Hello all and welcome to my talk. My name is Leslie Scheurer. I'm a graduate student at the Universi ty of Maryland Baltimore County. I studied alongside Ian Emge, who is an undergrad at UMBC. We worked on a project entitled Nanoengineered composites for Lotus Effect and Optical Limitation.

This project was introduced to us through an internship with the NASA Langley Research Center. W e worked with Dr. Prasad as our NASA contact. And then we also worked with our mentors, Dr. Sing h and Dr. Arnold at the University of Maryland Baltimore County.

So the objectives of this study were to achieve self-
cleaning and super hydrophobic properties in a polymer coating. And then in that same coating, intro duce an optical limiter species that can protect space components from high energy radiations. So o ur approach to this, the first half is the hydrophobicity half. That's Ian's part of the project, where we utilize the lotus effect to measure any change in the contact angles of water droplets on the surface.

And Ian tried to achieve the lotus effect by adding impurities, nanoparticles of titanium and copper. A nd then my half of the project was the optical limiter part. Where in that same polymer coating, I woul d investigate appropriate charge transfer complexes that could be viable optical emitter species.

So a little bit more about the lotus effect, if you've never heard of it. Basically, it's-
- well, it is named after the lotus leaf, because a lotus leaf is very hydrophobic and has self-
cleaning properties. And that's due to its microstructure. So on the right is an image of a leaf, where you can see all of these microscopic pillars, which create the hydrophobic effect.

You'll notice that the angle in which the droplet and, in the contact with the surface of the leaf, is reall y high, because that water is in a tight little bead. And that's how we're going to quantify hydrophobic ity going forward. But then you'll also notice there's some debris on the droplet. And that's because, i n general, dirt and debris has a preference to stick to the droplet as opposed to this microscopic pilla r structure that's on the leaf.

So you can imagine, as a water droplet rolls off, it can collect all of this debris. And then that's a self-
cleaning property. So that can be great for any kind of component that's not easily cleaned by huma ns or machines, so definitely space products.

So to create our own sort of lotus effect microstructure, first, it starts with a polymer base of polystyre ne and polymethyl methacrylate. Those are dissolved in toluene. And then about half of that solution is split off and nanoparticles are added to it, either the titanium or copper oxide nanoparticles. And th en that is stirred for the nanoparticles to be evenly suspended throughout the solution.

Then, to create our coating, this
is still in the solution form, a drop of this solution is placed on a glass slide and then spun to create a nice even surface reproducibly. And then, furthermore these glass slides were treated after the coati ng was added by annealing the coating in
an 170 degree oven, washing it with cyclohexane, or air drying it.

So here is an image of the slides after they're all prepared. You can see the coating on each of these slides. But I'll direct your attention right to the middle, where it is a close up of the titanium nanoparti cle slides. And you can see there are some white flecks.

The nanoparticles used were 10 nanometers. So it is safe to say 10 nanometer nanoparticle on their own are not visible to the human eye. However, these clearly are. So we think there may be some a

ggregation happening. And that's an indication that the surface might not be as uniform as we thoug ht it might be.

But nonetheless, the contact angle measurements can give us a little bit more information on how w ell the lotus effect surface we created is working. And so we have this little experimental setup, wher e the glass slide in the right hand picture is placed in front of the camera underneath a micropipette, which reproducibly gives us a 10 microliter drop of water.

And then that camera goes directly to the computer, in which we have a software where you can dro p points all along the outside of the water droplet, until you get to the glass slide again. And then the software will calculate the contact angle.

Notice that this method can have some human error when dropping the points. So for every single m easurement we did, for every single slide, this was done three times and averaged to get an average contact angle for every sample.

So the results of this are a little bit disappointing, I will admit. Because remember, I said, super hydro phobicity is going to be quantified as over 150 degree contact angle. That means the water droplet h as beaded right up. And it's going to be really easy to roll off and do its self-
cleaning thing. Regardless of if the coating had the titanium nanoparticle or not, the contact angle di dn't even get above 100 degrees. So that's already lacking a little bit in what we want.

But further, we don't really see a significant difference between the coating with the nanoparticles an d without. And the same goes for copper oxide contact angles. You could maybe say that cyclohexa ne had an effect on how hydrophobic the resulting coating is.

However, that trend only appears in the polymer samples, not the nanoparticle samples. And it hasn' t been investigated fully whether this is going to be reproducible. So as I just showed you, there is no t a significant change between nanoparticle slides and slides without the nanoparticles. Cyclohexane may have an effect.

We did measure that the overall hydrophobicity was increased from-
- a plane glass slide had a contact angle of 23 degrees. Whereas, all of our polymer samples were 7 1 to 90 degrees. But remember, superhydrophobic is quantified as 150 degrees. So we're not quite t here yet. However, if you think back to my image, and how there was some aggregation, that's an in dication that perhaps we weren't even creating a lotus surface at all.

And that could account for the reason why the plane polymer samples and the nanoparticle samples give similar results. So then we can move on to my half of the project, which is the optical limiter half. I like to introduce optical limiters as a transition lens.

So some of you in attendance may even have these. These are glasses that when you step out into t he sunlight, they turn more opaque. They turn into sunglasses. So that happens because of the UV li ght. The UV light causes a change in the structure of a compound that's within that lens, actually.

So in chemistry terms, the absorbance increases in the visible region, because we're blocking out so me of that visible light. That's because the lens is now absorbing that light before it can get to your e yes. And then, for a transition lens, this happens in a couple of minutes.

