UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS

National Center of Competence in Research for Bio-Inspired Materials

Research Projects Summer 2024

The National Center of Competence in Research (NCCR) Bio-Inspired Materials offers undergraduate students (from Switzerland and abroad) the opportunity to spend the summer break (8-12 weeks) participating in cutting-edge research within one of the Center's research groups. The undergraduate students have the opportunity to work on a research project and to interact with leading experts in their fields of interest and with fellow students from around the world. The students get a glimpse of advanced research work, gain desirable hands-on work experience, develop their transferable skills and have the unique opportunity to explore career options and network with professionals. Beyond conducting research in the hosting lab, undergraduates participate in scientific lectures, social and networking events. At the end of the summer, the students present the results of their research projects in a poster session followed by a summer party. The students have the opportunity to learn about Switzerland from an insider perspective, and to take the first steps toward learning or practicing French and/or German language skills.

Requirements

To apply to the program you need to fulfill the following conditions:

- Be a national of Switzerland, a member state of the European Union, or a country with a Visa exemption agreement with Switzerland for a maximum period of stay of 90 days;
- Be enrolled at a University as a full-time undergraduate student in a relevant field of natural sciences, such as medicine, biology, biochemistry, chemistry, physics or materials science;
- Be an undergraduate student having concluded a minimum of 2 years of a degree program by the start of the internship;
- Certify that you are and will be registered as an undergraduate at your University/College for the upcoming academic year;
- If you are studying in Switzerland, you cannot select a research project at the University where you are studying;
- Have very good (oral and written) English language skills (level B2/C1).

Terms of the research stay

Duration: 8-12 weeks; Only Period between June 15 – September 15

How to apply

Applicants must submit their applications online at www.bioinspired-materials.ch/

Applications are open from December 1, 2023 until January 20, 2024.

Project ID	Project title	Group	Field
P24-01_Acuna	Plasmonic sensing with DNA origami and rhodium nanoparticles	Acuna	Biology, Chemistry, Physics
P24-02_Acuna	Synthesis, characterization and application of DNA Origami plasmonic dimers in two-photon excitation	Acuna	Chemistry, Physics
P24-03_Acuna	DNA origami-based nanoantennas for studying light-matter interactions with single emitters	Acuna	Chemistry, Physics, Material Science & Engineering
P24-04_Clough	Nanoscopic force imaging in polymeric materials	Clough	Chemistry, Material Science & Engineering
P24-05_Lattuada	Magnetic surfactants as templating for the preparation of magnetic mesoporous materials	Lattuada	Chemistry, Material Science & Engineering
P24-06_Mayer	Biological nanopores for protein sensing	Mayer	Biology, Physics
P24-07_Mayer	Fluorescently modified surface for amyloid detection through super-resolution microscopy	Mayer	Biology, Chemistry, Material Science & Engineering
P24-08_ Mayer	Development of an electric organ to power artificial muscles using ion-selective membranes	Mayer	Biology, Chemistry, Material Science & Engineering
P24-09_Milic	Hybrid mechanophores as smart materials for energy conversion	Milic	Chemistry, Physics, Materials Science & Engineering
P24-10_Rothen	Tailoring hydrogel stiffness with gold nanoparticles for human breast carcinoma	Rothen	Biology, Biochemistry, Medicine
P24-11_Scheffold	Diffuse light scattering with controlled osmotic pressure	Scheffold	Physics, Materials Science & Engineering
P24-12_Steiner	Nanofabrication of networks for optical computing	Steiner	Chemistry, Physics
P24-13_Steiner	Colloidal self-assembly for fabricating optical materials with controlled order/disorder	Steiner	Chemistry, Physics, Materials Science & Engineering
P24-14_Steiner	From polymer self-assembly to complete 3D photonic band gap structures	Steiner	Chemistry, Physics, Materials Science & Engineering
P24-15_Steiner	Formation of structural color from lipidic lyotropic liquid crystals	Steiner	Chemistry, Physics
P24-16_Vanni	Mechanistic study of phase separation of intrinsically disordered proteins with molecular dynamics simulations	Vanni	Biology, Biochemistry, Chemistry, Materials Science & Engineering
P24-17_Weder	Light-responsive polymeric material systems	Weder	Chemistry, Materials Science & Engineering
P24-18_Weder	Artificial muscles based on stimuli-responsive composite hydrogels	Weder	Chemistry, Materials Science & Engineering
P24-19_Weder	Healable polymers	Weder	Chemistry, Materials Science & Engineering
P24-20_Weder	Visualizing mechanical stresses in hydrogels with mechanochromic force transducers	Weder	Chemistry, Materials Science & Engineering
P24-21_Giraud	Mapping immune cell and capillary responses for cardiac tissue repair	Giraud	Biology, Medicine

