Congratulations 2020-21 PPG MRL Assistantship Awardees!

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Anuva Aishwarya, Yoo Kyung Go, Dinesh Kumar, Jingcheng Ma, and Yi Zhang have been awarded PPG Materials Research Laboratory (MRL) Graduate Research Assistantships to pursue cutting-edge research broadly related to the areas of interest to PPG.

PPG's global community engagement efforts and the PPG Foundation aim to bring color and brightness to PPG communities around the world. The company invested more than $11 million in 2019, supporting hundreds of organizations across 38 countries. By investing in educational opportunities, PPG helps grow today's skilled workforce and develop tomorrow's innovators in fields related to coatings and manufacturing. Now in its fourth year, the PPG Foundation has donated more than $325,000 to the MRL Graduate Research Assistantships to support students and the University of Illinois community with new thought leaders at the MRL.

Anuva Aishwarya, Physics (Vidya Madhavan, Advisor)

Anuva: My doctoral work is aimed at integrating the powerful techniques of low temperature scanning tunneling microscopy/spectroscopy and atomic precision thin-film growth using molecular beam epitaxy, with device engineering. I want to navigate the rich phase-space of tunable monolayer transition metal dichalcogenides (TMDs) using electric field-induced carrier tuning and study the emergent phenomena. Monolayers of several TMDS have been identified to show drastically different properties from their bulk counterparts. The same material, in principle, can behave as a conductor, an insulator or a superconductor by tuning just one parameter - the number of electrons. One example of a material I want to study is monolayer niobium diselenide ($NbSe_2$). Scientists have looked at the 2H phase $NbSe_2$ since the 1970s and have studied the low temperature state in detail. Recently, it has been shown that a higher temperature favors the growth of a new phase of $NbSe_2$, namely the 1T-phase. While the 2H-phase is a metal, the 1T-phase is an insulator. Interestingly enough, it falls into a special class of insulators known as Mott insulators. Mott-insulator is used to describe a material that is expected to be a metal but acts as an insulator due to strong electron-electron interactions. There has been a continuous focus on the Mott state in the scientific community because it is the parent state of several interesting phases observed in strongly correlated electron systems such as the high temperature cuprate superconductors and the famous twisted bilayer graphene. Tuning the carriers in Mott insulators has been known to produce a plethora of exotic correlated quantum phases like the pseudogap state and strange metal phases in high temperature superconductors; correlation-driven superconductivity, novel charge and magnetic order and broken symmetries in twisted bilayer graphene. Finally, apart from the scientific prospects of this pursuit, such custom designed devices can be used as a platform to study thin films of many different material classes to discover novel phenomena that will lead to better technologies.

Vidya Madhavan, Aishwarya's advisor, states: "Anuva is currently finishing her third year as a graduate student. She already has data for multiple papers, and she has just begun to sink her teeth into her PhD work. She recently passed her preliminary (thesis proposal) exam where she gave an impressive talk. For her Ph.D, she has taken on a challenging project that combines thin film growth of Mott insulators with making field-effect devices for tuning the carrier concentration of the films *in situ* during STM studies. I am extremely impressed by her drive and her attention to detail and she clearly has all the elements of an excellent experimentalist."

Yoo Kyung Go, Materials Science and Engineering (Cecilia Leal, Advisor)

"My research focus under the PPG MRL fellowship will be to investigate a new class of hybrid materials by incorporating lipids into polymeric membranes which are promising for selective transport as well as antifouling coatings. When polymeric systems are hybridized with lipids, unexpected structural and interfacial properties emerge not seen with pure components. For instance, we have found that the presence of lipids in polymer films changes the preferential orientation of block copolymer microcrystallites as well as their preferred nanostructure. Since mass and heat transport is highly affected by polymer crystallinity and nanostructure, controlling crystal orientation and phase behavior might enable the design of new thermal as well as antifouling materials."

Cecilia Leal, Go's advisor, states: "Yoo Kyung's creativity sparked what I believe is a very fruitful project that will bring new insights into the assembly of composite soft-materials with potential applications that PPG cares about. I am also impressed with how Yoo Kyung is keeping up with the literature, often bringing to my attention recent papers with in-depth understanding of content. I am convinced that these traits are what it ultimately takes to become an excellent researcher and future scientific leader."

Dinesh Kumar, Chemical and Biomolecular Engineering (Charles Schroeder, Advisor)

"My Ph.D. research focuses on understanding the dynamic properties of vesicles and fluid-filled capsules using optical microscopy, automated flow control, and modeling. Such vesicle suspensions are encountered in several applications in our everyday lives, ranging from food products to pharmaceuticals and cosmetics. Moreover, capsules and vesicles are increasingly being used for advanced triggered release and reagent delivery applications in functional materials. To this end, my research has specifically focused on understanding the shape dynamics and phase behavior of single vesicles, as well as transient stretching and relaxation dynamics of membranes in steady and time-dependent extensional flows. Our experiments show that vesicles undergo a wide array of non-equilibrium shape transitions in flow, including symmetric dumbbell shapes with pearling, asymmetric dumbbell, buckling and wrinkling conformations," said Kumar.

