Physics Department Colloquia Speakers 2020/21

Prof Wilson Poon (FRSE FInstP, University of Edinburgh)

Soft matter physics and the COVID-19 pandemic

Friday 13 November 2020

Much of the science underpinning the global response to the COVID-19 pandemic lies in the soft matter domain. Coronaviruses are composite particles with a core of nucleic acids complexed to proteins surrounded by a protein-studded lipid bilayer shell. A dominant route for transmission is via air-borne aerosols and droplets. Viral interaction with polymeric body fluids, particularly mucus, and cell membranes controls their infectivity, while their interaction with skin and artificial surfaces underpins cleaning and disinfection and the efficacy of masks and other personal protective equipment. The global response to COVID-19 has highlighted gaps in the soft matter knowledge base. I will survey these gaps, especially as pertaining to the transmission of the disease, and suggest questions that can (and need to) be tackled, both in response to COVID-19 and to better prepare for future viral pandemics.

Prof Chiara Daraio (Caltech)

Organic temperature and IR sensors

Friday 4 December 2020

Organic electronic materials, including conductive and semiconductive polymers, are emerging as competitive alternatives to conventional, silicon-based microelectronics, due to their low-cost manufacturing and wider range of functionalities, such as stretchability, degradability and self-healing. The ability to synthetically tailor properties of organic compounds at the molecular levels makes them particularly appealing for sensing applications in wearable and implantable devices, which benefit from materials that are biocompatible and flexible, features that are difficult to achieve with inorganic materials and silicon-based manufacturing. Organic temperature sensing layers, for example, have been realized exploiting the variation of the polymers' electrical resistance with thermal expansion. Temperature sensing films offer exciting opportunities for wearable thermometer, environmental and industrial monitoring and for robotic surfaces to augment human-machine interactions. Our group demonstrated that pectin, a structurally and functionally complex, acid-rich polysaccharide found in plant cell walls, presents a record temperature response, linked to its ionic conductivity. In this talk, I will detail pectin’s temperature responsivity and I will describe the design and synthesis of a new synthetic polymer that mimics the structure of pectin and exhibits superior thermal sensitivity, while also being mechanically robust and flexible. With it, we realize temperature mapping systems and IR absorbing devices for consumer electronics.

Prof Stefan Maier (University of Munich, LMU/Imperial College London)

Nanoantennas for light harvesting and energy conversion

Friday 19 February 2021

Metallic and dielectric nanostructures provide distinct and unique means for shaping the electromagnetic near field, and for channelling radiation from the far field to the nanoscale. The associated electromagnetic field hot spots can be exploited for the enhancement of interactions between light and matter, most prominently for surface-enhanced spectroscopy and sensing, the boosting of non-linear interactions, and also for nanoscale spatial control over chemical reactions. In my lecture I will approach plasmonic and dielectric nanoantennas from the viewpoint of being a means for energy conversion at the nanoscale. With example materials systems such as gold and silver (plasmonic) and gallium phosphide (dielectric) I will highlight applications such as non-linear optics, photon-phonon interactions for the launching of acoustic surface waves, and the plasmon-assisted triggering of redox reactions.

Prof Jan Anton Koster (University of Groningen)

Towards efficient organic thermoelectrics

Friday 12 March 2021

Organic semiconductors are light-weight, flexible, and tuneable. This makes them excellent materials for a wide range of applications that rely on the ability to conduct electricity, such as solar cells, light-emitting diodes, thin-film transistors, and thermoelectrics. The 'phonon-glass electron-crystal' (PGEC) concept has triggered most of the progress that has been achieved in inorganic thermoelectrics in the past two decades. Organic thermoelectric materials, unlike their inorganic counterparts, exhibit molecular diversity, flexible mechanical properties and easy fabrication, and are mostly 'phonon glasses'. However, the thermoelectric performances of these organic materials are largely limited by low molecular order and they are therefore far from being 'electron crystals'. In this talk, I will discuss our recent efforts to improve the performance of n-type organic thermoelectrics through the use of polar side groups. Through meticulous design of the side chain we have been able to introduce a fullerene derivative that approaches an organic 'PGEC' thermoelectric material. This thermoelectric material exhibits an excellent electrical conductivity of >10 S/cm and an ultralow thermal conductivity of <0.1 W/mK, leading to the best figure of merit ZT = 0.34 (at 120 C) among all reported single-host n-type organic thermoelectric materials. The key factor to achieving the record performance is to use 'arm-shaped' double-triethylene-glycol-type side chains, which not only offer excellent doping efficiency (~60%) but also induce a disorder-to-order transition upon thermal annealing. This study illustrates the potential of organic semiconductors as thermoelectric materials.

Prof Andrea Liu (University of Pennsylvania)

How Materials Can Learn How to Function

Friday 26 March 2021

How does learning occur? In the context of neural networks, learning occurs via optimization, where a loss function is minimized to achieve the desired result. But physical networks such as mechanical spring networks or flow networks cannot minimize such a loss function by themselves—they need the help of a computer. An alternative is to encode local rules into those networks so that they can evolve under external driving to develop function. For example, if the springs in a mechanical network have equilibrium lengths that grow if the springs are stretched, and shrink when the springs are compressed, the network will naturally evolve under applied stresses. I will describe how both of these strategies—global minimization of a loss function as well as training by local rules–can be used to teach materials how to perform functions inspired by biology, such as the ability of proteins (e.g. hemoglobin) to change their conformations upon binding of an atom (oxygen) or molecule, or the ability of the brain's vascular network to send enhanced blood flow and oxygen to specific areas of the brain associated with a given task.

Prof Chris Bowen (University of Bath)

Piezoelectric and pyroelectric materials and structures for energy harvesting

Friday 30 April 2021

The continuing need for reduced power requirements for small electronic components, such as wireless sensor networks, has prompted renewed interest in recent years for energy harvesting technologies capable of capturing energy from ambient vibrations and heat. This presentation provides an overview of piezoelectric harvesting system along with the closely related sub-classes of pyroelectrics and ferroelectrics. These properties are, in many cases, present in the same material, providing the intriguing prospect of a material that can harvest energy from multiple sources including vibration and thermal fluctuations . Examples of modeling and manufacture of porous materials and pyroelectric harvesting are discussed where the harvesting generates power from temperature fluctuations using piezoelectric materials such as lead zirconate titanate (PZT) and polyvinylidenedifluoride (PVDF). The potential of novel porous and sandwich structures are also described. Water-splitting using pyroelectric materials are examined analytically and experimentally.