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS

National Center of Competence in Research for Bio-Inspired Materials

Research Projects Summer 2024

Project ID	**URI P24-01_Acuna**
Project title	**Plasmonic sensing with DNA origami and rhodium nanoparticles**
Research group	Prof. Guillermo Acuna https://www.unifr.ch/phys/en/research/groups/acuna/
Host Institution	Department of Physics, University of Fribourg
Duration	12 weeks
Possible period	**Period 15 June - 15 September including 22.08.2024**

Project summary

While a macroscopic piece of gold is yellow, gold nanoparticles can be all colors from red to purple. The vivid color of gold and other plasmonic nanoparticles is the result of the excitation of the resonance of surface plasmons on their surface. A more useful consequence of this interaction is the amplification the electric field around them, which is used to enhance the signal in various spectral methods such as fluorescence, SERS or circular dichroism. To date, scientific interest has focused on the use of nanoparticles with resonances in the VIS-IR region. However, the use of nanoparticles in the UV range can be very beneficial, for example for fluorescence measurements of proteins without labeling them with fluorophores. One of the main candidates for UV detection is rhodium nanoparticles. However, so far relatively few attempts have been made to realize UV detection using these nanoparticles.

The aim of this project is to realize UV plasmonic detection using rhodium nanoparticles. This will be achieved by synthesizing nanoparticle dimers from DNA origami, which can then be used for fluorescence and SERS measurements.

Keywords: rhodium nanoparticles, DNA origami, sensing.

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS
National Center of Competence in Research for Bio-Inspired Materials

Research Projects Summer 2024

Project ID	**URI P24-02_Acuna**
Project title	**Synthesis, characterization and application of DNA Origami plasmonic dimers in two-photon excitation**
Research group	Prof. Guillermo Acuna https://www.unifr.ch/phys/en/research/groups/acuna/
Host Institution	Department of Physics, University of Fribourg
Duration	10 weeks
Possible period	**Period 15 June - 15 September including 22.08.2024**

Project summary

The DNA Origami technique is a nanotechnology method based on base pairing of complementary oligonucleotides to synthesize complex and arbitrary 3D nanostructures. The high specificity and programmability of DNA make the technique an attractive tool for the bottom-up assembly of various nanosheets to produce functional nanostructures for a variety of applications. Among these, the most common use is of the plasmonic properties of nanoparticles, which, with the help of DNA origami, can be used to produce nanoantennas that increase signal intensity in spectral methods. A good example of a spectral method in which DNA origami-based nanoantennas can find application is two photon excitation. Two-photon excitation is the transition of electrons in molecules during the absorption of two photons, usually of near-infrared wavelength. It is a widely used technique in many fields including: physiology, neuroscience and embryology. However, it relies on the measurement of large amounts of fluorophores, which severely limits its use for understanding biological processes at the single-entity level and early detection of disease.

Keywords: two-photon excitation, plasmonic nanoparticles, DNA origami.

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS

National Center of Competence in Research for Bio-Inspired Materials

Research Projects Summer 2024

Project ID	**URI P24-03_Acuna**
Project title	**DNA origami-based nanoantennas for studying light-matter interactions with single emitters**
Research group	Prof. Guillermo Acuna https://www.unifr.ch/phys/en/research/groups/acuna/
Host Institution	Department of Physics, University of Fribourg
Duration	12 weeks
Possible period	**Period 15 June - 15 September including 22.08.2024**

Project summary

Light and matter can experience significant modifications through the utilization of nanoscale antennas. In particular, properties of fluorescent molecules such as lifetime, fluorescence intensity or spectrum can be influenced by the presence of antennas. Such effects have been shown to have applications in the fields of biosensing, fluorescence imaging and wireless communication, among others. However, precise study of these interactions requires accurate positioning and stoichiometry, something challenging to achieve with conventional top-down nanofabrication techniques. In our group, we employ DNA origami technique to achieve precise positioning of individual fluorophores and nanoparticles within predefined geometries. By tuning various geometrical parameters and utilizing different types of nanoparticles, we aim to examine their influence on emission properties of adjacent fluorophores that have not yet been explored, such as polarization or chirality, and investigate their possible applications for sensing or quantum optics.

