

Science and Technology Committee

Oral evidence: [Graphene](#), HC 960

Tuesday 26 April 2016

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Written evidence from witnesses:

- [Inclusive Designs Ltd](#)
- [Tim Harper](#)
- [The University of Manchester](#)

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Members present: Nicola Blackwood (Chair); Victoria Borwick; Stella Creasy; Jim Dowd; Chris Green; Dr Tania Mathias; Graham Stringer; Derek Thomas

Questions 1-111

Witnesses: **Tim Harper**, Tim Harper Graphene Investment and Consulting, **Dr Erik Cox**, Director, Inclusive Designs Ltd, **Ray Gibbs**, Chief Executive Officer, Haydale Graphene Industries Plc, **Harry Swan**, Managing Director, Thomas Swan and Company Ltd, and **Dr Liam Britnell**, UK Manager, BGT Materials Ltd, gave evidence.

Q1 Chair: I open this stand-alone session on graphene. We are looking into the state of research into and commercialisation of graphene and examining some of the claims that have been made recently. Can I ask Mr Swan to start by giving the Committee an understanding of the current status of the graphene market? There are various different claims in our written evidence, but should we understand graphene as a technology that competes with existing materials, or one that will bring with it completely new applications?

Harry Swan: I think it is a little bit of both. We are an SME based in the north-east of England. We are a chemical manufacturing business, and we have approached the development of graphene as a new material that adds value to what we are trying to do from a chemical production perspective.

We see the graphene market in some instances as involving a new material that brings new properties to new applications, or sometimes existing ones. An example could be printed electronics, where the alternative in the past has been carbon as an additive or metal additives. Carbon has been cheap but not particularly conductive, and graphene has dropped right in the middle as something that brings a new property to that particular application. It is still early days for us. We have been going since 2014, when we launched

the business, and we still see it as developmental. To give you an idea of where we are in our commercial cycle, we expect to be in profit next year, which is pretty fast.

Q2 Chair: Mr Gibbs, do you have views on the graphene market?

Ray Gibbs: Yes, I do. I see graphene as an enabling technology. I believe that it can be a massively enhanced composite material, in particular in conjunction with other materials, such as carbon nanotubes. Harry Swan manufactures carbon nanotubes. To define graphene on its own is the issue. Everyone talks about graphene. Graphene as a single layer or sheet of carbon atoms is a very difficult thing to manufacture, and even worse to use. The problem with graphene is that it is carbon and an inert product; it does not want to mix with other things so it needs to be functionalised. At Haydale we have a functionalisation process that adds chemical groups to the surface and aids dispersion. Uniform dispersion is going to make a big difference to the likes of the composite role it will be playing.

Dr Britnell: I would give an answer broadly similar to that. We can look at different avenues for the application of graphene. The ones that are clearly the lower-hanging fruit—those that are already being put into products by companies like ourselves and will be going to market this year—are either additives or a substitute for something where graphene adds significant improvement to the properties, but it is not a completely new application.

The status of the market is still pretty small. We are probably talking of revenues in the order of hundreds of thousands, not millions, even for the biggest companies selling raw materials. It is dominated by material producers, so there is a push from them to get generally larger companies to use the material. Typically, from what I have seen, the pull from the larger companies has been towards higher-quality graphene. I think we are now beginning to cross the divide where the quality is good enough to make a real difference.

Q3 Chair: Dr Cox, given that I understand from these witnesses that we have a nascent market for graphene, do you think that the approach of the University of Manchester is correct? They have written that they envisage the initial significant commercialisation of graphene will come from “engagement with established companies”, and that spin-outs and start-ups will come when the market “begins to mature”. We have had other evidence that large corporations generally do not engage in pioneering developments and prefer to wait until markets emerge and technologies stabilise, and then they will buy successful companies and license technologies with lower levels of risk. What is your judgment on these strategies, given your engagement with the graphene market?

Dr Cox: I would agree with the last statement you made: large companies do not want to get involved until they can see huge potential for themselves. If I can go back to the first point, the graphene market is very much in its infancy. A lot of hyperbole surrounds it, but there are many problems related just to the commercialisation of graphene that have not been addressed. The majority of graphene production is being used by universities and research facilities; it is not being used in actual products, and most graphene companies, Thomas Swan included, are manufacturing graphene itself and are not involved in applications. We feel that the way to move forward is for actual applications to be taken

on board. Let's identify the potential applications and tailor the research to answer that need.

Q4 Chair: Your judgment is that there needs to be a focus on SMEs in order to deliver those applications.

Dr Cox: Very much so. Being the director of an SME myself, we found it quite difficult to access capabilities and expertise.

Tim Harper: I think nascent is exactly the right word to describe the graphene market. We are still at the stage of technology push, which means that some people have come up with a new material and nobody is quite sure what it can be used for. There are lots of ideas about what it might be used for, but there is no conclusive proof. Large companies tend to be quite agnostic about new technologies. If something is significantly better or cheaper it might be worth a look, but in general the strategy tends to be to sit back and wait. If we are to get some real applications out of graphene, it is important to support the creative and innovative SME sector that can apply graphene.

The problem with any material is that it is very hard as a producer to make money out of it. Take the example of putting a pigment in a pot of paint. It is compounded into paint, put into a tin and sold by a retailer. The people who make that pigment capture very little of the value of the walls that are decorated with that paint. Graphene is in a similar position. To capture any value, you have to look at applying it in something innovative that addresses an unmet need. If you do not do that, it will probably go the same way as carbon nanotubes or fullerenes, in that people will spend and lose a lot of money on it. It might take 20 years to get to commercialisation, or it might never be commercialised.

Q5 Chair: In your experience, has there been any kind of disjunction between the priorities of researchers engaged in fundamental research on graphene at universities and those attempting to commercialise graphene, and is this causing any tension or friction in the system, as we attempt to get the benefits for UK plc?

Tim Harper: There is always a little bit of tension between the pure academic side and commercial side. One of the reasons for that is that people have very different objectives and speak very different languages. As an academic, you are curiosity-driven and you are rewarded by Nobel prizes and articles in high-impact, peer-reviewed papers, so it is not really the job of academics to find commercial applications. On the other hand, from a business perspective, it is a question of finding an unmet need and connecting a technology with that. If you are to do it successfully, you have to have the academic and the commercial side working together, and there is quite often a bit of a disconnect.

Q6 Dr Mathias: You have all been involved with either the University of Manchester or the National Graphene Institute. How would you describe your experience, and how does it relate to other university research departments?

Harry Swan: We have not been directly involved with it. The work we have done on graphene development was with Trinity College Dublin in Ireland. We chose a centre of

excellence. I did some research into it and we chose Professor Jonathan Coleman there to develop our process for us.

Q7 Dr Mathias: What was it about Trinity compared with, say, Manchester?

