## Transcript of the Q&A session of ‘Nanoexploring using electron microscopy – Seeing the invisible’

This is the transcript of the Q&A session following Professor Sarah Haigh’s talk entitled ‘Nanoexploring using electron microscopy – Seeing the invisible’ delivered on 29th July 2020. The chair of the session was Professor Alessandro Mottura.

*Prior to the start of the recording Sarah was asked at what stage do you need to specialise in order to pursue a career in Materials Science and engineering and how specialised is the field itself and the first part of the transcript reflects the end of her answer to this question.*

**Sarah Haigh:** [00:00:00] I get to work with scientists really from a huge range of disciplines, so it's absolutely something that you can specialize in after your degree or you can go straight in and do Materials Science as a degree science.

**Alessandro Mottura:** [00:00:10] And it's probably fair to say that it is something that is very varied as a discipline. So you can work on planes, but you can work on biology and you can work on all sorts of other aspects of how materials helps our society.

**Sarah Haigh:** [00:00:26] It's very neat, very versatile.

**Alessandro Mottura:** [00:00:30] We have another question, which is what is your favourite project application that you've worked on? Also they say, awesome talk, by the way.

**Sarah Haigh:** [00:00:42] That's very kind, thank you. Ok, we are quite excited at the moment about taking something like molybdenum disulfide and taking one layer of molybdenum disulfide and then twisting it to a very small angle.

**Sarah Haigh:** [00:00:52] And it turns out that all kinds of crazy stuff happens when you twist these two materials that are identical, but at a very small twist angle. The structures want to be at the same angle, but they can't because they're macroscopically large, although they're atomically thin. And so they locally reconstruct to make areas that are perfect and areas that are kind of deformed. And that mixture of perfect and deformity gives you some really, really strange properties.

**Sarah Haigh:** [00:01:19] And that's just the tip of the iceberg. It's really something we've only just started looking at this year. But there's a very large community of people getting excited by the potential of this, as I say, this idea of having these slightly twisted structures.

**Alessandro Mottura:** [00:01:36] Very good. Another question, which aircraft did you work on?

**Sarah Haigh:** [00:01:42] So I have to say, I don't work with any aircraft, unfortunately, I can't put it in the sky and say 'That's my plane'. So I'd say that all of the stuff that I do is is really right at the early stages of development. So really trying to make materials, understand their properties in terms of their strength and performance, in terms of fatigue or how you can bend them how many times you can bend them before they might break. If they were to break, how would they break that type of thing.

But there are many groups at Manchester that are working with the big aerospace companies. I know there's a big group working with Airbus in order to build more directly input onto the materials that are going into planes. So my work is very, very early stages. But you, absolutely, in the Materials department, you go right through to, I mean, in another project I've worked with a company where they said the production line has stopped because we've got this problem. There is the wrong texture in our final product and they send it to you. And you have to work over the weekend, or likely to work over the weekend to work over the weekend to try to understand this because the factory stopped until they get to the bottom. So that's a much more immediate what's gone wrong and the problem might be that there's a contamination in the process somewhere. So I'd say it was everything from the very blue skies, which is most of what I do right through to people who were directly helping the industry on a day-by-day, minute-by-minute basis.

**Alessandro Mottura:** [00:03:12] And that's actually very good because it touches upon I think one of the key features of Materials Science and Engineering is that it does have that spread of topics as it goes all the way from the very fundamental things that may be really pushing the boundaries of what is known all the way to solving practical problems in creative ways that you can span the whole sector, in a way, the whole range as a Materials Scientist.

**Sarah Haigh:** [00:03:37]. In graphene, I mean, at the moment we've got phones that are prototypes where they have a graphene touch screen, for example. So they're being produced by a number of manufacturers. And the aim there is that when you drop your phone, you wouldn't it wouldn't crack. Most people would have ended up breaking your phone because it cracked and that's because typically touch screens are made out of indium tin oxide which is a ceramic and it's quite brittle. So just to replace that component on the phone with a flexible materials like graphene would mean a life of phones would be much longer hopefully. So that's something which is already definitely a prototypes are being developed by industry, whereas graphene electronics is a lot further off. It's a hugely disruptive technology, more with huge potential for making fast and more efficient computing. But it's not going to be happening in the next couple of years.

**Alessandro Mottura**: [00:04:29] We have another question, which is a bit technical, which is what about coating if we want to use the SEM. How do I know if we need something needs to be coated or not coated? And I guess that's the question is asking.

**Sarah Haigh:** [00:04:41] Well, you could try not coating it and see if it charges. But one of the things that we get in an electron microscope is that if the electrons that you're putting in can't get away and they tend to jump and interfere with the imaging. And so you get this strange flashing, a little bit like lightning where the electrons are interfering with you being able to image. For that reason, we tend to put a conductive layer on the surface and that allows the electrons you are putting in to escape stops them d interfering with the imaging. Um, yeah. So often we would try not to coat if you can avoid it but sometimes you can't avoid it.

**Alessandro Mottura:** [00:05:15] The best picture, I should say, of a SEM that I have taken is one of a polyethylene sheet that is charged up so much that it essentially was a mirror acting for the microscope.. So it was like a selfie, an SEM selfie. Because we hadn’t coated the polymer. Some fascinating things. You can do with SEMs.

**Alessandro Mottura:** [00:05:37] Yes. One more question. How do we know that detecting in electron microscope does not interfere with what we see? Very good question. I think I'll break it I'll break it down into into a few questions because there's a few questions there. So I'll answer the first one question.