Keywords: fluorescence microscopy, single-molecule emission, nanoantennas, DNA origami.

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS

National Center of Competence in Research for Bio-Inspired Materials

Research Projects Summer 2024

Project ID	**URI P24-04_Clough**
Project title	**Nanoscopic force imaging in polymeric materials**
Research group	Prof. Jessica Clough https://www.ami.swiss/en/about-us/contact/people-a-z/person.html?personid=865
Host Institution	Adolphe Merkle Institute, University of Fribourg
Duration	10 weeks
Possible period	**Period 15 June - 15 September including 22.08.2024**

Project summary

Nature demonstrates many ways in which mechanical forces can be harnessed to perform a useful function, ranging from the sense of hearing to catching prey in a mechanically triggered trap. By contrast, in synthetic polymers, mechanotransduction processes usually cause defect formation and permanent damage, which limits the performance and lifetime of these materials in many applications. In this project, we will develop mechanochromic polymers that signal mechanical events by way of optical changes, such as a change in the material's fluorescence emission spectrum. We will study these materials with fluorescence spectroscopy and microscopy to image micro- and nanoscopic phenomena involved in crack initiation, which lead ultimately to macroscopic mechanical failure. This project can be tailored to the applicant's background and interests to focus on the synthesis and preparation of the mechanochromic polymers, materials characterization and mechanical testing, or the development of fluorescence imaging methodologies.

Keywords: mechanochemistry, stimuli-responsive polymers, fluorescence microscopy.

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS
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Research Projects Summer 2024

Project ID	**URI P24-05_Lattuada**
Project title	**Magnetic surfactants as templating for the preparation of magnetic mesoporous materials**
Research group	Prof. Marco Lattuada https://www.unifr.ch/chem/en/research/groups/lattuada/
Host Institution	Department of Chemistry, University of Fribourg
Duration	12 weeks
Possible period	**Period 15 June - 15 September including 22.08.2024**

Project summary

Structural color is the result of interference of light of specific wavelength with matter having ordered structural features at a length scale compatible with that of light. One of the most difficult aspects of structural coloration is that the outcome depends on the degree of ordering of the substrate. Both top-down and bottom up approaches can be used to prepared substrates displaying structural coloration. Our group is specialized in controlling self-assembly of particles, and one of our objectives is to guide self-organization of a variety of particles to obtain structural colors. This is achieved by preparing particles with various shapes, and functionalities (especially magnetic) and to control their organization into ordered structures with just the right degree of disordered. While it is known that monodisperse spherical particles can be arranged into face-centered cubic colloidal crystals, our objective is to introduce some disorder into their structural organization, by introducing defects in the particle shape, or by controlling orientation of non-spherical particles. The candidate will work on both the synthesis of a variety of particles, and on their deposition on substrates in order to control their optical properties.

Keywords: magnetic surfactants, mesoporous materials, surfactants templating, magnetic materials.

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS

National Center of Competence in Research for Bio-Inspired Materials

Research Projects Summer 2024

Project ID	**URI P24-06_Mayer**
Project title	**Biological nanopores for protein sensing**
Research group	Prof. Michael Mayer https://www.ami.swiss/biophysics/en/
Host Institution	Adolphe Merkle Institute, University of Fribourg
Duration	10 weeks
Possible period	**Period 15 June - 15 September including 22.08.2024**

Project summary

Measurement of ionic current through nanopores permits the single-molecule level characterization of analytes in a label-free manner in solution. Recently, biological nanopores have emerged as powerful tools to detect unfolded proteins, DNA, and polymers. However, studying folded proteins through nanopores is challenging since the commonly used biological nanopores were too small in diameter to allow the entry of large and globular molecules. Expansion of the nanopore diameter via modifications such as site-directed mutagenesis usually compromises the structure and stability of proteins. We wish to explore the possibility of using new biological nanopores and fine-tuning the diameter to accommodate full-length folded proteins. The student will help us in our efforts to develop protocols for bioanalytical protein sensing at single molecule level using biological nanopores.