"Under the PPG MRL Fellowship, I will investigate the collision and adhesion dynamics between two freely suspended vesicles using automated flow control, which will directly inform the stability and long-term viability of concentrated vesicle suspensions. These experiments will be performed on freely suspended vesicles without physically constraining the vesicles using micropipettes or solid surfaces. Overall, my experiments will shed new light on the design, synthesis, and processing of vesicle and capsule suspensions for the development of an exciting new class of materials with unique functional properties."

Charles Schroeder, Kumar's advisor, states: "Dinesh has demonstrated a high degree of intellectual insight and enthusiasm for his work, all of which makes him an impressive and productive graduate student. Importantly, Dinesh works in a largely independent fashion in the lab, and he is able to think creatively on both experimental and computational problems. His strong analytical skills have enabled him to study vesicle dynamics in an extremely rigorous and quantitative manner, which has brought new insight to the field. He is always interested to explore new directions or ideas that emerge from our regular discussions and meetings, and he has been a great mentor to several undergraduate students in the lab."

Jingcheng Ma, Mechanical Science and Engineering (Nenad Miljkovic, Advisor)

“My research focuses on understanding the dynamic interactions that occur between liquids and gases undergoing phase change and how thin polymer coatings can affect this process. Liquids experiencing a phase change to a gas or solid on surfaces, such as condensation, evaporation, boiling, and icing/frosting, is a common phenomenon occurring both in our daily lives and in many industrial processes. Controlling the behavior of the phase change process can be achieved by applying functional polymeric thin-film coatings on these surfaces. Therefore, it is important to understand the behavior and deformation of the coatings when phase change occurs on them. This research can lead to significant results that prevent coatings from undesired degradation. In addition, this research also provides new ways to fabricate functional thin film structures using phase-change liquids. Under the PPG-MRL assistantship, I primarily aim to develop durable thin coatings for enhancing heat transfer (specifically, condensation heat transfer) to increase the overall efficiency of power plants and reduce the carbon footprint on the environment,” said Ma.

Nenad, Miljkovic, Ma’s advisor, states: “Jingcheng’s work provided very important guidelines to properly enhance coating reliability, and based on his work, we have developed and identified many robust coating candidates for long-term dropwise condensation (including PPG formulations through collaboration with David Walters),” said Nenad Miljkovic. “Jingcheng is always trying to grasp the bigger picture from relatively focused specific research, which is an important and very rare quality for a graduate-level researcher.”

Yi Zhang, Materials Science and Engineering (Qing Cao, Advisor)

“My research focuses on developing a multifunctional smart coating for future orthopedic implants with both long-term antibacterial and high-resolution structural-health monitoring capabilities. The demand for orthopedic implants has been increasing rapidly with an aging global population. Despite their popularity, periprosthetic infections and implant fatigue failures are devastating and common complications in orthopedic surgeries. Here, I am developing a novel smart coating technology, with both nontoxic long-term antimicrobial capability and large-area high-spatial-resolution strain-mapping functionality, for orthopedic implants, to address these challenges. The outer surface of the smart-coating foil features arrays of high-density nanopillars that can kill attached bacterial pathogens through a purely physical process by mimicking the surface topology of cicada and dragonfly wings. They prevent surface colonization by a wide spectrum of pathogenic bacteria and reduce risk of infections. On the inner surface of the smart-

coating intended for conformal contact with the implant, I incorporate a multiplexed array of piezoresistive strain sensors built on transfer-printed flexible single-crystalline Si nanomembranes, offering not only high sensitivity with silicon's large piezoresistive coefficient, but also high-spatial-resolution strain-mapping functionality, with silicon active select transistors integrated together. They allow monitoring strain distribution on the implant surface to trace dangerous overloads and minimize risk of fatigue failure under dynamic load imposed from body movements. During the term of PPG-MRL Research Assistantship, I will further investigate the detailed bactericidal mechanism, and evaluate the efficacy and safety of this smart coating technology in small animal models."

Qing Cao, Zhang's advisor, states: "Yi is spearheading our efforts on developing bioinspired bactericidal surfaces, and he has developed a novel molding process to replicate the nanostructures on cicada wings in ultrathin polymer films. In addition to low cost and high fabrication throughput, his process also has the capability to precisely control the pillar-array topology, in terms of pillar height, pillar pitch, and pillar diameters, which is important for us to understand the detailed bactericidal mechanism and design biomimetic structures to outperform natural evolution" said Qing Cao. "He is exceptionally talented and ambitious, and well on track to translate his research further into a technology useful for PPG."