Western Science

WESTERN SCIENCE SPEAKS PODCAST
SEASON 3, EPISODE 8

EPISODE TITLE
Rolling the Dye: Synthetic Technology in Electricity

PODCAST SUMMARY
This week Western Science Speaks brings you the magic of synthetic chemistry – mixing molecules to create new materials! Dr. Joe Gilroy from the Department of Chemistry at Western University shares his insights about a new, cheaper and more efficient imaging dye designed in his synthetic chemistry lab. The molecules that make up the dye are red, and they glow! Listen here to find out more.

INTERVIEW

You're listening to the Western science speaks podcast. Presented by Henry Standage.

Henry Standage 0:15
Synthetic materials have been a transformative invention in the world of academia. Synthetics take our knowledge past that of the natural and allow us to optimise the properties of chemicals. Professor Joe Gilroy's lab in the Department of Chemistry is concerned with this optimization. They invent new synthetic materials that change the perception of what a molecule is supposed to be capable of. In this podcast, I chat with Professor Gilroy about the work he does with conductivity efficiency, infrared lighting, and the various fields in which this research can mark promising new solutions, perhaps most crucially, in medical diagnostics. Here's the interview.

Henry Standage 0:58
Can you describe your Research and explain the relationship between structure and property specifically?

Joe Gilroy 1:06
So, my research team is comprised mainly of synthetic chemists and we specialise in the manipulation of the structure of molecules. And the reason we're interested in doing that is that we want to induce specific properties from those molecules based on their structure. Now, one of the central challenges that we're trying to overcome is the tendency of most molecules to have electrons which are specifically located on the atoms that make up the molecular structure. What we're trying to do is encourage the molecules themselves to share the electrons across all of the atoms in the molecular structure. When we do this, we tend to make molecules which are electrically conductive, which can emit light of various different colours. And what we do on a regular basis is manipulate structure, study the properties and then ultimately use that information to establish structure property relationships. Now this can take on many different forms and specifically what we're typically interested in are molecules that have application in electronic displays, memory devices or even biological applications such as cell imaging.

Henry Standage 2:22
What role does the energy level play in this?

Joe Gilroy 2:25
We are interested in the energy levels of the occupied orbitals, or energy levels, the ones that have electrons in them, and the unoccupied energy levels. The closer those energies become; the more efficient electrical conductivity tends to be in a semiconductor material. So what we want to do is find ways to make those energy levels as close as possible. And we can study them using computational methods to look at the theory behind it. Or we can we can use experimental methods to assess the energy gap between those two energy levels,

Henry Standage 3:04
What is the relationship there between the energy levels being lower actually resulting in higher efficiency?

Joe Gilroy 3:10
So, when the energy level, the highest occupied and the lowest unoccupied energy levels are close in energy, what that allows is for electrons to hop between the different energy levels, and this is a fundamental process that's required for electrical conductivity in semiconductor materials. without the ability to hop between the levels. The materials are insulating, and they don't conduct electricity. So, the narrower the gap or the smaller the energy gap between the levels, typically the more efficient the electrical conductivity.

Henry Standage 3:47
Where does that lead to in your work? So, with this biological imaging, what do you use these lower energies for?

Joe Gilroy 3:56
In terms of where this leads us in our work with respect to electrical conductivity, we happen to make some special materials which can switch between a high conductivity state and a low conductivity state. Now we use these materials to make flash memory devices such as the memory that we're all familiar with and USB drives. And the high conductivity and low conductivity states are on/off or zero and one in a computational binary type of sense. And they allow us to both read and rate stored information. So, in these types of technologies, they're called resistive memory technologies. It's the change in resistance or the change in conductivity that leads to the data that can be read or written to these memory devices.

Henry Standage 4:46
What new materials or techniques are you guys developing in the biological imaging field?

Joe Gilroy 4:53
So, in our group, we work with a class of compounds known as formazans which are a famous class of dye molecules. They're red in colour, sometimes even purple. And when they're complex to inorganic elements such as boron, they emit light in the red or even in the near infrared region of the electromagnetic spectrum. And these are unique features for molecules that have such small structure. So, this is something that has opened up new doors in the imaging field. And specifically, it's the colour red or near infrared light that's attracting the attention in this context. Now, the reason that's important and the reason people want to study red emitters or near IR emitters is the fact that those wavelengths of radiation will pass through biological tissue much more efficiently than other wavelengths. And we've all probably witnessed this as kids when we shine a flashlight on our fingers, and we notice that they glow red. What's happening there is the red light is passing through our fingers and the rest of the light is being filtered out by our, our flesh in that particular case. So, when we're thinking about biological imaging, we want to, as efficiently as possible, collect the light that's emitted from the molecules within the cells. And if they're filtered out by the cells themselves or other biological tissue, that's not possible. So, by going into the red and the near infrared, we're making the process much more efficient. And we're, we're essentially making the images that we're collecting a lot brighter, which allows us to extract more information to realise higher resolutions and just to generally produce images that are much more valuable.

