Development of thermomechanical characterization methods for temperature resistant coatings

Temperature resistant coatings is a field of growing interest in the paint and coatings industry. Such coatings are composites of polymeric binder with various organic, inorganic, and metallic pigments and fillers, and are usually applied in the form of a wet paint or a powder coating onto a metal substrate to protect against corrosion and weathering, as well as for aesthetic purposes. Depending on the temperature of the substrate, various binder technologies are used, with epoxies being most common at low to medium temperatures (< 250 °C). At higher temperatures (normally up to 650 °C), silicones are the dominant technology.

When a temperature resistant coating is exposed to increasing temperatures, the polymeric matrix may go through curing, followed by thermal decomposition of organic groups, until finally a ceramic coating may be left on the metal substrate. These transformations drastically change the thermomechanical properties of the film, which in combination with the dissimilar thermal expansion and contraction of the coating and metal substrate during temperature cycling may lead to cracking and delamination of the coating.

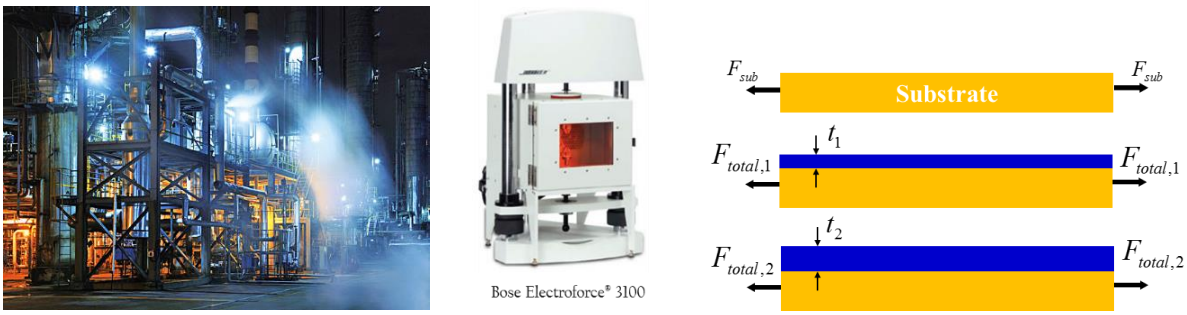

Figure 1: Typical structures where heat resistant coatings are applied (left), potential test instrument to be used in the project (center), and examples of parameters to be tested and modelled (right).

The goal of this project and master work (up to 3 – 4 students) will be to develop thermomechanical characterization methods and establish numerical models for temperature resistant coatings. These methods and models will be used to map and understand the various failure mechanisms occurring in such coatings, with the aim of optimizing the coating properties and predicting the lifetime of coatings.

The project work and the subsequent master theses will be a collaboration between NTNU Nanomechanical Lab (NML) and Jotun AS. Jotun is a major international manufacturer and supplier of temperature resistant coatings for the process and hydrocarbon processing industry (HPI) and will provide samples and guidance as a part of the project. Parts of the project may encompass visits to Jotun's corporate R&D facilities in Sandefjord, as well as the opportunity for one summer job position.

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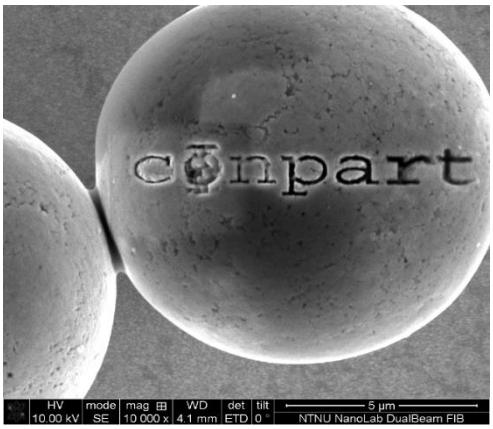
Surface characterization of nano-scale metal coatings on micron-size polymer particles

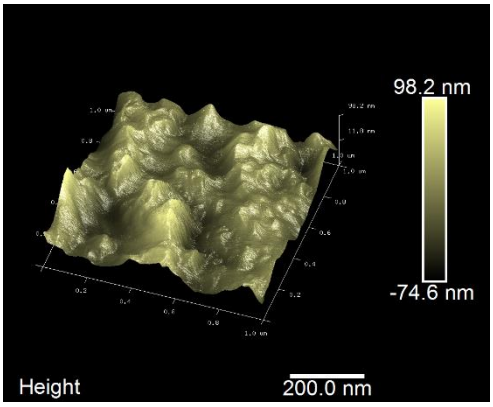


Conductive adhesives are integral in the assembly of electronic components such as LCD screens, solar cell modules and car electronics. Micron-sized polymer particles with nanoscale metal coatings are an important component in conductive adhesives. Using the Ugelstad process, Conpart AS produces polymer particles in the size range of 3-30 µm. The particles are further coated with a 30-300 nm thick layer of nickel, gold or silver, depending on the final application. Understanding the electrical, mechanical and thermal properties of these particles is critical to optimizing their function in application.

The coating roughness is a significant factor in the particle performance, and has not been studied in detail. In addition, the coating roughness will change due to plastic deformation as the particle is compressed, as is the case in many applications.

The subject of the proposed project/master's thesis will be developing a repeatable experimental technique for characterizing particle surface roughness. This may be further extended in combination with single particle compression tests to examine the plastic deformation of the coating roughness. Particles for testing will be provided by Conpart.

The following experimental techniques will be employed:



- **Atomic force microscopy** (AFM) for surface roughness measurements.

- **Scanning electron microscopy** (SEM) to image the particles, as a cross-reference to the AFM measurements.

