NDnano
Notre Dame Nanoscience and Technology

NDnano Summer Undergraduate Research 2022 Project Summary

1. Student name & home university: Brianna Dewey, Saint Mary's College

2. ND faculty name & department: Ed Kinzel, Department of Aerospace and Mechanical Engineering

3. Summer project title: Ultrafast Laser Processing for Surface Texturing

4. Briefly describe new skills you acquired during your summer research:
This summer I learned how to identify useful and applicable literature. Additionally, I learned how to use some of the machinery available in our lab, such as the OCA goniometer and two of the lasers. I spent time learning how to make plots and figures in OriginLab as well. Completing a report at the end of the week every week allowed me to better understand my results, as well as learn how to efficiently communicate scientific information. Collaboration and time management were necessary to balance the expectations and requirements of lab.

5. Briefly share a practical application/end use of your research:
Laser texturing can be used to manipulate and control the wettability of surfaces, which allows engineers to make hydrophilic or hydrophobic surfaces. Industry has many uses for these kinds of surfaces, such as self-cleaning or anti-adhesive

6. 50- to 75-word abstract of your project:
Contact angle measurements and surface energy calculations are two ways to characterize the wettability of liquids on a surface. The objective of this project is to adjust the texture of a surface using ultrafast laser techniques and observe how the water contact angle measurements change as a result of the input parameters. An additional aim is to manufacture a surface that shows low wettability and hydrophobicity as a result of the laser texturing.

7. References for papers, posters, or presentations of your research:

One-page project summary that describes problem, project goal and your activities / results:

Surface free energy is considered to be a quantification of the excess energy at the surface of a material, and it is often calculated from the measurement of the contact angle of a sessile droplet on a solid surface. The research detailed in this presentation used the Owens, Wendt, Rabel and Kaelble (OWRK) method, which uses information about the surface tension (polar and dispersive parts) alongside the contact angle of various known liquids to determine the surface energy. This method is frequently computed using a plot whose slope gives the polar component of the solid surface energy and the vertical intercept gives the dispersive component of the solid surface energy. The sum of these two components results in the total surface energy of the solid. During this summer's research, I used an optical contact angle goniometer (OCA11) to measure the contact angles of liquids on various surfaces to calculate their surface energies. Contact angles are measurements of the angle between the baseline and the tangent of the point of interaction between the droplet and the surface.

There exists a known relationship between the water contact angle and the surface energy of a solid, such that a low contact angle suggests a high surface energy. Additionally, contact angles less than 90° signify hydrophilic surfaces, contact angles greater than 90° signify hydrophobic surfaces, and contact angles greater than 150° signify superhydrophobic surfaces. Superhydrophobic surfaces, like Lotus leaves, exist in nature and act as inspiration for industrial use. Their ability to wick water off of their surfaces at contact angles of greater than 160° is interesting and could be scientifically replicated in different environments. The below figure shows two surfaces that display different wettability. The left surface is wetted by water and the droplet exhibits a water contact angle of 27° when in contact with the surface. It is considered a hydrophilic surface because of the small water contact angle. The surface on the right repels the water droplet, and displays a water contact angle of 137°. This is considered a hydrophobic surface because of the large water contact angle.

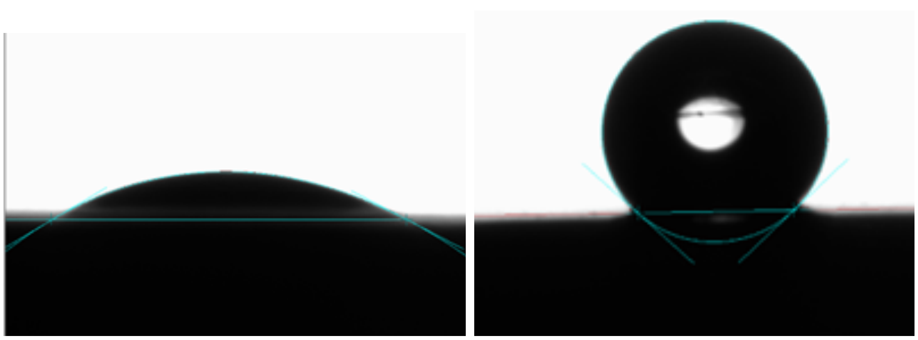

Figure 1: Images from OCA11 during contact angle measurements, showing high wetting with water contact angle of 27° (left) and low wetting with water contact angle of 137° (right).

Another interesting relationship is that between the contact angle and the wetting state. Liquid wets surfaces in a few ways including that described by the Wenzel model, which describes a surface which has rough structures and is penetrable by liquid droplets, and the Cassie-Baxter model which describes a surface which isn't penetrable by liquid due to the air trapped in rough structures of the surface. Literature suggests that there are techniques which allow the surface to transition from the Wenzel state to the Cassie-Baxter state, which becomes beneficial for manufacturing of hydrophobic and superhydrophobic surfaces.

One aim of this summer's research is to examine the wetting behaviors of the 4 categories of surface texturing: LIPSS, random nanostructures, mounds and hills, and damaged microlayers. Images from a scanning electron microscope (SEM) will provide visualizations of the laser textured surfaces and images from an optical contact angle goniometer will display the wetting behaviors of sessile droplets on these surfaces. The objective of this work is to use ultrafast laser texturing techniques with a femtosecond laser to examine the relationship between surface characteristics and surface energy to learn to control the interactions between surfaces and certain liquids. Understanding wetting behaviors is beneficial because it allows us to find relationships between variables, such as that between surface energy and wettability, surface energy and input parameters, and input parameters and liquid behaviors. This is useful in industrial applications where it is necessary to guide liquid away from electronics using hydrophobic channels or finding an ideal interface for increased/decreased adhesion.