Harry Swan: It was principally the person—meeting Professor Coleman, as we did a number of years ago. I listened to a presentation he gave at a Cambridge conference that I was at. We got talking afterwards, and it felt that he was the right person to develop a process for us; he had understanding of the commercial sensitivities as well as what they were trying to do academically. There seemed to be a very good partnership between us, so we got on and funded it.

Ray Gibbs: We have been involved with Manchester. We started to get there because we are heavily involved in the composite market. We do not make the materials; we take everyone else's material and every single one is different, so you need to know which one works. We have created some graphene pre-pregs, which are pre-impregnated carbon fibres, and composite materials that we are going to launch with the Graphene Institute, probably at the Farnborough Airshow soon.

I travel around the world an awful lot; I lecture at various conferences just about everywhere. Wherever I go, everyone talks about Manchester and the NGI. For me, it has a very high international presence in the marketplace. We should make the best we can of that because it is such an important barometer for the United Kingdom. After all, we discovered graphene here and we started the process. Others work very hard and quickly, in particular in the far east; they move rapidly. We have been involved in the far east. I keep saying that we need to grow the graphene market massively. There are too many players in a smallish marketplace. We need to grow it, and I think we will do that through the composite market, through conductive inks and sensors, and probably some work in the battery market too. We should not underestimate Manchester's profile in the international field. It is very important.

Q8 Dr Mathias: Your experience is piggybacking with the name.

Ray Gibbs: I am just reporting back that people have spoken to me about my experiences with Manchester. It has been positive.

Dr Britnell: We have a very good relationship with the university in general and with the NGI. We have run several collaborative projects at the university. It is in the nature of research that they are not always successful, but we have had some successful results. We are one of two strategic partners working on graphene at the NGI at the university, and through that we have been successfully linked with other potential project partners outside that relationship and with potential customers. We have also had the opportunity to demonstrate some of our products, like the graphene lightbulb we developed and the wireless communication techs. Broadly speaking, our experience of the university has been very good.

Q9 Dr Mathias: That is very positive.

Dr Cox: We have not had any experience with the University of Manchester or the National Graphene Institute, and therein lies the problem. My company, Inclusive Designs Ltd, is developing a solid state cooling technology called DeHeat, which we hope will use graphene to enhance the product's performance. However, once we contacted the NGI and tried to arrange a meeting to discuss potential collaboration, we were met with a brick wall immediately, by which I mean that within 15 minutes of emailing them we got a negative response saying they could not meet us "due to possible confidentiality issues with other projects." This was strange to us, given that we had not given them full disclosure of what our technology is, obviously. If they had worries about confidentiality issues, one would have thought they would be interested to know exactly what IP we had, if only to ensure they were operating freely. We have had many positive experiences with other universities. We have had very useful relationships and partnerships with the Cambridge Graphene Centre, the Centre for Process Innovation and the Manufacturing Technology Centre. I cannot tell you much more about the University of Manchester and the NGI until we have actually had a meeting with them.

Q10 Dr Mathias: Cambridge did not have the same concerns.

Dr Cox: Cambridge immediately wanted to partner with us. We submitted a joint application for an Innovate UK grant with Cambridge Graphene Centre.

Tim Harper: I looked at a couple of technologies from the NGI for various clients. One was a water filtration technology, but after looking at it we took the decision that it was not ready to be commercialised, and it did not seem to be made or owned by the university. We were a little unclear as to who owned the technology and where it would come from. Some rather large numbers were mentioned even for getting samples, which to me seemed a little odd. We looked at possibly co-locating our water filtration company G2O at the NGI, but as we were going through that process and talking to some people we could not find any real commercial reason for us to do that, other than that it would be nice to have that name and tag along. Then there were all the other things that came out in *The Sunday Times* article. If I bring up the NGI on any of the boards I sit on, that is the first thing people point to, so that is potentially quite damaging. The other thing we were never quite clear about was whether the NGI was supposed to be a research institute or commercialising things. It always seems to be a little fuzzy in the message.

Q11 Dr Mathias: But how would you describe Manchester in your dealings?

Tim Harper: We had some initial dealings and they were never taken any further, so we did not push it.

Q12 Dr Mathias: They were mutually not beneficial.

Tim Harper: That is right.

Q13 Dr Mathias: Do you think that any partnerships Manchester has have prevented other companies getting involved?

Tim Harper: That would be difficult to say, but given the publicity around the recent allegations, you would think twice.

Q14 Dr Mathias: But from your experience.

Tim Harper: We were not aware of any conflict, but we did not go into it in any great depth.

Q15 Dr Mathias: Dr Cox, do you think any partnerships affected your approach?

Dr Cox: I would agree with Tim. It is hard for me to say. I would not like to make any further comment before I have had a meeting with Manchester and the NGI.

Q16 Dr Mathias: Dr Britnell, do you think there is any problem with partnerships preventing other partnerships?

Dr Britnell: No, it is certainly not reflected in our experience. The only time I could see it would be is if perhaps the university knows it is going to work on a project with a particular partner, or is already engaged in a project, and there is a clear conflict with another company. I imagine that then it might be an issue that is raised, but it has not come up in my experience.

Ray Gibbs: I think the NGI is there to take materials to technical readiness levels 3 and 4, which is not commercialisation. That is where 8 and 9 sit. We are a business that is about commercialising graphene, so from our perspective working with the NGI is an obvious fit and is something we do. We work with Cambridge and a range of other universities all around the globe.

Q17 Dr Mathias: Mr Swan, you would not have the experience to know.

Harry Swan: Going forward, it is going to be very important that the emphasis is on application development. My impression is that that is what is going to be provided. The other key thing from our perspective, again going back to the market question, is that at the moment it is an industrial R and D market; people are buying material to do research rather than necessarily commercial development. The key challenge is that either you have one big company that sits over the supply chain for a new product and you can control each of the phases of that process development, which is rare—if you get that, they tend not to be particularly innovative and are quite slow—or you have a load of individual companies throughout the whole supply chain, from the beginning of the material to the end application product, and you need to get those working together. Having that supported somewhere like Manchester or the Graphene Institute is going to be very important. It is also a great benefit when you have Innovate UK grant funding that those companies are aligned, because it gets the product from raw material from people like us into an application and ensures that everyone down the supply chain can make money.

Q18 Dr Mathias: Is there anything that you would want the National Graphene Institute to do differently?

Harry Swan: Not from my perspective. We approach any external investment in research on a case-by-case basis and we go to a centre of excellence. Depending on what is provided by that centre of excellence, we will go to the place where we think it is most likely to be done best. For application development we would naturally gravitate towards Manchester, but there may be other opportunities and other things that happen elsewhere, but from the point of view of what they are doing currently they are very visible to us. We are well aware that it will be a good place to work when we find application developments to collaborate with.

Ray Gibbs: The answer is to collaborate with as many applications houses as possible and provide guidance and help on a technical basis, because Manchester and the NGI have massive knowledge. For me, the answer is that we have to continue to promote them, and they need to continue to promote themselves on an international basis. I keep on about that. It is an important global market and it needs to expand, and in my view they have a massive role to play in that arena.