- Flat-punch electromechanical **nanoindentation** for compression testing of individual particles. This set-up is exclusively available to student at NTNU Nanomechanical Lab.

Keywords: Metallized polymer particles; electro-mechanical characterization; nanoindentation

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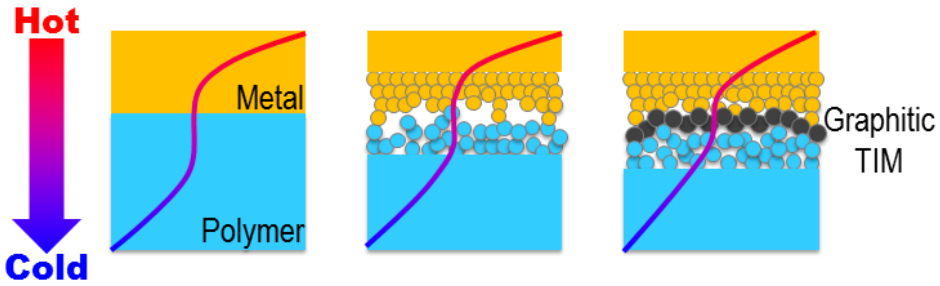
Syntheses and Multiphysical Characterization of Ultra-thin Metal Film on Polymer Substrate

Interfaces are everywhere in nature and engineering. Their properties are critical to a variety of processes and systems, ranging from thermal management of electronics, icing of solid surfaces to renewable energy applications. The intrinsic mechanisms that underlie interface properties are intertwined and inherently coupled with mechanical stresses. One extremely complex example, upon which this proposal is focused, is the heat conduction through metal and polymer interfaces with characteristic length scales ranged from a few nanometers to tens of micrometers. Due to the dissimilarity between metal and polymer, a major stress-coupled thermal resistance arises at the interface and impacts the functionality of the material system. Though the interface mechanical and thermal properties have been studied individually, the stress-coupled heat transfer is so far untouched either theoretically or experimentally.

Thermal interface materials (TIM) have been first introduced in polymer composites, and accepted in electronic systems as the route for improving the interface thermal conduction between semiconductor chips and metal heat spreaders, heat pipes and heat sinks. In the project, we will for the first time bring TIMs to the metal and polymer interface to optimize the stress-coupled thermal properties. Nanostructured graphitic TIMs, such as carbon nanotube (CNT), graphene and their derivatives, are expected to significantly improve the paths of heat transfer within the interface and smooth the dissimilarities of metal and polymer.



The project work and master thesis aim to synthesize nanoscale polymer-metal bilayer structure and characterize thermal-mechanical properties. This is a part of FRINATEK Young Research Talent (YRT) project Engineering Metal-Polymer Interface for Enhanced Heat Transfer (HEFACE http://www.ntnu.edu/nml/heface). Both simulation and experimental work at NanoLab or NTNU Nanomechanical Lab are possible, depending on the interest.

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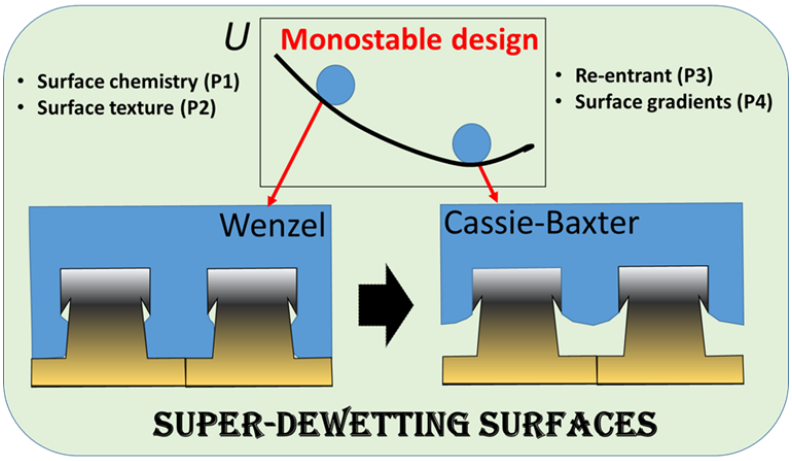
Super-Dewetting Surfaces

In the past decade, we have witnessed a drastic increase in the understanding and applications of the so-called superhydrophobic surfaces. It is now well understood that a superhydrophobic surface with its ability to repel invading water—that is, to display a very large apparent contact angle (> 150°) and a very small roll-off angle, can be created by combining the surface roughness with a hydrophobic material. Superhydrophobic surfaces find numerous applications, for example, in oil-water separation, drag reduction, stain repellency, self-cleaning, fog harvesting, micro fluidics and efficient dropwise CO_2 condensation. However, the development of the state-of-the-art superhydrophobic surfaces has come across one bottleneck. Surface superhydrophobicity is attributed to the formation of the Cassie-Baxter wetting state where a water droplet contacts only the tips of the rough surface. The problem is that the designed Cassie-Baxter state is mostly metastable. The superhydrophobicity is remarkably fragile and can break down, due to the wetting of the surface texture to yield the Wenzel state under various environmental conditions, such as elevated pressure, high droplet impact and in particular vapor condensation. Due to large energetic barriers that impede the reverse transition (dewetting), this breakdown in superhydrophobicity has been widely believed to be irreversible.

Recently, there is a clear indication that this limitation can be overcome by manipulating the 4 parameters shown in the following figure.



The project study will be a literature survey and develop an understanding of the scientific problem. The master thesis will *design and fabricate* ***super-dewetting surfaces,*** *which enable spontaneous transition from Wenzel to Cassie-Baxter state by manipulating surface chemistry, topology and gradients.* **The topic has high breakthrough potential and great possibility for international journal publications.**

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