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Title of the doctoral dissertation: **“Nanoarchitectonics of Adaptive Colloidal Langmuir Films at the Air-Water Interface”**

Abstract

Stimuli-responsive, adaptive, and interactive materials are an increasingly important direction in nanotechnology. The capability to construct complex functional systems and integrate them with biological systems, in particular, was identified by over 100 prominent nanoscientists, led by Chad A. Mirkin, as one of the main challenges in modern nanotechnology (2025). While three-dimensional systems are being intensively developed, two-dimensional systems operating at fluid-fluid interfaces remain comparatively underexplored. Thin films, such as membranes, are key components of compartmentalisation and functionalisation of living organisms; examples of artificial responsive structures of this type are limited. On the other hand, reducing the material's thickness is of interest to industry in fields such as functional coating, photovoltaics, and catalysis.

This thesis aims to address the abovementioned issues by developing nanoarchitectonics of stimuli-responsive colloidal Langmuir films. Nanoarchitectonics refers to the rational design of the properties and functions of nanomaterials by tuning the interactions and nanoscale phenomena within a system. In parallel, the Langmuir trough is a well-defined platform for investigating interactions and interfacial phenomena in nanoparticle monolayers.

The thesis first outlines the current outlook on nanotechnology as a branch of science and briefly presents its macroeconomic perspective. Then, stimuli-responsive and adaptive 2D and pseudo-2D systems are introduced, with emphasis on their principles and key design aspects.

The experimental part focuses on a system based on nanoparticles capped with short thermoresponsive oligomers (PNIPAM, 24 monomer units). The study is divided into two parts: the first examines the properties of a system operating at the air-water interface, and the second investigates the increased complexity introduced by increasing ionic strength in the subphase (replacing the subphase with a KCl solution).

The investigated systems exhibit several counterintuitive behaviours, including a decrease in surface pressure upon heating, aggregation of nanoparticles below their lower critical solution temperature (opposite to the behaviour of the used thermoresponsive polymer), and increased interparticulate distances at the same surface pressures despite electrostatic screening and a decrease in the Debye length.

To rationalise these observations, the thesis investigates physicochemical properties, including surface rheology, to explain them and provide data useful for further development in nanoarchitectonics of Langmuir films.

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