Aalto University
School of Science

Aalto University, Department of Applied Physics,
Complex Systems and Materials group
10.1.2024

This year, we offer summer internship projects in a) **experimental** and b) **computational** physics, as well as c) **commercial** projects. Submit your application through the Department of Physics summer trainee application system and indicate which type of project you would be interested in (a, b and/or c).

The projects listed below are examples of the projects we offer.

Experimental

Manufacturing layered biobased particles

In biological applications encasing a compound in a protective structure can significantly enhance the functional properties of the resulting particle. In this project the student's task is to explore the methods of manufacturing layered onion-like structures, consisting of biobased materials, for food industry applications. The nature of the structure makes the particle dissolve layer-by-layer, enabling functional properties, such as the release of the encased compound at a predetermined rate.

The project contains experimental work as well as some design of experiments. Different numbers of layers and different particle sizes will be explored, depending on the capabilities of the method and the desired application.

The expected outcomes of the project are prototype molecules containing the desired compounds, and a bachelor's thesis.

Contact person: **Tero Mäkinen**

Characterization of the acoustic properties of cellulose-based foam materials

Current solutions in sound management applications (acoustic panels, space dividers...) rely on oil-based materials, e.g. polyurethane. There is therefore a need to replace these with sustainale and low-cost alternatives. A cellulose-based foam material developed in our research group is such an alternative.

The aim of this project is to characterize the acoustic properties of foam blocks made from this material. This entails characterizing the sound absorption properties of the bulk foam, as well as sound diffusion properties of the surface. The expected outcome of the project is a bachelor's thesis or a similar report depending on the students situation.

Contact person: **Isaac Miranda-Valdez**

Rheological properties of particle laden fluids

Newtonian fluids have linear force-displacement response. This project explores experimentally what happens when particles are added to liquids. With high particle concentrations the fluid has become non-Newtonian. In this project, optical and/or tomographic imaging is combined to measurements in a rheometer to observe internal local structures and their relation to global properties of the fluid. The goal is to define the transition from dilute Newtonian particle laden liquids to dense suspensions.

Contact Person: **Juha Koivisto**

Deformation of materials

In a large enough scale all engineering materials deform in a smooth manner under loading. The global stress-strain response can be described by only a few elastic and viscoplastic parameters such as Young's Modulus and Yield point. However, in microscale the internal structure of the material starts to dominate and the behavior is intermittent and erratic.

This project explores the behavior of sample material and its relation to its internal structure. Depending of the material at hand, the deformation can be observed with optical imaging, increased heat or acoustic emission. The projects contains experimental, numerical and theoretical aspects that lead to Bachelor's or Master's thesis and/or publications based on applicant interests and skills.

Contact Person: **Tero Mäkinen**

Fatigue crack growth

When a material is loaded in a cyclic fashion below its yield point localized damage occurs in the form of fatigue. In experiments with prenotched samples this can be optically seen as crack growth. There are experimental results that relate the stress around the crack tip to the increase in the crack length per loading cycle but a more fundamental understanding of the process is lacking.

In this project the student will perform fatigue tests and study the statistics of the crack growth rate. The expected outcomes are Bachelor's or Master's Thesis or similar report.

Contact Person: **Tero Mäkinen**

Experimental observation of cognitive living systems

Society of organisms might be defined as a cognitive living network with a common feature – an agent (element of the system carrying information) moving in space. This project intended to explore a collective behaviour of dynamic "society" of living ants colony during development in different biasing circumstances.

Your job is to take care of an ant colony, develop a table based experimental setup to track collective movement of multiple elements, collect and process the data. The applicant is expected to have an interest and basic experience in video/image processing using programming tools, patience and absence of myrmecophobia. Possible outcomes of the project are Bachelor's thesis or similar report.

Contact Person: **Ivan Lomakin**

Characterization of solid materials

All crystalline materials have an unique lattice structure. One of the main and earlier experimental technique for qualitative and quantitative characterization of this structure is the X-Ray diffraction (XRD). Using this technique an unique "fingerprint" of material can be determined. As well as XRD provides an averaged characteristics of microstructure one can determine disorder parameters of the alloys to represent the density of linear defects of the crystal lattice.

Despite the immensity of the topic, this particular project will cover statistical distribution of the lattice's disorder over a big surface of the specimen. The applicant will be involved in data analysis by writing their own code for effective experimental data processing.

The expected outcomes are Bachelor's or Master's Thesis or similar report. The applicant is expected to have an interest and basic experience in programming. Most probably, this work will also imply some time spent in collaboration with XRD unit of the Department of Applied Physics.

Contact Person: **Ivan Lomakin**

Data-driven rheology of viscoelastic materials

Rheology is the branch of physics dealing with the deformation and flow of matter. Rheological properties of materials, in particular soft materials, are multi-parameter dependent. Therefore, a rheologist needs to iterate an experiment several times, varying the number and magnitude of parameters. The outcome of rheological tests is multidimensional data that becomes very complex for humans to understand. The applicant will be involved in data acquisition and data analysis by writing their own code for a physics-informed machine learning algorithm.

The expected outcomes are a successful use of physics-informed machine learning to process rheological data efficiently; the results would be expected to be translated into a research paper. The applicant is expected to have an interest in hands-on experimentation and advanced experience in programming (Python) and machine learning. Also, knowledge in rheology and soft matter physics is beneficial but not mandatory.

