environments.
The developed system will also be studied using AFM colloidal probe in collabor tion with ESR1 at IPF in Dresden.

Networking: Collaboration with ESR 1 on model polymer brushes and AFM CP technique; with ESR 4 & 5 (ESPCI) on underwater adhesion tack measurements; with ESR10 on formation of polyelectrolyte complexes is ongoing.

WP1/Task1.4 (ESR11/ICI , Slough UK)

Industrial material design:
"Advanced adhesion paints"



Design of decorative
paints with insect-repellent properties (AkzoNobel-ICI): Critical parameters to prevent insect climbing on decorative paints on vertical surfaces are currently thought to be the surface roughness and the surface energy of paints. In this period, formulation, synthesis and characterization of complete decorative paints, targeting the formulating region thought to deliver appropriate

surface roughness and surface energy, have been completed. Traditional paint properties and insect climbing ability have been measured. In the light of these initial results, paints based on specifically formulated latexes were defined to systematically study the influence of each ingredient on its surface properties. Formulation, synthesis and characterization of decorative paints based on synthesized latexes and a limited number of decorative paint ingredients is now underway and is currently the subject of a secondment of ESR11 to the University of Cambridge (ESR8). High Throughput Experimentation is aiding the evaluation of as wide a formulating region as possible. The academic supervision of this BioSmartTrainee PhD is undertaken by Prof. J. van der Gucht (Wageningen University) with whom there are regular discussions to ensure the work maintains sufficient academic rigor for a PhD.

Next steps: In the next future, next steps as formulation of paints using simpler latex polymer binders to obtain a better understanding of the desired structure property relationship in decorative paints; complete a literature review, potentially for publication, on the current knowledge of the interaction of decorative paints with insects; further insect climbing abilities testing; adhesion testing with insect feet models; replications of paint surfaces to understand better surface chemistry as well as analytical characterization at Wageningen University towards adhesion are planned.

Networking: Collaboration with ESR 8 on understanding of mechanisms in natural adhesive systems is ongoing. Coallboration with Wageningen University to ensure academic rigor of PhD studies

INTERNATIONAL CONFERENCES

Generally, the project aims, strategies and activities to all relevant stakeholders were already presented at two international conferences - ECOF 2017, July 17-20 in Dresden/Germany and Gordon Research Seminar and Gordon Research Conference on Adhesion 2017, July 22-28/, as was planned in the project. Specifically, session on BioSmarttRainee was included as the Joint German Network wide event into ECOF 2017, where German partners from IPF, INM and BASF delivered lectures and poster presentation and discussed tzhe maintain academia-industry cooperation.

We are very proud to announce that, within the ECOF international conference, the first poster price was awarded to ESR6 from INM - Vaishali Chopra who was presenting the first results on her project related to adhesion of micro patterned adhesives on soft substrates.

The Gordon Research Seminar (22-23 July 2017/ Mount Holyoke College, South Hadley, MA) as well as the Gordon Research Conference (from 23-28th July 2017) devoted to Molecular Insight to understand Fracture and Adhesion suggested an excellence opportunity for BiosmartTrainee PhD students and supervisors to present, discuss and exchange the knowledge on the results from BiosmartTrainee. Especially, ESR4 - Francisco I. Cedano (Underwater adhesion between model gels and functionalized surfaces) and ESR2 - Maria Villiou (Bioinspired medical adhesives) successfully presented their results in frames of poster sessions.

Moreover, two International Conferences are planned in the project (August 2018 at WU in Netherlands and September 2019 at IPF Dresden). All participants in the BioSmartTrainee project will be attend other events, conferences organized outside the BioSmartTrainee project to disseminate the project results – for instance the 41st Annual Meeting the Adhesion Society, February 25th – March 1st, 2018, San Diego, USA (poster presentations form ESRs are planned).

SPACE FOR NOTES

Training in Bio-Inspired Design of Smart Adhesive Materials

PROJECT

BioSmartTrainee with **10 partners** from 5 different EU-countries will provide a training to **11 Early-Stage Researchers** by a combination of three complementary scientific fields: **POLYMER SCIENCE**, **ADHESION** and **(FLUID)Biomechanics/Modelling**.

www.biosmarttrainee.eu

PARTNERS

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Motivation

The last half century has seen a tremendous advancement in adhesives technology and has led to widespread replacement of mechanical fasteners with adhesive bonds (e.g. aircraft, automobile, construction, etc.). Bonding to wet, rough and fouled surfaces, however, remains challenging and adhesive technology is rarely applied for bonding in wet conditions, such as in (orthopaedic) medicine. Therefore young researchers are trained in this **interdisciplinary research field of controlling adhesion under wet conditions** and to **bridge the gap between the fundamentals of underwater adhesives and their practice.**

We aim to

(I) extract principles from biological systems and mimic them to design synthetic materials

(II) experimentally test their adhesion properties in wet conditions

(III) clarify the adhesion mechanisms based on natural examples, theoretical modelling and detailed computer simulations

Application

These innovative materials will be useful for reversible attachment to a variety of surfaces in wet environments and, therefore, be highly relevant for products from European industry such as technological adhesives, coatings, tissue adhesives, wound dressings or transdermal delivery devices.

