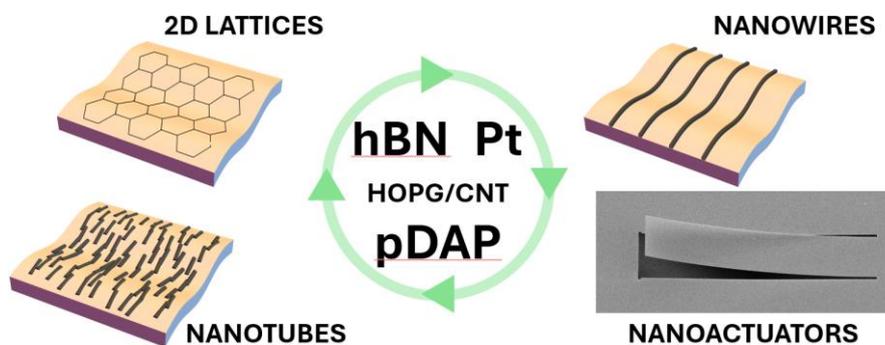


At the beginning of the 21st century, a new challenge was set for everyday devices – they must be flexible while maintaining durability. Above all, flexibility enables the design of deformable, innovative, and futuristic forms and shapes, and makes them more comfortable to use. Foldable and rollable displays, ultra-thin elastic health-monitoring sensors that can be attached to the skin, and smart fabrics equipped with sensors or photovoltaic cells are already gaining immense popularity.

However, such a broad range of applications for flexible technologies requires materials with exceptional properties – they must combine flexibility with resistance to cracking and damage while also efficiently dissipate heat. Conventional silicon-based electronics is rigid and brittle, and does not meet these requirements. On the other hand, flexible polymers used in organic electronics have low thermal conductivity, which can lead to overheating and degradation of continuously miniaturized devices.

In this project, we aim to develop hybrid materials that combine two key components: ultra-thin polymer membranes providing flexibility and nanomaterials with high thermal conductivity. These hybrid structures will allow us to integrate the advantages of both components synergistically. The polymer membranes will be made of poly-1,3-diaminopropane (pDAP), and their thermal properties will be enhanced by incorporating nanosheets of hexagonal boron nitride (hBN) and highly oriented pyrolytic graphite (HOPG), hBN and carbon nanotubes (CNT), as well as ordered platinum nanowires. In our research, we will utilize state-of-the-art, non-contact optical methods: micro Brillouin light scattering spectroscopy and frequency-domain thermoreflectance techniques. Both methods will allow us to precisely determine the mechanical and thermal properties of the hybrid membranes. To further test their durability to cyclic bending, we will then create nanoactuators that can convert laser radiation energy into mechanical work observed as the deflection of the nanoactuator.

The obtained research results will allow us to answer several fundamental questions: (i) Can the incorporation of 2D nanosheets into polymer-based membranes and films simultaneously enhance their elasticity and thermal conductivity? (ii) How does the geometry of ordered nanotubes and nanowires modulate the elastic anisotropy and heat dissipation in polymer-based heterostructures? (iii) How can the photoactuation dynamics of polymer-based heterostructures be engineered to minimize relaxation times and reduce the required light power to trigger mechanical motion; What are the key material and structural factors influencing this optimization?



*Fig. Hybrid nanomembranes and nanoactuators.*