OK, so that works great for going in and out of buildings. Then, if we move on, and think about how NASA might apply an optical limiter. There can be high energy radiations that-
- radiation can definitely damage any equipment, whether in space or on Earth. But we may want a c oating that can protect from the radiations.

But a couple of minutes is not going to, likely, be fast enough, especially if we've got really high inten sity beams happening. And then we also might want a little bit more selectivity. Instead of kind of abs orbing a general visible region, we might want to selectively absorb some prevalent wavelength.

So the idea for us is that we'll utilize charge transfer complex to achieve the optimal limitation. And I'll walk you through, first, this kinetic scheme, I guess, or perhaps not kinetic, but elementary steps in t his sort of reaction. So first, we put together two specific kinds of species, an acceptor and a donor. They diffuse together, create a complex.

From there, the complex can absorb light and turn into a radical ion pair. Typically, this first extinctio n coefficient to turn it into the radical ion pair is pretty low. So you're going to need something that's high intensity to move it onto this. But once you are in the radical ion pair, what I have labeled as eps ilon 2 and 3, those absorbances are going to happen very, very readily.

And so you can think of epsilon 1 as kind of being this switch. There's a high intensity beam, turns it i nto the radical ion pair. And then from there on, everything's going to be absorbed. But it takes that h igh intensity beam to flip the switch.

And so this is useful, because low intensity beam may
be allowed to go through. Think of that as the first step in the glasses. You still want to see as well a s can when you're indoors. But you only want to block when there is a threat presence, like that the UV light or the sun. So that's what that first step does.

And then you may have also noticed that I split apart the radical ion pairs into two separate things. S o we've got-
- even though they're still together, I've drawn them as being split apart. And that's because they hav e their own unique absorbance spectrum. Even when they are in a complex form, you get characteri stics from the acceptor, as well as characteristics from the donor.

So that makes this a very highly selective and adjustable type of idea. So there's countless pairs of a cceptors and donors. And you just find what region you want to block. And all of this is reversible, m uch faster than minutes. We're talking reaction dynamics. Light absorption, which generously, we'll s ay nanoseconds. But it could be even faster.

So specific example here, if you take the complex of tetracyanobenzene and naphthalene, on the up per right curve, this solid line, that is the ground state complex of tetracyanobenzene and naphthalen e. It has a low, broad absorption. The extinction coefficient there is about 300 per molar per centimet er.

But if a high intensity beam occurs, even though it's only at 300 per molar per centimeter, that groun d state complex will absorb and change it into the radical ion pair. And once we're in the radical ion p air, that's what our big spectra are. The green one is the naphthalene radical cation.

And the black solid line is the tetracyanobenzene radical anion. And if you just look at the extinction coefficients, even in mid-

range, 4,000 per molar per centimeter, over 10 times as strongly absorbent. So after that initial inten se beam, any further intense beam is going to be absorbed, because now, we have this high extincti on coefficient in the radical ion pairs.

And that can work really well. And this is tetracyanobenzene-
naphthalene. But like I said, there are countless pairs of acceptor-
donors to get exactly what kind of absorption profile you're looking for. So a proposed experimental t echnique to see that this works the way we think it is is kind of drawn out below.

My PowerPoint drawing skills were tested with this. But if I have an incident beam, we'll call LED1, th at's a high-- that's our high intensity beam, we'll call it, that's like
a laser. If we optically chop that, and it would work as well if you have a pulse laser, or something lik e that, optically chop that.

And that's basically saying, OK, there's a high intensity beam. And then there's going to be the abse nce of a high intensity beam, of course. And so then, even at the same wavelength, we pick off a littl e bit of the LED1. We're going to call that LED2 now, even though it's the same wavelength.

And send that through, that's kind of going to be our probe, our probe beam. We're monitoring how much of that beam gets through at any given time. And then LED1 is going to be our-
- what's going to change the properties of the coating. So when the laser is on, that means we're in t he radical ion pair version, and high absorbance, low transmission, as I have in my little theoretical fi gure up here.

There's going to be low transmission, because we're in the radical ion
pair, which absorbs strongly. But then as soon as you-
- that pulse passes, and we're in the laser is off, now LED2, that extinction coefficient is low. And so more of that will be transmitted. More LED2 is transmitted when the laser is off. And then that can cy cle through. And we can hopefully monitor that and correlate the change in transmission with whethe r the laser is on or off.

Unfortunately, we did not to get to this point in the research project. But I would say this is a great ex periment to test out the variety of acceptor-
donor combinations and see if the optical limiter will work for charge transfer complex.

So concluding thoughts, thank you all for staying with me. Going back to the lotus effect, employing some scanning electron microscopy might be beneficial to determine how the nanoparticles are distri buting themselves. We want to avoid that aggregation and make sure we get a nice, uniform structur e, just like the lotus leaf does. And then, depending on the results of that, perhaps alter the preparati on method to optimize the nanoparticle arrangement.

And then in terms of the optical limiter, we will have to consider the thickness of the coating for effect ive absorption. That's simply the Beer-
Lambert law. If the coating that we make is only a couple of microns thick, we're going to need a hig h extinction coefficient to significantly absorb. So these are things that we are going to want to think about moving forward.

And so that is all I have I would love to acknowledge NASA Langley Research Center and NASA he adquarters for their support. We had other students who helped us along the way, or did previous ite

rations of this project. Brett Setera, David Sachs, Christopher Cooper, and Ryan Grant, thank you all so much.

Thank you UMBC for allowing us to use the lab space for NASA work. And of course, thank you so, so much to our mentors, Dr. Prasad, Dr. Singh, and Dr. Arnold, and you. Thank you for your time. An d I hope you enjoy the rest of the conference. Thanks