Keywords: proteins, single-channel measurements, biosensors.

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS

National Center of Competence in Research for Bio-Inspired Materials

Research Projects Summer 2024

Project ID	**URI P24-07_Mayer**
Project title	**Fluorescently modified surface for amyloid detection through super-resolution microscopy**
Research group	Prof. Michael Mayer https://www.ami.swiss/biophysics/en/
Host Institution	Adolphe Merkle Institute, University of Fribourg
Duration	8 to 12 weeks
Possible period	**Period 15 June - 15 September including 22.08.2024**

Project summary

Abnormal protein aggregation is proven to be related to the occurrence of neurodegenerative diseases, such as Alzheimer's disease or Parkinson's disease.

For this reason, monitoring the presence of such aggregates is pivotal. Fluorescence is a useful tool to achieve this goal and the golden standard in the field is Thioflavin-T, a poorly fluorescent dye in aqueous solutions, which enormously increases its luminescence upon binding with aggregates.

Nonetheless, amongst aggregates, oligomers are found to be more toxic than longer fibrils, so it is crucial to have information on their dimensions not only in bulk but at the single-molecule level.

To this aim, we want to engineer a glass surface with amyloid-binding dyes to monitor their concentration and abundance of different populations of the aggregates binding to the surface. The student will help us in our ongoing efforts on surface modification and super-resolution microscopy studies to better investigate neurodegenerative diseases at the single-molecule level.

Keywords: amyloid sensing, surface modification, super-resolution microscopy.

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS

National Center of Competence in Research for Bio-Inspired Materials

Research Projects Summer 2024

Project ID	**URI P24-08_Mayer**
Project title	**Development of an electric organ to power artificial muscles using ion-selective membranes**
Research group	Prof. Michael Mayer https://www.ami.swiss/biophysics/en/
Host Institution	Adolphe Merkle Institute, University of Fribourg
Duration	8 to 12 weeks
Possible period	**Period 15 June - 15 September including 22.08.2024**

Project summary

Animals like Torpedo rays and Electric eels are able to convert metabolic energy into strong electrical discharges. We try to mimic this mechanism to create an implantable electric organ capable of converting the metabolic energy of the human body into electrical energy that can aliment active devices like artificial muscles.

To do this, one valuable strategy consists of developing ultrathin (nanometric scale) membranes by self-assembly using amphiphilic block copolymers (BCPs), which can assemble mimicking natural phospholipidic membranes, and then, introducing selectivity in the formed membranes thanks to the incorporation of ion channels with biomimetic transport properties.

We wish to explore the possibility of using traditional bilayer membrane preparation methods to form BCP bilayers and study the incorporation of ion channels to harvest energy from solutions with an ionic gradient.

Keywords: ion-selective membranes, amphiphilic block copolymers, self-assembly, ion channels.

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS

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Research Projects Summer 2024

Project ID	**URI P24-09_Milic**
Project title	**Hybrid mechanophores as smart materials for energy conversion**
Research group	Prof. Jovana Milic https://www.ami.swiss/physics/en/groups/smart-energy-materials/
Host Institution	Adolphe Merkle Institute, University of Fribourg
Duration	10 to 12 weeks
Possible period	**Period 15 June - 15 September including 22.08.2024**

Project summary

Biological systems rely on mechanically responsive materials for various stress-induced functions, such as actuation or sensing. However, these bio-inspired functionalities remain underexploited in artificial systems for energy conversion, such as solar-to-electric energy conversion in photovoltaics. One of the leading semiconductors for modern photovoltaics are so-called metal halide perovskites, which are uniquely soft yet crystalline materials with exceptional optoelectronic characteristics. Their perovskite analogues based on tailored organic moieties templating inorganic perovskite slabs were recently found to feature reversible mechanochromism (Adv. Mat. 2022, 202108720), i.e., color change in response to external pressure, which is of interest to the development of mechanoresponsive systems for smart energy conversion technologies that remain to be realized.