Henry Standage 6:40
Can you explain briefly what you mean by dye just for somebody who doesn't know?

Joe Gilroy 6:44
So, a dye in the simplest senses is a molecule that's highly coloured and formazans themselves were initially used as red dye so literally the dye clothing or textiles. Now the term dye is also often used to describe fluorescent materials. And really, it's intensely coloured molecules that are loosely described as dyes in this context. So, these molecules are very, very intensely coloured and they very efficiently emit red or near infrared light as well. So, they'd be classified as near infrared dyes.

Henry Standage 7:24

Why is it important to create new materials like this for biological imaging?

Joe Gilroy 7:29
There are really two challenges in my opinion. Of course, there are many sub challenges but the primary challenges that we are attacking in our approach are both cost and function. With respect to cost, our materials are extremely easy to produce. Now we can produce them for usually around a factor of 1000 cheaper than the average commercially available alternative. So that's one aspect if we can produce them more cheaply, they can potentially at some point be sold for less money and used more widely. Now the second challenge, as I mentioned, is function. And the near infrared emission that we have managed to coax out of our molecules is actually a really rare phenomenon, and very difficult to achieve. And what's unique about our molecules is they have a very small skeletal framework; their molecular weights are not very high. Usually to, to realise a near infrared emission, you'd have to have much larger molecules that tend not to be compatible with biological systems. So, we've managed to discover a unique class of fluorescent dyes that happened to emit in the near IR that are also easy to make, which is sort of the combination that everyone is looking for in this type of application.

Henry Standage 8:54
What does that bring to the table that you didn't have before?

Joe Gilroy 8:58
Well, it's really this combination of low cost and high performance that can be achieved via other systems, but it's very difficult to combine them.

Henry Standage 9:09
So, I mean in, in the performance domain what can they do that wasn't previously accessible?

Joe Gilroy 9:15
So, in the performance domain with the advantage of our systems is really the fact that we can produce these very small molecules that give intense near infrared emission. This is very difficult to achieve with related families of molecules, where the synthesis required would be very extensive in order to achieve similar wavelengths. And in most cases, the molecules themselves would not be compatible with biological conditions.

Henry Standage 9:47
Can you take me through the process of how you're able to use these by getting inside the cell? And then once it's in what indicators are you looking for?

Joe Gilroy 9:58
So, one of the challenges here is the fact that it's actually very difficult to predict cell uptake. And that's what we're considering here is we want the cells to uptake our molecules. Now, what we typically do is we develop a molecule we assess its properties and identify it as a strong candidate or a poor candidate for imaging applications. When we identify a strong candidate, we introduce the dye or the fluorescent dye in this case into the cells via essentially dissolving it in a biologically compatible medium.

Henry Standage 10:33
So, what are the characteristics of a strong candidate?

Joe Gilroy 10:37
So, a strong candidate would be, for example, a near infrared emitter, easily accessible, highly efficient fluorescent because we want that fluorescence to be as bright as possible, it differs from material to material. So those criteria are related to our molecules, not to the cells. So, when we introduce them into cells, what we're looking for is first evolve, does the cell uptake the material does it enter the cell at all? And we assess that using a technique called confocal fluorescence microscopy, which allows us to visualise the cells, and specifically to visualise the areas that are fluorescing from our die. So, we actually get a visual picture to assess whether or not it's been taken into the cell. Now, we had a good hint that formazans and their complexes would be taken into the cells for these

applications, because they're actually used in one of the most common assays to determine whether or not cells are living.

Henry Standage 11:42
The end line in this particular field of research is presumably diagnostic imaging, but are other any other possible practical applications?

Joe Gilroy 11:52
Absolutely. We're still quite interested in and it should be said that this is a multi year challenge to produce the next potentially commercially available cell imaging agents, we're very interested in continuing this work. And the next step has to be to extend to disease targeting examples where we can append different structures to our fluorescent dyes that will essentially talk to various parts of the cell in different ways and be taken into the different features of the cell and allow them to be imaged independently. So that's the challenge we're currently working on. One of the other areas where these molecules will likely have significant application is in photodynamic therapy. And in photodynamic therapy, what we're doing is we're absorbing light, which our dyes are extremely well suited for. And we're generating reactive oxygen via reaction of the dye after it's absorbed light and oxygen in a cell. And that reactive oxygen species will go on to kill cells. Which is an advantage in anti cancer therapeutics and in applications such as that, so we have not begun working in that area, but I think there's a lot of promise for our classes of dyes in that specific area.