Q19 Dr Mathias: Dr Britnell, what do you say?

Dr Britnell: It is probably doing the job that was intended, just looking at the names of the project partners—I am not talking about companies as small as mine, but larger people. The fact that the name of Manchester is able to draw them and back it up with the technology and know-how of researchers is evidence enough. Let's not forget that it is a reasonably short time since the institute was opened, and in that short time we have seen a significant amount of development in our company.

Q20 Dr Mathias: Dr Cox, would you want it to do anything different?

Dr Cox: I would like the NGI to be more open and accessible to micro-SMEs like my company. We have a potential ground-breaking application, yet we find it difficult to access capabilities and expertise. That's what I'd like.

Tim Harper: From an entrepreneurial perspective, there are a lot of people around who would like to be able to figure out how to apply graphene in various areas. It would be good if institutes like the NGI were open to discussions with people about that. A lot of these ideas might be crazy and impractical for all kinds of technical reasons, but some might fly. Open engagement with the creative and entrepreneurial community is probably something I would wish for.

Q21 Chair: I want to clarify a couple of points. Dr Cox, in your written evidence you talked about not receiving engagement from the NGI on the grounds of confidentiality. You also said that, following contact from your local MP, they followed up and said that a meeting would not be a problem.

Dr Cox: That is correct.

Q22 Chair: You are still waiting for that meeting.

Dr Cox: I have not arranged it yet; I thought it best to come to this first.

Q23 Chair: Did you receive any explanation as to what had happened?

Dr Cox: No. The last email I received from Ivan Buckley gave the impression that it was his first email to me: “I believe you want to have a meeting with us. That won’t be a problem.” Unfortunately, it still had attached to it his first email to me saying, “We won’t be able to meet with you.”

Q24 Chair: I just wanted to clear it up. Mr Harper, you said it was unclear whether the NGI was there for research or commercialisation. In the evidence we have received from the University of Manchester it is stated quite clearly that the NGI is there for “academic-led research (TRL 1-5)”, and that the GEIC will focus “on industry led technology development (TRL 3-6)”. Is that not widely known among industrial partners? Is this new information?

Tim Harper: It is a little unclear from looking at the NGI and the number of partners they have—the likes of Rolls-Royce, Tata Steel and others; it seems to be a fuzzy line. There is always a bit of an issue when you ask academics to commercialise things and they are stepping a little outside their comfort zone. In general, that can cause some major problems.

Q25 Chair: Can it ever be anything other than a fuzzy line?

Tim Harper: I think it can. It is probably like defining any project. You look at what the deliverables and the boundaries are, and who is supposed to be doing what. There is always a temptation in any organisation for creep of scope, which is natural; it happens everywhere, but to get some kind of deliverable out of institutes like the NGI there has to be a very clear line where the academic part stops and the commercial-led work starts. Otherwise, you run the risk of having an industry-facing institute that has been designed by academics and ends up not being fit for purpose.

Q26 Chair: Mr Swan and Mr Gibbs, do you have the same impression of the NGI and GEIC? It is not clear what they are there to deliver and you are not clear which is doing academic research and which is doing industry-facing research. Is it unclear to you, or do you feel you know what is going on?

Harry Swan: We are comfortable that we know what is going on. People in my company have had various meetings with them, so we are aware of where they sit.

Ray Gibbs: I am clear. I have said already that I think the NGI was there for up to TRL 3 or 4. They said it was 5. I am okay with that. On the GEIC, my perspective is that I am all about trying to commercialise graphene as quickly as I practically can. I cannot wait for things like that to happen, so I am going out to the marketplace and developing applications through demand pull with resin companies such as Huntsman, which has

worked with us to create some value-add in their base resins. They are our super-sales force; they are a \$10 billion business and we are an SME.

Q27 Chair: Dr Britnell, I assume you feel that you know what the NGI's limits are and where the GEIC will start.

Dr Britnell: Yes. You referred to the TRL levels; I saw those slides at numerous public conferences in the years leading up to the creation of the building. We were very comfortable before we started the relationship there.

Q28 Jim Dowd: Dr Britnell, you mentioned in response to an earlier question that you regarded your relationship with both the university and the NGI as very good. Mr Harper, you mentioned the recent article in *The Sunday Times*. I want to ask Dr Britnell a few questions about that. It made the allegation that BGT had made agreements with a Chinese business and a Chinese university to develop graphene technologies similar to those involved at Manchester. Is that true?

Dr Britnell: No. Let me clear that up a little bit. It is true that we signed a letter of intent in 2014 to work on broadly similar topics. If you look in a bit more detail at the size of those topics, we are talking about topics such as energy storage, which covers batteries and super-capacitors. Those are multibillion-pound industries in themselves.

Q29 Jim Dowd: You signed that with whom?

Dr Britnell: The University of Xiamen. Let me be clear: no projects were ever undertaken. That was terminated in 2014 before any project work was ever done and before any more formal contact was ever reached. Aside from that, every interaction we have, whether it is with the University of Manchester, the University of Xiamen or other companies and research organisations, is always done either under a bilateral NDA—non-disclosure agreement—or under a research contract. It is very explicitly stated that you cannot expose any confidential information brought by the other company or institute, or that arises from those projects, to any third party. We are very respectful of those agreements, and everything we do is under them.

Q30 Jim Dowd: You can give an absolute guarantee that you have not shared any intellectual property gleaned from Manchester with either an academic institution or any companies in China.

Dr Britnell: Absolutely.

Q31 Jim Dowd: You can do that.

Dr Britnell: Yes.

Q32 Jim Dowd: The article also suggested that researchers at Manchester were concerned about the security of their work because of your links. Have any specific concerns or complaints been made directly to you? If so, have they been investigated and found to have any validity?

Dr Britnell: No direct claims have been made to me personally. I believe that a claim was made to BGT and that was dealt with. I do not have any more information about that.

Q33 Jim Dowd: I did not ask you whether it was made to you personally, but BGT as an organisation did receive complaints.

Dr Britnell: I think there were some questions about how the projects were run, but that is natural when you have multiple people and multiple companies with different interests. Let me make it very clear: we find it quite strange that we are even in this position. We do not have an office or labs at the institute. Our access is the same as any external party. Any visitor to the NGI signs in at the front desk and signs out when they leave. We find it very strange that these claims are being made at all.

Q34 Jim Dowd: How were the complaints resolved, or were they just noted and ignored?

Dr Britnell: I do not think they had any basis. We do not have access to any confidential information outside the projects we had with the NGI. An investigation was made inside the company but without having access to any confidential information about any party, whether it is another company or organisation, at the NGI. We cannot release information that way.

Q35 Jim Dowd: Are there any arrangements in place, should your products prove profitable, to share those with Manchester University?