This project will rely on incorporating layered hybrid perovskites within a polymer matrix to assess their capacity as novel mechanophores. They will be investigated by a combination of structural and optoelectronic characterization techniques and incorporated into perovskite solar cells to realize a new generation of bio-inspired mechanoresponsive materials for smart self-powered devices.

Keywords: mechanically-responsive materials, smart materials, energy conversion, hybrid perovskites, photovoltaics.

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS
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Research Projects Summer 2024

Project ID	**URI P24-10_Rothen-Rutishauser**
Project title	**Tailoring hydrogel stiffness with gold nanoparticles for human breast carcinoma**
Research group	Prof. Barbara Rothen-Rutishauser https://www.ami.swiss/bionanomaterials/en/
Host Institution	Department of Chemistry, University of Fribourg
Duration	8 to 12 weeks
Possible period	**Period 15 June - 15 September including 22.08.2024**

Project summary

In the realm of photothermal therapy (PTT), hydrogel stiffness plays a pivotal role in shaping cellular responses. Integrating gold nanoparticles (AuNPs), such as nanospheres and nanostars, within hydrogels offers a unique avenue to modulate stiffness. This project will focus on exploring the influence of hydrogels with integrated AuNPs, on Human Breast Carcinoma (MCF-7) cell behavior. Our primary aim is to investigate the relationship between hydrogel stiffness modulated by AuNPs and the resulting behavior of MCF-7 cells. Using established methodologies routinely practiced in our laboratory, the student will evaluate cell viability and correlate these observed effects with focal adhesion markers, analyzing them via laser scanning microscopy (LSM). By exploring cellular responses on customized substrates, the goal of the project is to elucidate how variations in hydrogel stiffness impact efficacy for MCF-7 cells. The student will obtain knowledge in cell culture procedures, including cell viability assessment, and will be introduced to laser scanning microscopy and handling with nanomaterials. The findings from this project will influence the design of bionanomaterials, offering tailored solutions to improve PTT outcomes in cancer treatment.

Keywords: gold nanoparticles, cell culture, cell viability, laser scanning microscopy.

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS
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Research Projects Summer 2024

Project ID	**URI P24-11_Scheffold**
Project title	**Diffuse light scattering with controlled osmotic pressure**
Research group	Prof. Frank Scheffold https://www.unifr.ch/phys/en/research/groups/scheffold/
Host Institution	Department of Physics, University of Fribourg
Duration	10 weeks
Possible period	**Period 15 June - 15 September including 22.08.2024**

Project summary

Diffuse Light scattering is an optical technique that studies the dynamics of scattered light. It has been widely used to probe the dynamics and rheological properties of samples such as colloidal suspensions, emulsions, foams and gels.

The aim of this project is to develop an improved design of a light-scattering cell for diffuse scattering from a dense colloidal suspension. The external osmotic pressure can be controlled by bringing a colloidal suspension into contact with a reservoir containing a high molecular weight polymer such as dextran via a dialysis membrane. The cell is produced using 3D printing and laser cutting. For diffuse light scattering, a commercial DWS device is used to capture the colloidal dynamics. A standard colloidal particle suspension of polystyrene will be used.

The student will be introduced to the techniques of light scattering and microrheology.

Keywords: light scattering, colloids, statistical physics, soft matter, 3D printing.

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS
National Center of Competence in Research for Bio-Inspired Materials

Research Projects Summer 2024

Project ID	**URI P24-12 Steiner**
Project title	**Nanofabrication of networks for optical computing**
Research group	Prof. Ullrich Steiner https://www.ami.swiss/physics/en/
Host Institution	Adolphe Merkle Institute, University of Fribourg
Duration	12 weeks
Possible period	**Period 15 June - 15 September including 22.08.2024**

Project summary

Block copolymer self-assembly is a dynamic tool to mimic various 3D morphologies such as gyroid or diamond networks found in butterfly and weevil scales. Nature's ingenuity in achieving captivating structural coloration inspires us to employ block copolymer templates for applications in polarization, structural coloration or optical elements on computerchips.