**Sarah Haigh**: [00:05:55] I think I think I showed you in the example of molybdenum disulphide, but we can't be sure if there is an effect of the imaging on the specimen, but have the same problem in lots of other techniques as X-rays and light microscopy. Both can change the material depending on how sensitive it is. And we have to therefore do experiments whereby you start with a lot of electrons and you reduce the number of electrons as far down as you possibly can in order to be able to see whether the material still looks the same. You have to use complementary techniques to see if they can confirm what you're looking at. I have to say, usually when something has changed is the electron beam it's fairly obvious. And if you can imagine, if you're taking movies and you're taking that movie for a very long time and there's no changes, then probably nothing is happening to the electron beam. But if it's a dynamic system, then I think you have to be very careful with interpreting what you're doing. I mean, I should say that we've used the electron beam damage as a tool. So we've used it to create patterns which are effectively conductive channels to make an electronic device, for example, and you can use the electron to make very, very precise structures in the microscope, which have specific properties effectively deliberately cutting with the electron to produce a new structure.

**Alessandro Mottura** [00:07:19] Very good. And then the next follow up question is for graphene. Is there a chance that it could be mass produced in the near future?

**Sarah Haigh** [00:07:27] So I know that people are making chemical vapour deposition graphene, so graphene effectively supported on a polymeric support, and that is roll to roll processing and I've seen processing's there are tens of meters long , sorry tens of metres wide and infinitely long.  So that, as already achieved with CVD graphene. CVD graphene made like that is not is not quite as good as some of the graphene that we need for electronic devices. But it's more than good enough for composites and membranes and of lots of other applications. So I think it already is being mass-produced and it's just a question of whether the mass production can be cost effective for the application in question.

**Alessandro Mottura**: [00:08:11] And there was actually a hidden question in the context of the previous question, which was, can the electron beam of the SEM itself change the detector, and how do you know if the detector is damaged by the beam.

**Sarah Haigh**: [00:08:28] So sometimes it's obvious because there's all the images that you get off that one look the same because somebody has burned an image onto the camera. If you can imagine, when you look at the sun in your eye, you can have a sort of shadow picture of the sun when you go and look somewhere else. And the same thing can happen with detectors and electron microscope. And you look at an image of graphene and then from then on, everything else has kind of a shadow image of graphene. Then you shout to the student because they've done something wrong and they burn the detector. So it definitely can damage the detector and the detectors only have a finite lifetime anyway so they do need replacing periodically.

**Alessandro Mottura**: [00:09:05] And they are usually pretty expensive right?

**Sarah Haigh**: [00:09:07] Some of them are very expensive. So in general, I mean, the microscopes themselves are pretty expensive, you know, from tens of thousands to millions of pounds are the microscopes that we use every day.

So but I mean, I have to say that even undergraduate projects use these microscopes under supervision, of course, but it is one of the privileges of being a material scientist that we have access to fantastic characterisation (techniques).

**Alessandro Mottura** [00:09:33] All right. There is one more question. Let's make this the final one. And if someone asking you showed a lot of names of co-workers, how important is teamworking, collaborating with others in your work? And I'll follow that up and say, how easy is it to actually get an image because it might be easy to get the image, but preparing the material to better give you that image is probably not that easy.

**Sarah Haigh** [00:09:59] No, I think. First of all, on team working, it's absolutely crucial. And I think that the I mean, particularly for the work I do, because it tends to be part of the bigger picture. So I don’t make materials myself. I help other people to understand what's going on in those materials. And that's really everything that I do is is collaborative. The only exception might be to do and show some imaging techniques that it works. And then the idea is to attract collaborators who want to use that technique. So I'd say it's absolutely crucial and it's one of the really good things about materials is being able to interact with lots of different scientists in order to be able to solve interesting problems.

And what was the second question?

**Alessandro Mottura** [00:10:45]:  The second question was about the sample. You said it's easy to get a picture, but I guess because the sample is the difficult part, isn't it?

**Sarah Haigh** [00:10:54] I didn't say it would be easy to get a picture. Sometimes it's very, very hard to get a picture. So sorry. The picture of the toddler on the microscope was slightly flippant. You don't have problems using your microscopes any more than we have toddlers using sellotape and pencils peeling to make graphene and that's an urban myth, that's not true.

So it's not easy. And the sample preparation is a huge challenge to some materials more than others. So is that the gold nanoparticles you can just put them onto like a carbon net and you combine the carbon nets commercially and you just drop the liquid onto a carbon net and then you put carbon net in the microscope and you get the image relatively straightforwardly so for some materials it's easy. For graphene, you kind of peel off the layer and then you stick it down on a grid, which can be difficult or hard, depending on the particular material that you're looking at. For sample preparation you imagine you're trying to look at the crack tip inside a turbine blade, you want to understand what happened, what went wrong to cause that crack by making sure that you take an electron microscope image at the 10 - 20 atoms that are the crack tip and not in some other 10 - 20 atoms within the material is hugely challenging but then it is something which we have lots of different techniques but it is achievable. Challenging, challenging but achievable.

**Alessandro Mottura** [00:12:20] Cool, I think this is a good place where to end so thank you very much Professor Haigh for the talk, it was a very, very interesting and fascinating talk.

And I'll end by saying that you should receive future activities by email from Dr Chris Hamlett he will send you links, particularly for future videos that will appear tomorrow, as well as for the Q&A sessions about your infographics on Friday.

So remember to think about how materials have helped you during the current pandemic and think of ways you could describe or explain those materials using infographics. And we look forward to seeing you again on Friday for the live session and then again next Tuesday for the final live session of the week.

So thank you.