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So, yeah.

Hi, everyone. Good afternoon. Thank you for coming. So, I'm going to-  
- I'm here to talk to you about an ongoing project in our lab determining the quality of sensor materials.

So I'll take you through some of our objectives for the project. Why are we doing it? And why is it important? Some of the background. Some information we know about these sensor materials, typical characterization methods, and then how we're going to build on those for our new methods. And I'm going to take you through some of our preliminary data on the studies that we did with birefringence and reflectance.

So why are we doing this project? We want to develop fast and low cost methods to estimate defects in certain sensor materials. So we know that these sensor materials are a very important industry. They have a lot of applications. But how can we determine how good they are fast, quickly?

We know that some materials can be doped. This leads to defects. And we want to see if our techniques measuring the refractive index, kind of, exploiting what we know about that can give us some insight into their structure.

So these are some examples of the materials that we're using. These are telluride and selenide crystals that were grown. Since either-  
- 1A. So typically crystals are characterized with a variety of different methods, like scanning electron microscopy, transmission electron microscopy, X-ray diffraction. These methods that are typically used are very expensive, materials are not readily available, and they take a lot of time. So we're looking to achieve the same outcome, but with something fast and very low cost.

So just taking you through some examples of why we're doing this. When you look at a crystal, like the one shown above, you might think you can't see anything wrong with it. It's pretty transparent to the eye. You can't see any defects. But when you look at something, like the SEM image, you can then see that there's a lot of voids, misorientations, and just overall it's not homogeneous, and it might not look as good as it did when you were looking at it with your naked eye.

Just some more examples using X-ray diffraction studies, more SEM. Just-  
- They really give insight into characteristics of and quality of the materials. And that's what we're trying to achieve using different methods that are easier to use and more readily available.

This is another SEM image that just characterizes the flaws. You can see there's different dark lines, facets. So even though you might have looked at the crystal and thought it was ready to go, it was actually a lot wrong with it in processing.

There are more electrical characterizations that you can do for these crystal materials, like resistivity measurements, absorption measurements, things like that.

So the methods that we were building upon were-

- that we knew that defects in our bulk and single crystals would cause-
- would affect the refractive index and the surface reflectance of our materials. And so we wanted to develop a technique based on that and show it through our reflectance studies, which I'll go into later.

And we know that doping with dopants of different sizes and valency will cause defects in the crystal as well. We wanted to see if we could dope our materials and then get the right outcome, so we could see that in our studies.

So for our methods, we really wanted to come up with a solution that was cheap and that we could achieve, that was adaptable, and we could do it in our own lab. So we decided to 3D print our materials. These materials are very low cost. We know that we could have bought these for thousands of dollars, but we were able to achieve this in-house. And it's easily printable and adaptable. We can customize it to anything we want to measure.

Someone?

So like I said, we wanted to, sort of, exploit what we knew about refractive index to see if we could achieve or see if we could detect some of these defects in the crystal that way. So just we know that light comes in and it's reflected off of a surface. We know that the incident ray comes and is reflected right off. And that's all related to absorption. We know that light is transmitted that way.

So for our design, our first design, we came up with this dome, sort of, concept that locked into a base plate. We 3D printed this so that we could take measurements with a 45-degree incident angle. We used this black filament design in order to reduce any possible interference from any ambient light and any other reflectance from the apparatus itself. And then in the final design, we used white as well. And that did not-  
- we found that that did not impact any peak positions compared to the black design. So it reduced our S to N ratio.

A second design. We used this V design that allows for a 30-degree incident angle to be measured. This is a much more adaptable and flexible shape, so we can really measure a much wider range of shapes and sizes with this.

Our second, sort of, method to measure these qualities was through birefringence interferometry. So we wanted to design an apparatus in our lab that could take these measurements quickly and easily. So we set it up like this image below. We have this laser that comes through a lens, it's collimated, it goes through a polarizer into the crystal, through another polarizer, and then we have a video camera sitting at the back so that we can take quick and easy images. And, sort of, just investigate what birefringence looks like. Are these good quality crystals or not this way?

So I'm going to take you through some of our reflectance measurements starting with gallium selenide. So this is a graph of our transmission reflectance data across 420 to 640 nanometer wavelength range. This is our absorption coefficient graph for gallium selenide across the same wavelength range. We know that the cutoff wavelength is there based on literature values. And this is our refractive index measurements across the same wavelength range measured against known literature values.

Similar graphs for thallium lead iodide. This is our absorption coefficient across a similar wavelength range against our known cutoff wavelengths. And this is the refractive index.

And so then we looked at our zinc selenide crystals. We doped them with iron and chromium. And so we wanted to see if we could really investigate the effects of the dopants against known pure values for zinc selenide. So we grew these crystals and then sliced it into, you see A, B, C, D slices. We wanted to see if the concentrations at different points in the crystal, because it had been grown, were different. So we used two different slices to get, sort of, a complete picture of the crystal.

And this is a measure of our absorption coefficient. You can see they're pretty similar, but probably due to the growing methods, their concentrations are a bit different, so they differ a bit in the graph. And this is a measure of our refractive index for the iron doped zinc selenide against the known literature values of the pure zinc selenide. So we can see that the iron doping-- how it affected it.

This is just the same, and-- OK.

And then for the chromium doping, we did a similar process. We sliced our crystal, used two different slices to see how the concentrations would differ, and, if that would give rise to different properties. Here again, the absorption coefficient graph pretty similar to the

iron doped one. You can see these are more consistent with each other, though. The cutoff wavelength. And the refractive index against the known literature values.

I think it's-- OK.

And then--

- So we wanted to take some fluorescence spectra of the crystals just to see what those characteristics would show. So on the left, we have the iron doped zinc selenide fluorescence spectra excited at different wavelengths and scanned from 900 to 1,400 width nanometers. And then on the right, we have another fluorescence spectra of the iron doped zinc selenide excited at 880 nanometers, scanned from similar wavelength range. And so we think that there are multiple peaks showing the difference in local populations of defects in the crystal at different places.

Similarly for the chromium doped zinc selenide, we took fluorescence imaging with an 850-nanometer excitation wavelength.

And we saw similar peak splitting, which we think are due to the defects. We also took the SEM image of chromium doped zinc selenide at 4-micrometer scale.

And we can see that all of the line defects in creation of the crystal. So based on that, we knew that it wasn't as pure as we're thinking.

So, as I described before, we wanted to look at birefringence of our crystals. And so, we know that a very good crystal will have very few fringes and will be very good quality. But something with a lot of defects will have many fringes that are scrambled, scattered. It won't be very uniform at all. So we thought we could get quick measurements based on the apparatus that we built in order to look at the defects.

This is still ongoing. We have very preliminary data of the birefringence, as I'll show. So using a 600-nanometer wavelength laser you can't really see much.

It's too harsh of a light. So we have a future work plan to use something at a longer wavelength, like 785 nanometers.

If you look closely and up, like up the contrast, you can maybe see some fringes, but it's not good enough data to tell right now. So that's where our future work is headed.

So overall, we just wanted to summarize--

- Or I just wanted to summarize what we went over. We went through some preliminary studies of our reflectance and birefringence of these crystals. We really just wanted to develop something low cost, and fast, and that was efficient. That would be reliable for us

to use. That wouldn't take such extensive sample preparation as something, like an SEM would do.

Right.

[AUDIENCE CLAPPING]