We will use our self-assembled gyroid samples to perform selective etching on the polymers in our triblock copolymer, to achieve large-scale homogeneous single gyroid networks. These are crucial for the evaluation of magnetic and optical properties which we analyze with the help of our collaborators in Tohoku.

You should have a basic knowledge of polymer chemistry and an intrinsic motivation and passion in solving chemical riddles. You will get introduced to different etching methods (Fenton-Reaction, UV-light etching), learn electrodeposition of metals into voided polymer samples for imaging and get insight into Secondary Electron Microscopy (SEM) and Focused Ion Beam (FIB) imaging techniques.

Keywords: block copolymer self-assembly, gyroid polymer template, polymer chemistry, electrodeposition, reservoir computing, atomic force microscopy.

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS
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Research Projects Summer 2024

Project ID	**URI P24-13_Steiner**
Project title	**Colloidal self-assembly for fabricating optical materials with controlled order/disorder**
Research group	Prof. Ullrich Steiner https://www.ami.swiss/physics/en/
Host Institution	Adolphe Merkle Institute, University of Fribourg
Duration	12 weeks
Possible period	**Period 15 June - 15 September including 22.08.2024**

Project summary

Nature displays the beauty of evolution in the scales of insects with bright colors emerging from periodic diamond or disordered diamond-like morphologies, an example of structural color.

The overall goal is to reproduce these natural optical properties in the lab for the first time and establish a toolbox system to further investigate the unique properties of diamond-like structures. For this, a polymer colloidal self-assembly process is developed and allows for DNA-mediated self-assembly with controlled order/disorder interplay.

The project focuses on the control and investigation of the self-assembled degree of order/disorder and the resulting optical response by a combination of state-of-the-art microscopy techniques (Fluorescence, SEM, FIB-SEM). The findings are supplemented by Python simulation.

Still, it can be adjusted according to individual preferences and the project progression to ensure tasks at the forefront of scientific research.

Keywords: colloidal diamond; DNA self-assembly; microscopy (SEM, FIB-SEM).

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS
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Research Projects Summer 2024

Project ID	**URI P24-14_Steiner**
Project title	**From polymer self-assembly to complete 3D photonic band gap structures**
Research group	Prof. Ullrich Steiner https://www.ami.swiss/physics/en/
Host Institution	Adolphe Merkle Institute, University of Fribourg
Duration	12 weeks
Possible period	**Period 15 June - 15 September including 22.08.2024**

Project summary

The goal is to fabricate structures with complete 3D photonic band gap in the visible range. Instead of using expensive top-down methods like nanolithography, the bottom-up approach of polymer self-assembly is followed. Custom-made but provided triblock terpolymer bottlebrushes are used. Chemical parameters need to be optimized to lead to targeted structures. Desired gyroid and diamond morphologies are characterized by electron microscopy (FIB-SEM). Optical characterizations (microscopy and ellipsometry) are compared with computational electromagnetics of the photonic structures to control the fabrication process and performance.

The focus lies on specific tasks depending on the stage of the project but can also be shifted depending on specific preferences.

Keywords: polymer self-assembly, bottlebrush blockcopolymers, FIB-EM, computational electromagnetics, photonic crystals.

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS
National Center of Competence in Research for Bio-Inspired Materials

Research Projects Summer 2024

Project ID	**URI P24-15_Steiner**
Project title	**Formation of structural color from lipidic lyotropic liquid crystals**
Research group	Prof. Ullrich Steiner https://www.ami.swiss/physics/en/
Host Institution	Adolphe Merkle Institute, University of Fribourg
Duration	10 to 12 weeks
Possible period	**Period 15 June - 15 September including 22.08.2024**

Project summary

Photonic crystals (PhCs) are nanostructures with a periodically varying refractive index in up to three spatial directions. In Biology, PhCs are often summarized as structural coloration to distinguish the color appearance from pigments. These PhCs are present in arthropods (butterflies, beetles, spiders and crustaceans) as well as birds and serve for many different purposes such as camouflage, communication and attraction. It is increasingly understood which photonic structures can be present in these species and how their optical mechanisms work, it is still not understood how these highly complex photonic structures develop. This fundamental question is at the core of this project. Topological nanostructures found in nature comprise lamellar, inverse hexagonal columns, gyroid, diamond, etc. One equilibrium self-assembly system that can generate these symmetries out of biological components are lipidic lyotropic liquid crystals. In this internship, the student will develop a dissipative particle dynamics simulation model in python/Julia to predict and engineer the biological building blocks that are necessary to build the right symmetry and unit cell dimensions.

