Case Study - University of Liverpool

The power of stillness

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Researchers at the University of Liverpool are using PI actuators to precisely hold and manipulate single molecules in their research into molecular electronics. Their work is looking at the fundamental principles underlying this potentially powerful technology, and PI's N-216 NEXLINE® series actuators are helping to achieve far more than was previously possible. Dr Andrea Vezzoli, a Royal Society Research Fellow from the Department of Chemistry and Stephenson Institute for Renewable Energy at the university, discusses this exciting field and describes the difference that precise positioning has made to his work.

The promise of molecular electronics

Interest in molecular electronics began in earnest in the 1990s, promising a wealth of opportunities for miniaturising and reducing the cost of electronics for all kinds of applications. The ultimate goal was - and still is - to create electronic components made from molecules that are smaller and faster than today's wafer-based options. However, nearly 30 years on, the molecular computer is still a pipe dream and slow progress has somewhat marred the field.

In the last few years, research into the technology is back on track, and there are even now a few niche products available based on these underlying principles, including a device for guitar distortion. These recent breakthroughs really show the potential of molecular electronics; instead of manufacturing a device from a large silicon wafer and breaking it down into smaller components, developers can now think about building a product from the ground up, creating bespoke components for a specific application rather than 'making do' with existing electronic components. The main drivers for developing this concept further are undoubtedly to drastically reduce the size and cost of components; although industrial scale-up is still not quite within our reach, the cost saving of creating electronic devices from just a few atoms would be huge.

Getting back to basics

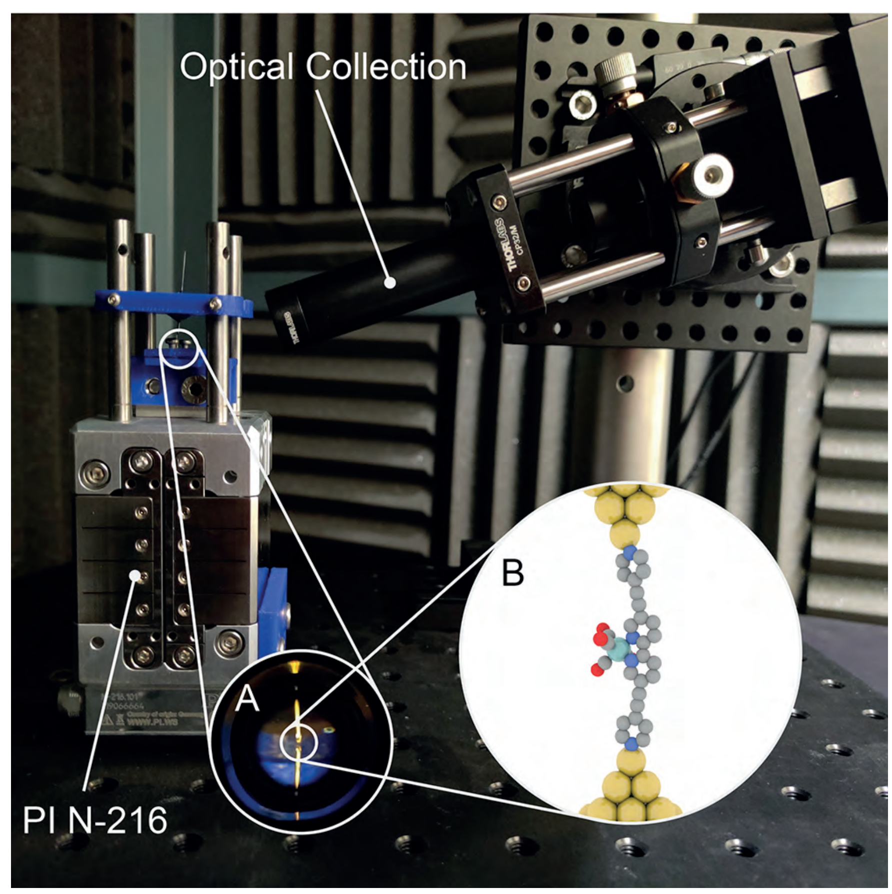
Our research is focused on the fundamental phenomena behind this technology, at how molecules behave at a quantum level, and at the chemical complexity involved. This knowledge will eventually feed into product development, exploiting these quantum phenomena in order to achieve the ultimate performance - novel functionality and better charge transport, but using less power.

One aspect of this is studying light emission from incredibly small single-entity electronic devices in the 1-2 nm range. Our hope is that by understanding what happens in one molecule, we will then be able to scale this model up and understand what happens in the collection of molecules that make an OLED, like the ones we use in our phones. Until now, it was a real challenge to extract good data, because there are all sorts of neighbouring effects and we had to rely on sample averaging from measuring hundreds of thousands of molecules. The ability to measure a single molecule would give us far more accurate data and from that we would be able to establish the fundamental laws behind light emission from these molecules.

The power of stillness

A major stumbling block for this work was the collection of light. Our experimental set-up is based on a single molecule positioned between two electrodes – one anchored to stop it moving, and the other linked to a piezo positioner for small adjustments. The junction can then be fine-tuned to the correct dimensions where the molecule is perfectly extended, and not stretched or compressed. With our previous device, we could only ever hold a molecular junction for a few seconds but, if we could keep it in place for longer, we would be able to collect more photons. We needed a very precise and stable positioner, and found this in the NEXLINE series from PI.

The N-216 NEXLINE actuator works with the PiezoWalk principle, offering us sub-nanometre precision and, most importantly, incredible stability; they can hold a position for minutes with no significant drift and very low piezo creep, avoiding all the problems we had with our previous piezo positioner. The result is a stable molecular junction held for minutes, rather than just a few seconds, at room temperature. Collecting light emission for this length of time means that we can now record a whole spectrum, compared to the low counts only at the emission maxima we could achieve before.



Experimental single-molecule light emission set-up using a PI N-216 nanopositioner. Inset (A) shows a magnification of the two electrodes. Inset (B) shows an idealised depiction of a single molecule suspended between the two.

Choosing the right tools

A very important aspect of choosing PI is that its products are all RoHS compliant. European regulations are far more stringent on the composition and materials used in components and we have had real issues with this in the past from other suppliers. We first approached the company with a good idea of what was needed, but the advice and support we received meant that we have ended up with an excellent positioning system for our application. I have been particularly struck by PI's unique approach, especially in the PiezoWalk system that combines regular, sheer and compression actuators, all working together seamlessly. Overall, it amazes me that we can do what we do with such precision.