Testing the quality of graphene with T-Waves

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Our own research has revealed there are 68 organisations making top-down and bottom-up graphene in 17 countries. How do they know the quality of what they are making? It is time to take a look at some of the measurement methods being developed for graphene.

At the moment if someone wants to analyse the graphene, and the devices made from the material, they have to hire a laboratory equipped with very expensive machines such as electron microscopes, and Raman spectrometers with a trained staff to operate them.

The number of applications for graphene is starting to increase in areas as diverse as bulk materials for construction right down to highly sensitive micro scale sensors for medical applications and everything in between. As we have noted in previous column entries quality means different things for different applications and the emerging graphene industry needs to understand and communicate this to its customers. Let's take a look at one of the emerging methods.

Terahertz time domain spectroscopy

Terahertz radiation (THz or T-Waves) is part of the electromagnetic spectrum made of the same stuff as visible light. This occurs between the far-infrared and microwave bands so they are invisible to our eyes. T-Waves are non-ionising and completely safe.

Pulses (short bursts) of THz radiation are used rather than a

continuous beam because this allows the detection of echoes generated by the properties of the sample. These returning pulses are measured in time and this is why it is called time domain spectroscopy.

THz pulses are sent down to the graphene deposited on a surface. These pulses penetrate the material and the substrate underneath and are reflected back to the detector. Not all of the pulse returns at the same time. There are echoes that are caused by internal reflections between the layer and underlying substrate. Multiple layers cause more internal reflections and more of these echoes.

The THz pulse is sensitive to the conductivity of the material. The higher the conductivity, the stronger the reflection of THz radiation. The difference of conductivity between a graphene layer and the substrate is often strong enough that THz can be used to detect it.

What all this means is that THz waves can detect the presence of graphene, tell how many layers there are and show the quality and continuity of the layer by its electrical conductivity. In addition because it bounces light from the surface it does not damage the sample and it is a non-destructive test method.

The Onyx spectrometer

Making THz spectrometers is a specialist business; there are a small number of manufacturers such as Advantest Corporation and Das-Nano who makes the Onyx spectrometer. I recently met the Das-Nano people and was impressed by them and the system they have developed. Let’s have a closer look.

The spectrometer has two parts. A scanning stage shines T-Wave light down on to the sample and picks up the reflected light. The analysis is done in the attached computer that produces

coloured contour maps of the surface showing how the graphene covers the surface.

The design team have taken a pragmatic approach to structuring the way it works. A fast scan can be obtained in a matter of seconds and gives a low-resolution picture. If you need more refined detail then the scan takes longer.

I asked the team about the repeatability and they have addressed this too. Tests have been done with different operators on the same samples and the consistency of results seems impressive. You can see for yourself at this link.

Onyx is a desktop system oriented to the research and laboratory characterization markets. However, the same technology can be implemented directly on the production line such as roll-to-roll processes.

In summary

Reliable test methods like this are going to be needed to prove the quality of graphene made from graphite and by chemical vapour deposition. This foundational work measuring graphene is really important because it will support the growth of the emerging industry. I know the Das-Nano people are already cooperating with the International Standards Organisation. Indeed, a standardization document is on its way to be voted and approved shortly.

Measurable standards are the foundations that will support the graphene industry as it emerges from the laboratory to enter a truly profitable commercial phase.