Dr Britnell: Yes. The university is a shareholder of BGT Materials. Hopefully, we will expand and grow in the coming years, and they may decide to sell their stake at some point.

Q36 Jim Dowd: But the only income they would derive from successful marketing of products would be as a shareholder in BGT. There is no other relationship.

Dr Britnell: Let me make it clear: the products were developed entirely by BGT Materials. We have two products: lighting products and wireless communication techs. Everything—the patent portfolio—was developed by us, by BGT Materials. The university is a shareholder of the company, and that is how they would do it.

Q37 Jim Dowd: If they were not a shareholder of the company, they would not derive anything from any successful marketing by BGT.

Dr Britnell: No, because they have not done the development. We have certain projects that we run with the university—that any company would run with the university. The IP

from that would be shared as per agreement. If the company is developing everything in-house, the company owns the intellectual property for that. Outside the projects run co-operatively with the university, there is no agreement to share any other intellectual property from us.

Q38 Chair: If you are, as BGT, just like any other company that signs in and out and has no additional access, why are there so many claims that you have a privileged position with the university? Does it hinge solely on the university's shareholding in your company?

Dr Britnell: That may be one aspect. Another possibility is that I and one of my colleagues are former students of the university, and we maintain personal relationships with people there, outside the institute. If you look at the sheer number of people who are working at the institute, the claims are coming from one or two people. I do not know the basis for those claims.

Q39 Chair: You have no closer relationship with the university than Airbus or any of the other companies engaged with the NGI.

Dr Britnell: We were a strategic partner, so you might say that by that we are closer, but I do not see that our relationship is any different from any of those project partners.

Q40 Chair: Is there another company that is as close as you are?

Dr Britnell: I think anyone else working there is. There is another company based inside the NGI, which we are not. I would say that they have as close a relationship, or a closer relationship than we do.

Q41 Chris Green: Mr Gibbs, what are your views on Manchester University's approach to graphene intellectual property? Do you think it follows the right strategy?

Ray Gibbs: I have no real view, because I have not been associated with Manchester University's IP. I know my own IP. We have a process, and we have extended the intellectual property. The rules of engagement in the IP world are that whoever pays for intellectual property ends up owning it, or the majority of it. I cannot comment on the Manchester IP because I have no interaction with it. We would work with it or any other university using research and knowledge to develop applications in the composite world, or in inks, coatings and anything else that makes sense.

Q42 Chris Green: Do you have a broader concern about people taking out patents, perhaps not necessarily because they want to develop anything based on them but acquiring patents for reputational reasons?

Ray Gibbs: You need look no further than China for that perspective, because they are the leaders in the patent race, if you can call it such. Anecdotally, we are told that people are paid money to generate patents and leave them to lie there, and of course then you have prior art that you can do nothing with. I would argue that a lot of the patents that come out

of China in particular do not go anywhere from a commercialisation perspective. For me, if a patent works and it can be commercialised, you have a big tick in the box.

Q43 Chris Green: It is quite an immature industry at the moment. Are these concerns that would arise more with a new and developing industry, or is it something particular that is happening in China?

Ray Gibbs: I think China is driven by trying that, in the sense of trying to have control of the market per se. I know from personal experience that when you prosecute a patent and you have a granted patent and you then put it around the world, it costs a lot of money to start to bring all the granted patents across the appropriate geographic territories. Once you have one and you want to make it a success, it costs a lot of money; we are talking about six-figure sums.

Q44 Chris Green: Dr Britnell, do you have any views on the University of Manchester's approach to patents?

Dr Britnell: No. That was alluded to in the previous question. We find it broadly similar to the arrangements that have been proposed when we have looked at working with other people. You own what you bring to the table and you share, depending on who does the development. I do not think we find that to be any different.

Q45 Chris Green: Do you think that where Manchester has taken out patents businesses are getting sufficient opportunities to develop products, perhaps through appropriate licensing arrangements?

Dr Britnell: We have had only one conversation about potential licensing, which they were reasonably open to discussing, but we decided that the terms were not very good.

Q46 Chris Green: Dr Cox, do you have a view about the university?

Dr Cox: It is difficult. It is very easy to look back in hindsight with 20/20 vision and say what they should or should not have done at the time. We do not know the full story, but it seems incredible that Manchester University did not manage to file some kind of seminal building-block patent based on Geim and Novoselov's method of manufacture. Most companies manufacturing quality graphene today use an exfoliation method, which is a variation of Geim and Novoselov's method. If they had had that patent, they would have had protection. However, this is not just a problem in Manchester; it is endemic throughout British academia. I am a former research scientist, so I know that the pressures on scientists working in academia to publish scientific papers are huge. They can outweigh the need to publish patents. You cannot publish a scientific paper before you patent something, because it is then in the public domain. There is always this trade-off in academia: "Should I publish or should I patent?" It is a problem that needs addressing. There is a huge chasm between the laboratory and the marketplace that is just not being filled. We should not expect academics or scientists to bridge that gap, but we need a more functional means of tech transfer.

Q47 Chris Green: So the relationship between academia and innovation and getting the products is not working at the moment. As Mr Gibbs highlighted earlier, are there any particular concerns about the status of the National Graphene Institute and the University of Manchester? The status and name of the University of Manchester itself resonates. If so much is caught up in Manchester, it makes it very difficult for people outside. I am not suggesting there is any particular Liverpool-Manchester rivalry in this.

Dr Cox: Liverpool-Manchester rivalry? I've never heard that before.

Q48 Chris Green: If there is too much concentration of knowledge, it seems that it raises concerns.

Dr Cox: Yes.

Q49 Chris Green: Are there any other countries or universities that you believe would show a better approach to graphene patenting and licensing?

Dr Cox: With respect to graphene, I am not that sure. In terms of the general way of doing things, if you look to Harvard, Oxford and Cambridge, they seem to have it right, or better. Singapore has a good mechanism.

Ray Gibbs: I would look no further than the Fraunhofer Institute in Germany, which in my view is a very class act. It has a turnover of €1.3 billion, and is 50% funded by the Government and 50% funded by researchers or companies that go to Fraunhofer. There are 51 Fraunhofer sites in Germany. We have worked with two or three. We have produced a reel-to-reel gravure-printed biomedical sensor for developing pathogens. I know that in 18 months' time that material will become a commercial product, because they are driven to make it happen. That is very powerful. The way they have set themselves up, with pockets of excellence all around Germany, is a fantastic profile.

Q50 Stella Creasy: I want to come back to the questions you raised about the tension in working with different countries with different patents. Dr Britnell, you said something very striking. You said that the letter of intent was signed in 2014 and the agreement was terminated in 2014. Could you explain why that was? It seems a very short period of time to go from thinking you could make something happen to deciding it is not appropriate.

Dr Britnell: The letter of intent was signed in May 2014. I have the terms of the letter here, if you would like them. The letter of intent set out how in principle we would share technology, but when we got a chance to review the research contract it became very clear that we would be edged out of any potential profits, so we said, "This isn't beneficial to our company at all, so we will remove ourselves from it."