Keywords: photonic crystals, dissipative particle dynamics simulations, lipids.

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS
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Research Projects Summer 2024

Project ID	**URI P24-16_Vanni**
Project title	**Mechanistic study of phase separation of intrinsically disordered proteins with molecular dynamics simulations.**
Research group	Prof. Stefano Vanni https://www3.unifr.ch/bio/en/research/bioinformatics/vanni.html
Host Institution	Department of Biology, University of Fribourg
Duration	12 weeks
Possible period	**Period 15 June - 15 September including 22.08.2024**

Project summary

Intrinsically disordered proteins (IDPs) represent a unique class of biomolecules lacking a well-defined three-dimensional structure. Many IDPs commonly undergo liquid-liquid phase separation (LLPS) to form membrane-less organelles in the cell, contributing to regulation of intracellular biochemical reactions. Dysregulation of these liquid droplets/condensates can also lead to the formation of neurotoxic oligomers/fibrils, causing several disorders. Aggregation propensity of IDPs are influenced by various factors, and characterization of interaction dynamics is a challenging task.

In this project, we aim to leverage simulation techniques, such as molecular dynamics, to investigate the underlying driving forces behind the LLPS of various IDPs. These simulations will enable us to explore the multi chain association processes of these proteins at different lengths and time scales and in diverse environmental conditions such as presence of molecular crowders.

Keywords: intrinsically disordered proteins, molecular dynamics simulation, liquid-liquid phase separation (LLPS).

BIO-INSPIRED MATERIALS
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UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS
National Center of Competence in Research for Bio-Inspired Materials

Research Projects Summer 2024

Project ID	**URI P24-17_Weder**
Project title	**Light-responsive polymeric material systems**
Research group	Prof. Christoph Weder https://www.ami.swiss/en/groups/polymer-chemistry-and-materials/
Host Institution	Adolphe Merkle Institute, University of Fribourg
Duration	10 weeks
Possible period	**Period 15 June - 15 September including 22.08.2024**

Project summary

Nature abounds with examples of stimuli-responsive materials, which change their properties in response to external cues, for example exposure to light. In many plants, this effect is used to cause motion, such as bending of the plant towards or away from the light source, or the opening and closing of stomata - pores that control the transport of gases through the plant leaves. The aim of this project is to mimic such functions and to explore a new and simple approach to polymeric materials that change their mechanical or water-uptake properties upon exposure to light. For this purpose, reversible photo-acids (R-PA) will be incorporated into judiciously selected polymers. The R-PA resembles a proton pump that can be controlled with light of different wavelengths. This function allows for modulated water-swelling or assembly of materials thereby, endowing supramolecular polymer systems with switchable mechanical properties upon light actuation.

Keywords: stimuli-responsive polymers, light-responsive polymers, mechanical characterization, water-uptake.

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS
National Center of Competence in Research for Bio-Inspired Materials

Research Projects Summer 2024

Project ID	**URI P24-18_Weder**
Project title	**Artificial muscles based on stimuli-responsive composite hydrogels**
Research group	Prof. Christoph Weder https://www.ami.swiss/en/groups/polymer-chemistry-and-materials/
Host Institution	Adolphe Merkle Institute, University of Fribourg
Duration	10 weeks
Possible period	**Period 15 June - 15 September including 22.08.2024**

Project summary

The ability to transform energy into motion is a crucial feature of living organisms and has inspired us to construct advanced materials capable of actuating upon energy input. However, our ability to mimic mammal muscles remains a challenge.

Powerful artificial muscles are often based on rigid materials that suffer from a mismatch with soft tissues, while softer counterparts lack powerful actuation. To overcome this issue, the project aims to develop artificial muscles based on composite materials. The proposed muscle architectures combine the mechanical strength of rigid nanoparticles and the biological relevance of hydrophilic polymers. For the system to actuate, stimuli-responsive polymers are used. To provide directionality, the colloids will be oriented. Functionalizing the colloids with polymers will allow the preparation of composite hydrogels with muscle-like actuation upon stimulation. These artificial muscles will be evaluated and optimized based on their ability to actuate in one direction and on their biocompatibility.