WP 1: Polymer Science — **MATERIAL SYNTHESIS**

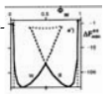
WP 2: Adhesion — **ADHESION TESTING**

WP 3: (Fluid)biomechanics/Modelling — **MODEL DEVELOPMENT**

ESR 1: Ugo Giovanni Sidoli
Leibniz-Institut für Polymerforschung Dresden e.V.
Responsive polymeric surfaces with controllable underwater adhesion properties

ESR 4: Francisco J. Cedano
CNRS/ESPCI, Paris, France
Underwater adhesion between model gels and functionalized surfaces: from molecular interactions to macroscopic adhesion

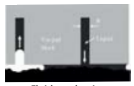
ESR 10: Dimitris Mintis
University of Patras, Greece
Molecular modelling and simulation of polymers and polypeptides with controllable and adaptive adhesion properties in wet environments



ESR 3: Marco Dompé
Wageningen University, The Netherlands
Bioinspired underwater adhesives using complex coacervation

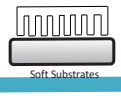
ESR 5: Mehdi Vahdati
CNRS/ESPCI, Paris, France
Adhesive properties of injectable hydrogels

ESR 9: Maciej K. Chudak
Technical University Eindhoven, The Netherlands
The physics of adhesion to wet and icy surfaces

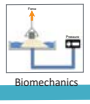


ESR 2: Maria Villiou
Leibniz-Institut für Neue Materialien gGmbH, Saarbrücken, Germany
Bioinspired medical adhesives

ESR 6: Vaishali Chopra
Leibniz-Institut für Neue Materialien gGmbH, Saarbrücken, Germany
Adhesion of bioinspired micropatterned adhesives on soft substrates



ESR 8: Ki Woong (Victor) Kang
Cambridge University, UK
Biomechanics of animal adhesion in wet environments



ESR 11: Aurélie Féat
Imperial Chemical Industries Limited, ICI, UK
Advanced adhesion paints

ESR 7: Justine Tavera
BASF SE, Ludwigshafen/Saarland University
Functional Polymers and Latex particles for improved adhesion on fouled surfaces

URGO
associated partner
Biomedical surfaces

Industry perspective

The BioSmartTrainee project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 642861.

Third Training School

at CNRS/ESPCI in Paris, France

Advances in Mechanics and Chemistry of Adhesion

13th September:

08:30 - 08:45 Registration
08:45 - 09:00 Welcome (Yvette Tran, CNRS/ESPCI and Alla Synytska, IPF Dresden)

Session I : Surface Functionalization and Characterization

09:00 - 09:45 **Surface Functionalization on Particles, Model Rough Surfaces** (Alla Synytska, IPF)
09:45 - 10:30 **Techniques for surface and thin films analysis** (Yvette Tran, ESPCI)
10:30 - 10:50 *Coffee Break*

Session II : Adhesion: Fundamentals and applications

10:50 - 11:35 **Fundamentals of Adhesion I** (Matteo Ciccotti, ESPCI)
11:35 - 12:35 **Presentation research projects by ESRs**
11:35 - 11:55 ESR6: *Vaishali Chopra*
11:55 - 12:15 ESR4: *Francisco Cedano*
12:15 - 12:35 ESR5: *Mehdi Vahdati*
12:35 - 13:45 *Lunch*
13:45 - 14:15 **Fundamentals of Adhesion II** (Matteo Ciccotti, ESPCI)
14:15 - 15:00 **Molecular effects on Adhesion: role of entanglements** (Frederic Restagno, CNRS)
15:00 - 15:20 *Coffee Break*
15:20 - 16:20 **Bioinspired reversible Adhesion** (Al Crosby, University MA Amherst)
16:20 - 16:40 ESR 8: *Victor Kang*
16:40 - 17:00 ESR 9: *Justine Tavera*

19:00 Sightseeing and Dinner

14th September

Session III: Fundamentals of Molecular Simulations

09:00 - 10:15 **Fundamentals of Simulations I** (Vlasis Mavrantzas, UPATRAS)
10:15 - 11:00 **Experimental aspects of tack experiments in water** (Costantino Creton, ESPCI)
11:00 - 11:20 *Coffee Break*
11:20 - 12:20 **Presentation research projects by ESRs**
11:20 - 11:40 ESR 9: *Maciej Chudak*
11:40 - 12:00 ESR10: *Dimitris Mintis*
12:00 - 12:20 ESR11: *Aurélie Féat*
12:20 - 13:30 *Lunch*

Session IV : Viscoelasticity in Adhesion

13:30 - 14:30 **Dynamic networks** (Niels Holten-Andersen, MiT, Cambridge)
14:30 - 15:15 **Viscoelastic adhesives: rheology and adhesion** (Costantino Creton, ESPIC)
15:15 - 15:35 *Coffee Break*
15:15 - 16:35 **Presentation research projects by ESRs**
15:35 - 15:55 ESR 3: *Marco Dompé*
15:55 - 16:15 ESR 2: *Maria Villiou*
16:15 - 16:35 ESR 1: *Ugo Sidoli*
16:15 -18:00 **BioSmartTrainee administrative aspects** (Sandra Martinka, IPF)

15th September

Session V : Soft Skill

09:30 - 10:10 **Starting your own company** (Andrew Griffiths)
10:10 - 10:50 **Fundamentals about IP protection** (Karla Balaa)
10:50 - 11:10 *Coffee Break*
11:10 - 11:50 **Introduction to Funding in Academia** (Costantino Creton, ESPCI)
11:50 - 13:00 *Lunch*

Session VI : Training elements

13:00 -16:00 **Workshop Adhesion Tests** (Francisco Cedano and Mehdi Vahdati)