Q51 Stella Creasy: Do you still have a relationship with the Chinese university you were talking about?

Dr Britnell: Not particularly, no.

Q52 Stella Creasy: Therefore, it is not a live issue now. What do you think can be learned from that experience? You are saying that, in the letter of intent, intent turned out not to be application. That is quite striking. What do you think we can learn from that in terms of some of the issues we have been talking about today?

Dr Britnell: This whole landscape is shifting very quickly and it is beginning to reach something like a steady state. We were very eager to try to capitalise on the opportunities as they were cropping up, and perhaps we were too quick to act when we saw an opportunity to partake in what looked as if it would be a very successful project. From the company's point of view, we need to be more careful about the relationships we enter into. I am not sure anything can be learned particularly in a wider context than that.

Q53 Stella Creasy: Mr Gibbs, you are suggesting that there is a German model that is very clearly directed towards commercial applications and the speed with which they can come in. There seems to be a tension there. How do we overcome that, given Dr Cox's point about academics not being the people to make these agreements happen?

Ray Gibbs: If I'm honest, I think you work with the Fraunhofer Institute because it is such a fantastic organisation.

Q54 Stella Creasy: You are not concerned about the German patent, as opposed to the Chinese patent.

Ray Gibbs: No, I am not. I am very focused on commercialising graphene, because it needs to be commercialised. There are some very strong academic institutions outside Manchester in the United Kingdom: Queen's Medical, Nottingham, Loughborough, Swansea and Cambridge, to name but a few. Each of those has its own specialisation in various different areas: composites, inks, coatings and batteries—for example, Warwick Manufacturing Group. There is an awful lot of inbuilt knowledge in the United Kingdom. It is a matter of accessing that. Who is best to help an application get taken to market with an institution or company that wants to do that and pull it forward? There is an awful lot of inbuilt knowledge in those institutions in the United Kingdom.

I take the point that the pressure for scientific papers is great. My belief is that you work with the university in very close order to make sure that, if there is something patentable, it gets patented before the scientific paper is published; otherwise, you end up with prior art. We have done that very successfully by working very closely with Swansea University, because we are based partly in Wales.

Q55 Graham Stringer: Can I declare an interest as a non-paid member of the advisory board to the department of chemistry at University of Manchester? When we visited the NGI we were told there was a lot of poor quality graphene about, and the key to exploiting graphene commercially was having clear standards defined internationally. Is that true? How would you go about establishing those standards?

Dr Britnell: It certainly is true. There is nothing to stop you putting the name graphene on anything. The assumption as a community is that anything under 10 layers thick of graphite can be called graphene. The nomenclature around graphene needs to be clarified by the appropriate body. The difficulty is that graphene has so many applications; it has applications in the field of composites, energy storage and displays, and each requires a different set of important properties to be known before someone is going to use it. My advice would be that the standards need to have some basis in the desired application of the material.

Q56 Graham Stringer: Is the process of having national and/or international standards happening?

Dr Britnell: We have had interaction with the National Physical Laboratory in this regard. We have applied for both national and European funding jointly with the NPL to develop methods to characterise the materials more effectively and to clarify the nomenclature. To date, those projects have not been funded, so it seems to me that it is not seen by the research councils to be as important as we believe it is.

Q57 Chair: One issue that has come up in written evidence is that the funding model for the NGI in particular “is seemingly further inhibiting optimal relationships and behaviours” between—I think the witness means—industry and academia. As I understand it, the NGI website says that projects range from a quick look for between £50,000 and £100,000 to strategic relationships in exchange for £1 million a year for three to five years. Do you think this funding model is or is not working?

Harry Swan: Will you restate the question? Are they offering that as advertising as to how you would interact with the university in return for—

Q58 Chair: It is how you access the NGI. Is this a funding model that makes sense to you as a business engaged in the market?

Harry Swan: You are saying it is £50K to £100K for—

Q59 Chair: A quick look, and as a strategic partner in exchange for £1 million a year for three to five years.

Harry Swan: The way we would approach typical collaborations with any university or institution would be on a project-specific basis. You would arrive and say, “What is it that you have that we need?” We are an SME, so our research is restricted to the number of people we have in our own R and D centre, and when we have something like developing a process for graphene we have to outsource it. You then go to the centre of excellence, whether it be an organisation or university, and enter negotiations around how you are going to work together. Typically, I would not be looking for an organisation to say in a blanket way, “This is the way we would approach it.” I would be looking to negotiate with them specifically on the project we were interested in and work out something acceptable from the point of view of how we see the market developing. Those figures are not

extraordinary if you are entering into a major contractual negotiation; for instance, the one we did with Trinity College Dublin was a £650,000 investment over three years. That gave us our process, which we then developed.

Ray Gibbs: I would say that the funding levels you are talking about are aimed at the larger businesses, many of which may have shed R and D resources and are looking for inbound research to help them move up the value chain. As an SME, I could not entertain that. I have 250 shareholders in a publicly quoted company. I would not be able to establish that; I would not go there at all, but if I was Rolls-Royce, Tata Steel or whatever, I might think of that as value.

Q60 Chair: Dr Britnell, do you recognise this?

Dr Britnell: Yes. My understanding is that it is done on a project basis. Research is quite expensive. It is probably a consequence of a lot of money being put up for the building and for equipment for the NGI, but not necessarily much for ongoing costs. They need to run a sustainable operation. I agree that it is an expensive business to fund some of these experiments.

Q61 Chair: Do you think that the funding model makes sure that the ideal partnerships are getting established, or is it pricing out start-ups and innovative companies that could be coming in? I am trying to understand what your view is.

Dr Britnell: They are engaged with everything from companies comprising one or two people working at the institute now all the way up to multinational companies. It does not seem to me that it is pricing people out.

Q62 Chair: These start-ups are paying £50,000, are they, or do they come in under a different arrangement?

Dr Britnell: I do not know.

Dr Cox: It would certainly price us out—that's for sure. It totally precludes my company from engaging with the NGI. We do not have that kind of capital to invest in a quick look, and that is where we think a lot of the problem is. The best chance of a good return on investment is to engage with small and micro-companies that have potential and real applications in mind for great products and profit for the UK; otherwise, all that is happening is that you have partnerships with the likes of Rolls-Royce and BAE Systems and it is just a subsidy for them. They will do the research anyway; they have plenty of money. My feeling is that it is just a subsidised research facility for big business.

Tim Harper: Those funding levels sound a bit like gold, silver and bronze sponsorship for conferences. You are left wondering whether SMEs might get a chance to sponsor the coffee cups or something. I agree with Dr Cox that it is the SMEs and small companies that will become the medium-size companies and, hopefully, the large ones that should be getting the support and any subsidies, rather than large established companies. As we saw with Tata Steel, they probably had no impact whatsoever on its decision to close down UK operations, whereas for a small company £50,000 is a lot of money that would be far

better spent on payroll. Part of the problem is full economic costing at universities. If you just want to engage with a university, you suddenly find yourself paying for all the facilities, the estate and everything else. Generally, that makes it very difficult for small companies to engage, unless they can leverage some funding from people like Innovate UK. Innovate UK funding for graphene for 2016-17 is £1.5 million, so it will not go very far.