Contact Person: **Isaac Miranda-Valdez**

Material testing

Our cellulose-based foam material has previously been refined to achieve optimal mechanical properties, increased hydrophobicity and resistance against bacterial growth. As part of commercialization tasks, it now needs to be tested in real use cases. The properties to be tested include e.g. recyclability and the rigidity of the structure.

In this project you will be responsible for planning the testing rounds, running the properties tests and analysing the collected data. You are also expected to conduct research related to the topic, prepare the material samples for tests and propose ways to improve the foam properties.

The expected outcome is a report – potentially a bachelor or special assignment – documenting the process and presenting the analysed data and its main results. The applicant is expected to have keen interest in sustainable materials and material development. Knowledge about fiber-based materials and mechanical testing is a plus.

Contact person: **Isaac Miranda-Valdez**

Computational

Speed up of material design and development with artificial intelligence

Developing novel materials is slow due to the complex experimental nature of the topic. It is impossible to understand the relations of dozens of interacting parameters of the raw components and manufacturing processes, for humans that is. For machines, understanding the relations of hundreds or thousands of interacting input parameters is walk in the park thanks to modern data-analysis and machine learning. At the moment, machines beat humans at chess. Come to develop a machine that beats humans in science.

Your job is to create a self-learning algorithm that suggests the next compound or manufacturing protocol based on existing data – from experiment or materials simulation – in order to reach the user specified goal. This purely numerical task requires a keen interest in programming and artificial intelligence. The project is connected to both the experimental projects of the CSM group and in our efforts to understand how to get tougher and lighter materials from metals to foams to glasses. The expected outcome is a Bachelor's or Master's Thesis or similar report.

Contact person: **Juha Koivisto**

Machine learning crystal plasticity

Plastic deformation of crystalline materials is mediated by dislocations, the line-like discontinuities of the crystal lattice. Therefore in materials science, understanding of dislocation processes, both collective inter-dislocation phenomena and dislocation interaction with lattice impurities such as precipitates, is highly pursued. And in materials science, like in numerous other scientific branches, machine learning has become an exciting way to approach the problem.

In this project, your task is to perform simulations of discrete dislocation dynamics and apply machine learning to predict how crystalline materials yield. The main aim is to find ways to estimate how certain dislocation structures respond to external loading, but ultimately you can also affect the shape of the project. Previous experience in machine learning is a must and background in C programming is recommended.

Contact person: **Juha Koivisto**

Specimen reconstruction as a Bayesian inference or Inverse problem

Atom probe tomography (APT) is an experimental technique in which the tip specimen is irreversibly destroyed as the surface atoms are desorbed one at a time and projected onto the position-sensitive detector in the process known as field-evaporation. The information that is obtained in the end is the 2D detector coordinates of the atom, the evaporation sequence ID of the atoms, time-of-flight (TOF) information to identify the chemical identity of atoms and other various information mostly pertaining to the physics of evaporation. The most important aspects of atom probe analysis is the reconstruction of the specimen so that the microstructural features of the specimen could be visualized and studied. Even though geometrical-based reconstruction algorithms exist for reconstruction, we envision a different route and implement the specimen reconstruction as a Bayesian inference or Inverse problem.

In this project, the applicant is expected to implement specimen reconstruction routines in an efficient manner in the programming language of their choice (preferably, C++). You should be comfortable with matrix algebra, optimization problems, probability and the likes and the knack to implement the mathematical equations into a well-written code.

The expected outcomes are Bachelor's/Master's Thesis or similar report. You are expected to document and present your progress in a written report.

Contact Person: **Aslam Shaikh**

Specimen reconstruction using machine learning

Atom Probe Tomography is the only material analysis technique offering extensive capabilities for both 3D imaging and chemical composition measurements at the atomic scale to provide unique information about nanoscale microstructures. In APT, a carefully prepared tip sample is field-evaporated and the the atom-by-atom imprint is collected on the position-sensitive detector. This data is then used to digitally reconstruct the sample back (which tends to get destroyed during the analysis).

In this project, the student is expected to generate a number of datasets with the available forward model and then run them through a machine learning model deemed appropriate to reconstruct the specimen. The trained model will be tested on real experimental datasets.

The student is expected to have some experience working with ML projects and should be skilled in at least one programming language of their choice (knowing C++ is going to be helpful) . The student is expected to document their progress in a written report.

Contact Person: **Aslam Shaikh**

Commercial

From personal assistant to CEO in two years

Here at CSM we have a long tradition in commercializing science. Hence we offer a position that prepares you to be the CEO of the next spin-off on 2025. As a personal assistant to Dr. Koivisto, you will be introduced to all major investors and fund managers in Finland (seed and A-round). In exchange, you commit to take the role of the general manager (CEO) of the next commercialization project.

The work consists of online activity one hour per day every day + weekly meetings as well as participation in scheduled meetings. Work load is adjusted to your studies. The main task is the administrative back office, preparing documents, agreeing meetings, answering trivial requests and following daily operations of a research group and start-ups.

The expected outcome is a fully funded start-up and a report – potentially a masters thesis or a special assignment including the components of a business plan. The applicant is expected to have keen interest on start-up way of life. Own limited company or positions of trust are a plus.

Contact person: **Juha Koivisto**