Keywords: stimuli-responsive polymers, artificial muscles, hydrogels, actuation.

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS
National Center of Competence in Research for Bio-Inspired Materials

Research Projects Summer 2024

Project ID	**URI P24-19_Weder**
Project title	**Healable polymers**
Research group	Prof. Christoph Weder https://www.ami.swiss/en/groups/polymer-chemistry-and-materials/
Host Institution	Adolphe Merkle Institute, University of Fribourg
Duration	12 weeks
Possible period	**Period 15 June - 15 September including 22.08.2024**

Project summary

One of the key features of living materials is their capability to heal. This function can be mimicked in polymers and this can extend the lifetime, increase reliability, and improve the performance of these materials. While conventional thermoplastic polymers can be healed by heating them above their glass transition or melting temperature, the healing process is impractically slow, due to the high molecular weight of the macromolecules that form these materials. To solve this problem, we introduce dynamic covalent bonds into conventional thermoplastics. These motifs exchange at elevated temperatures, which accelerates the healing process significantly. In this project we will synthesize a new series of dynamic polymers and investigate their mechanical and rheological properties as well as their healing behavior. The study will advance our understanding of structure-property relations in these polymers and in the best case afford new materials that offer a unique combination of efficient healing at elevated temperatures and unchanged mechanical performance under usage conditions.

Keywords: healable polymers, dynamic covalent bonds, healing behavior.

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS
National Center of Competence in Research for Bio-Inspired Materials

Research Projects Summer 2024

Project ID	**URI P24-20_Weder**
Project title	**Visualizing mechanical stresses in hydrogels with mechanochromic force transducers**
Research group	Prof. Christoph Weder https://www.ami.swiss/en/groups/polymer-chemistry-and-materials/
Host Institution	Adolphe Merkle Institute, University of Fribourg
Duration	10 weeks
Possible period	**Period 15 June - 15 September including 22.08.2024**

Project summary

Mechanical forces are widely involved in essential biological processes and cells rely on the interaction with their environment for their continued development. Through mechanotransduction, cells translate these mechanical forces into biochemical signals, thus readapting to their new environment. Similarly, chemists have developed synthetic molecular motifs, termed mechanophores, that convert mechanical forces into different responses (e.g. change of color) and are extensively used as force sensors in synthetic polymeric materials. However, they are currently limited to hydrophobic materials and cannot be employed to investigate mechanical processes in aqueous biomaterials and biological systems. This project focuses on the synthesis and development of water-compatible supramolecular mechanophores, which can be integrated into aqueous materials and can be used as molecular force sensors. Incorporating such sensors into hydrogel networks enables the direct visualization of mechanical stresses and allows the study of molecular forces upon deformation.

Keywords: mechanophore, synthesis, polymers, hydrogels, fluorescence, force-sensor.

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS

National Center of Competence in Research for Bio-Inspired Materials

Research Projects Summer 2024

Project ID	**URI P24-21_Giraud**
Project title	**Mapping immune cell and capillary responses for cardiac tissue repair**
Research group	Prof. Marie-Noelle Giraud https://www.unifr.ch/med/de/research/group/marie-noelle-giraud/
Host Institution	Department of Medicine, University of Fribourg
Duration	12 weeks
Possible period	**Period 15 June - 15 September including 22.08.2024**

Project summary

We explore new regenerative therapies for repairing damaged cardiac tissue by combining natural biomaterials and cells. Our previous studies have shown promising results in improving cardiac function and reducing heart scars using these therapies.

The project goal is to use a Multiplex Imaging platform to spatially map immune cells and capillaries in the heart tissue after treatment.

This will involve optimizing and validating multiplex immunofluorescence techniques and workflow to analyze how the therapy influences cell distribution and interactions within the heart.

The project will enhance the student's skills in advanced imaging techniques and contribute to our understanding of how biomaterials and cells interact with the immune system during cardiac repair.

Keywords: cardiac repair, natural biomaterials, immune response, multiplex immunofluorescence, automation, regenerative medicine.