Chair: Thank you. Thank you all for coming in; I know that for some of you it was at relatively short notice. I am grateful to you for your time and evidence. We might have a few follow-up questions. I hope you will write back to us and answer those questions, because we want to make sure we look at this issue properly. We think graphene is a national asset and we want to make sure that we are leveraging it to the best of our ability as a country. Thank you very much for your evidence.

Examination of Witnesses

Witnesses: **Sir André Geim**, Regius Professor, The University of Manchester, and Research Professor, The Royal Society, and **Professor Luke Georghiou**, Vice-President for Research and Innovation, The University of Manchester, gave evidence.

Q63 Chair: Sir André and Professor Georghiou, welcome to the table and thank you for coming to this evidence session. I saw that you were sitting in for the previous panel so you will have heard the evidence that was given. We will discuss some of the issues that have been raised so far, but I am aware that you have brought some samples. Perhaps you could start by setting the scene for us and giving the Committee a sense of how important graphene technology and the discoveries associated with it will be compared with previous breakthrough technologies, especially for the UK? Sir André, would you like to start?

Sir André Geim: It is probably a question for me. Let me try to draw a very big picture. If we look around ourselves, everything we have been familiar with in terms of materials has width, lines and thickness. Until 10 years ago, people were not even aware that there were materials that are one atom or one molecule thick, so it is a revolution in terms of new materials. Some people say that this material is as important as bronze, plastic, silicon, iron or whatever; maybe this is the two-dimensional age. It is not only one material. Graphene is now used as shorthand for hundreds of different materials that are equally very thin. We just name this group of materials graphene. Academically speaking, it is as big as it could possibly be.

Ten years ago people did not believe in this material; they thought it was a blip on a computer screen of the human race. The situation has dramatically changed during, say, the last five years. Now it is widely accepted that this group of materials will be with us for many years—forever. It becomes a tool in our arsenal to explore this world. As for commercial opportunities, I am not a business oracle to predict the future of the graphene industry, but all the superlatives that the material has attracted—the strongest, the thinnest, the most conductive, the most pliable and so on—definitely indicate that there are many possibilities. People have suggested very revolutionary—I sometimes say science fiction—ideas. It remains to be seen.

What we are witnessing now is the first stage of the commercialisation of graphene. It is probably less than five years since it was demonstrated that this group of materials could be obtained in tonnes and in square kilometres. People have started to look carefully at this material. There are dozens of companies in the UK, maybe hundreds or thousands around the world, looking into these materials and trying to figure out what is and is not possible. Most companies are focused on graphene, which came a little earlier than other materials. At the moment all applications are, frankly speaking, simple, dirty and marginal improvements, not the killer applications that everyone is talking about. This is the natural progression.

Take the silicon age. It took between 20 and 40 years to study the properties of silicon in terms of fundamental research and applications. Then some very obscure applications came about, first ugly transistors, then simplistic circuits and so on. It took 50 to 60 years before we got our shiny iPhones. The same is happening in graphene. At the moment, there are marginal improvements in different areas: conductive composites, stronger composites, better tyres—people say that it has improved durability by a factor of two—better protective paint and so on. There are different companies focusing on different applications, but that is a natural process and we are at the very beginning of commercialisation.

Professor Georghiou: I would support what Professor Geim said. We are in an era of what you might call incremental innovations based around graphene, and a great deal more research and development will be necessary before the more radical properties can be exploited.

Q64 Chair: Can you explain, from the perspective of the university, what role the Government have played in R and D for graphene, and what has been their level of investment in Manchester so far? To your understanding, have the Government put any objectives or conditions on their investment, especially in terms of what the NGI is expected to deliver?

Professor Georghiou: The initial investment from the Engineering and Physical Science Research Council and the European Union was funding for the basic science that led to it. The university also put substantial early investment into the area, with its own resources. The scale-up of investment came after the Nobel prize when it was very clear that other countries were spending orders of magnitude more in supporting their researchers than the UK, and there was a Government decision to spend the sum of £50 million on graphene at that time. Of that, £38 million went to Manchester as part-funding for the capital cost of what is now the National Graphene Institute; the other £12 million was a competitive grant programme. It was only part of the cost of the institute, and we went on to make a case to the European regional development fund for the balance, as well as our own resources.

In terms of attached conditions, the specific aims of the National Graphene Institute were principally to pursue research, and at the same time to train people—PhDs and others—for the research to engage with business. It is not in any sense a catapult. There has been catapult-type funding subsequently for graphene—£14 million from Innovate UK to the Centre for Process Innovation—and we ourselves have taken the initiative to produce what we felt was a missing element in the graphene ecosystem by putting forward the project for the Graphene Engineering Innovation Centre. That attracted major inward foreign

investment from Mubadala Industry of £30 million. They asked that that should be matched from UK sources. It went competitively into the Higher Education Innovation Fund competition, and was supported with further funding from Innovate UK and a couple of other sources. That probably explains the capital funding picture. I see from EPSRC's evidence that they have a portfolio of about £88 million. That was our own calculation of what they are spending as well.

Q65 Chair: Thank you. You will have heard the previous evidence and seen the written evidence, as you just stated. A number of witnesses have made the criticism that academics are perhaps not best placed to make commercial judgments and establish commercial relationships; they do not have the necessary skillset by natural training, and that with graphene, as with other technologies, this can lead to missed opportunities and confusion in relationships. How do you respond to that allegation? Do you think it is well founded? If you do, what has the University of Manchester been doing to try to improve its expertise in the commercialisation of graphene?

Professor Georghiou: First, we would not expect our research scientists to be establishing the relationships with business. We employ professionals with very substantial business experience to do that. Of course, they do not define the science but they define the contractual environment and ensure that a proper system is put in place. Similarly, we have a wholly owned subsidiary dealing with intellectual property, UMI³, entirely staffed by professionals who are not on the university staff. It is a company with its own board, and by any measure it is seen as one of the UK's top companies of that kind. We were contrasted earlier with Cambridge and Oxford. We work very closely with them; there is no distinction in our approach. Our professionals work closely with their professionals. We are always in the top five for spin-outs, and we perform well in licensing. You may have seen in the newspapers in the last few days the announcement of a very major deal for retinopathy, essentially a potential genetic therapy for blindness of a particular kind.

Q66 Chair: Can you explain to me how many research projects are currently under way at the NGI?

Professor Georghiou: I am not sure that is a number that exists in one place. I can tell you how many partners or companies the NGI is working with.

Sir André Geim: I am not in any administrative position in the NGI or the university, but I think there are 47 commercial partners.

Professor Georghiou: My colleague has informed me that there are 65 projects altogether.

Q67 Chair: They are working on 65 projects.

Professor Georghiou: Yes.

Chair: That is very helpful.

Q68 Graham Stringer: Professor Geim, we have talked a lot about the commercial exploitation of graphene, which is very important for the country's economy, but how much has science in Manchester and the country benefited from your discovery of two-dimensional materials?

Sir André Geim: In what sense?

Q69 Graham Stringer: I am thinking of hard cash. We have heard that £38 million has been invested in the National Graphene Institute. Has there been a similar boost in science?

Sir André Geim: I am not sure I am answering the right question. Let me look at this from life—the social and economic perspective. Historically, universities have two major remits: one is education and the other is bringing basic knowledge. All of a sudden, big companies completely withdrew from long-term investment into curiosity-driven research. Government tried to plug this valley of death. Universities and big companies also responded. Universities moved in one direction and big companies moved even further, trying to leave everything to the taxpayer.

Now we have a new situation where universities are going from asking questions to being held responsible for commercialisation, which has never previously been a remit of universities. There is nothing wrong with that. As universities we are publicly funded organisations, and of course it is Government and the taxpayer who own the remit of the universities, but because it is a recent situation this remit is neither adequately funded nor does it even have a legal basis. Graphene and NGI is a perfect example. It was first organised as support so as not to lose our advantage in a very competitive scientific field. It is supposed to be an academic institution, but the pressure from outside pushed the university to do something about commercialisation. All of it was done from the university's coffers. There was an initial building and equipment for the university, but there are no running costs. It all comes at the expense of the quality of education and curiosity-driven research. In addition to the fact that research council initiatives are pushing more and more towards commercialisation, universities at a very local level are now starting to spend their money on commercialisation. It is done on a voluntary basis in the case of NGI. We have seen that there is a lot of misunderstanding or confusion as to what NGI is for.

Five years ago, I got an inquiry every day from companies about what they could do with graphene and whether we could help. Fortunately, now all those inquiries end up at the NGI. I heard that there are 900 every year, so there are about four inquiries per day from companies. How are you going to deal with this? The university managed to find money for one or two managers who can speak the same language as the companies, but there is no infrastructure, so it is about adequate funding. We are not a graphene catapult. Graphene catapults are funded. We are not funded for that, so the money comes from somewhere else. There are the same concerns about the legal framework. Because it is a publicly funded body, how do we do commercialisation? Are we allowed to deal with, say, Chinese or Russian companies and others, or should we get our graphene only from British firms and deal only with British companies? All of that is open.

Referring to *The Sunday Times*, it is ridiculous to ask a question about someone who deals with Taiwanese manufacture. If you are asking for commercialisation, you should provide

a level playing field for the universities. This field has not been defined. One thing that I would like to come out of this inquiry is an acknowledgement of this new third remit for universities, which was recently imposed, partially voluntarily, and to think about how it can be adequately funded and how the legal structure can be dealt with.

Q70 Graham Stringer: That is a very interesting answer. I do not want to put words into your mouth, but effectively you are saying that the Government have provided a nice building but have taken resources from elsewhere in terms of the research needed within the university.

Sir André Geim: Absolutely.

Q71 Graham Stringer: You are a very clever man, so I am entitled to ask you impossible questions. If the UK was to establish itself as the most competitive country in research and commercial exploitation, how much more money would the Government have to put into science and commercial development?

Sir André Geim: You put words into my mouth. You probably know the answer. In terms of the science budget, you know the numbers better than I do. In the G8 we are in the last position, below Russia and Italy, somewhere on a par with Greece, I believe, whether or not it is acceptable. In addition, the same flat budget for many years has now been eroded by the drive for commercialisation and the research councils' enthusiasm for it. There is nothing wrong with commercialisation; it should be done, but not at the expense of the quality of education and curiosity-driven research.

Q72 Graham Stringer: In terms of standardisation, I was surprised by the previous panel's evidence. If I correctly understood what they were saying, it was that there was no support for the standardisation of graphene in two-dimensional materials. If that is correct, what should be done about it?

Sir André Geim: For me, standardisation is a very small element in the big picture of both the science and the application of graphene. Commercialisation stops many companies looking at graphene, because essentially people say they are producing graphene. It is just the same graphite powder with completely different properties. These days, some graphite mines go to public listing, claiming that they mine graphene rather than graphite. That is not so. It has become hyped. It is very important to get standardisation, not only in our country but in others. People feel the need for standardisation, but maybe it would be better to ask Luke and the NPL how much money is needed to do that properly.

Professor Georghiou: I think you have a White Paper jointly authored by our colleagues and NPL that sets out the need for an initiative in this area. This is a very direct answer to the question posed by this inquiry: what elements are needed to support the commercialisation of graphene? We have an incomplete ecosystem; there are other missing intangibles—for example, a well-developed venture capital sector that fully understands graphene and is able to invest in it. I would support that. At one end, you need standards to eliminate what André referred to earlier—the bottom feeders who pretend they have graphene when they do not—but it is much more important, as we go up the

system, to ensure that there are proper trading relationships and to help those who are developing applications to know exactly what material they are dealing with.

Q73 Chair: In his answer Sir André spoke of some confusion, which was very interesting to the Committee. Is this confusion about the different roles of the NGI and GEIC? Most of our industry witnesses seemed quite clear about the different roles and seemed to understand TRLs and so on. Are you experiencing challenges in this area, or do you think there is no confusion?

Professor Georghiou: It is very difficult to disagree with somebody who has a Nobel prize and is talking about the subject they know more about than anyone else in the world, but speaking from a broader university perspective, we value our engagement with business. We had the highest level of engagement with UK business in 2013-14 and the second highest last year, and the third with SMEs as well. We are a university that, since its foundation in Victorian times, has been committed to working with business in our normal activities. That is where the National Graphene Institute is situated. It is part of the university. It is an institute because there are benefits from having concentration; it allows a better quality of facilities and, as we have heard, it allows a very clear signal to be sent not only to UK industry but around the world; and it helps, as it has proven, to attract inward investment to the country, but its prime mission is none the less not that of a catapult or a Fraunhofer institute. That job belongs to the Centre for Process Innovation and will in future belong, in a slightly different way, to the Graphene Engineering Innovation Centre.

Q74 Chair: Do you think industrial partners are clear about the different roles that the NGI, the GEIC and the Centre for Process Innovation will play?

Professor Georghiou: I believe so. We welcome criticism; it helps us to improve, but this Committee has heard a very concentrated dose of it from probably the only quarter at the moment.

Q75 Derek Thomas: You said that about a third of your engagement was with SMEs. How do you respond to the criticism you have heard this afternoon from some SMEs that they do not get fair access to the institute's research facilities in comparison with your larger business partners?

Professor Georghiou: We said in our evidence that we find it easier to work with established companies. That is not necessarily a statement about size; we include SMEs in the term "established companies", but they have to have a sufficiently developed infrastructure and employ people who are able to use the relevant science.

Quite separately, we are putting a lot of effort into supporting start-ups. A number have been generated not only by our IP but our students. We have attracted funds to set up student-led businesses in the area of graphene, with some quite radical ideas, supported by very successful business alumni who themselves have founded global corporations. We work with SMEs. We try to direct them to support schemes. We heard discussion about the quick look earlier. That is modelled exactly on the Government's SBIR scheme and is

the entry point for it. We use it to try to take companies to get Innovate UK funding. We are not even allowed to provide a free service, other than friendly conversation and events, because that would contravene state aid rules; £50,000 may sound like a lot of money, but it would be what it costs us—we tend to work at cost—to employ a postdoctoral researcher to do the necessary work.

Q76 Derek Thomas: To continue that theme, to what extent do your partnerships with large businesses, and any confidentiality agreements with them, prevent you from working with SMEs? Do you understand the concern that some SMEs may feel they do not get fair access because of those agreements?

Professor Georghiou: I think it would be better to say that if there is a partnership with a business in a particular area and our researchers are working with one company, we cannot then work with another company in an area very close to that. It would not matter if the incumbent was a large firm or a small firm; that would be the reason. Indeed, that is the reason for the case you heard about earlier. I have to say that the 15-minute response was to the second inquiry when the same material was submitted, so naturally it could be dealt with very quickly. The further email about being willing to meet was a courtesy to the Member of Parliament. We did not say we would change what we did in the project. If we were engaged with somebody already in that area, we would not be allowed to go further.

Q77 Derek Thomas: You referred to your support for start-ups and spin-outs, but in your earlier submission you referred to the fact they would come in at what you call the second or third phase, when the market begins to mature.

Professor Georghiou: Yes. That phase is now starting. We are not saying that it is something in the future. We have a group of those.

Q78 Derek Thomas: To a lay person like me, what is a mature market in graphene?

Professor Georghiou: As we have been hearing, it is probably characterised by a move from the first wave of companies, who perhaps overpopulated graphene manufacturing activity, to the engagement of those who make graphene with applications. This has been a theme we have heard in both sessions, but there is now a move to applications, which will feed back into manufacture as well; they are not separate. That is an example of maturity. Of course, applications will generate revenues for companies and allow real growth.

Q79 Derek Thomas: Do you think the opportunities for SMEs will suddenly become better now—the place will expand and the landscape will change for them?

Professor Georghiou: There are already opportunities for SMEs. Perhaps we need to distinguish research partnership, which is what a university can do, and sometimes perhaps commercialisation of intellectual property, and what you might call the diffusion of technology or extension services. There could be a role for Innovate UK and others to do more in helping companies learn about the knowledge that is already there and make best use of it.

Q80 Derek Thomas: Is it possible that one of the small SMEs that at the moment has not had access has the very piece of application you have been waiting for all these years?

Professor Georghiou: If they come in with something we can help with and we are not working with their direct competitor, which would be damaging for them, we would be delighted to hear from them. As my colleague said, we have slightly more than 1,000 inquiries a year, of which 600 are from businesses. We have a total of 250 academics, including postdocs, working in the area.

Q81 Jim Dowd: I noticed that both of you were sitting at the back of the room when we heard the first panel. You will have heard my questions to Dr Britnell about BGT's relationship with a university. Can I ask about the other side of that relationship? Professor Geim, I noticed that you were not particularly complimentary about *The Sunday Times* article; you described it as ridiculous.

Sir André Geim: As you better than all other people will know, how can you believe some of the comments written by some journalists?

Q82 Jim Dowd: Indeed. We have been on the other end of that on many occasions. Could you characterise the university's relationship with BGT?

Professor Georghiou: The relationship began as a larger-scale research collaboration in BGT's previous existence. It lost a substantial investor at a certain point and moved to its current position of project partner. We have shares in the company, as previously stated. That has allowed us to have strategic discussions, but those are kept completely separate from the relationship we have with them in projects, which is contractually bound. I would like to stress what you were told in the previous session. BGT is not in the National Graphene Institute; it does not work specifically with the NGI and never has.

Sir André Geim: The relationship with BGT came from experience, which was mainly with big multinational companies. During the last 10 years probably every single well-known multinational sent its scout to my office. They come and go. They find that there is no immediate threat to their business and they can wait until small companies try these uncharted waters. Their standard model these days is to snap up those small companies. Small companies are important, as was emphasised again and again. This company in its previous incarnation as Bluestone—*[Interruption.]*

Chair: I am going to suspend the session until after we have voted and we are quorate.

Sitting suspended for Divisions in the House.

On resuming—

Chair: I apologise for the delay in restarting the session. Occasionally, democracy intervenes in our Select Committee proceedings, and I am afraid we cannot rush it. Thank you very much for your patience.

Q83 Jim Dowd: Before we were so rudely interrupted, you gave your impression of the relationship with BGT. You will recall that I asked Dr Britnell various questions. He said they now had no connections—I am not sure whether he was referring to Chinese businesses—certainly with the university in China. He also gave an absolute undertaking that they had not shared any intellectual property with any of their far east connections. From your knowledge, do you have any reason to dispute that?

Sir André Geim: I know the situation with BGT. I was involved, mostly from the scientific perspective, with the whole story. I know the whole story. It is kosher; the university has done absolutely nothing wrong. I am surprised that we are repeating *The Sunday Times* allegations so many times during this session. The university investigated the story. I personally know the academic who complained. That person complained to me about other academics stealing academic secrets. The person also complained about another company, 2-DTech, which submitted evidence. That was a university company, which, essentially, was spun out by my former PhD, a postdoc. If I were a journalist and had the choice of making allegations against a university and a British company and a company with a Taiwanese element, which is translated as Chinese, I would probably select the second story.

Q84 Jim Dowd: There were two different organisations: one was Chinese and one was Taiwanese. They are not the same.

Sir André Geim: I know.

Q85 Jim Dowd: You must understand that if allegations of impropriety or wrongdoing are made to this or any other parliamentary Committee, there is an onus on us at least to examine it rather than ignore it.

Sir André Geim: I appreciate that.

Q86 Jim Dowd: Do you understand people's reservations, when dealing with the NGI and the university, if the university has a financial interest and shareholding in one of the partners but not the others? Do you understand why people would be concerned, or is it entirely unreasonable?

Sir André Geim: You now go from one specific case to another. This was a very specific case after many years of frustration in dealing with big companies that did not want to do anything. Well before the Nobel prize and the NGI, I started pushing our PhD students and postdocs to start their own companies. I did not have shares in any of those companies and rejected any remuneration, but I am happy about how those companies grew. For example, Graphene Industries began in 2007 and is still trading. It was profitable from day one. As to 2-DTech, another company, the story goes that I told the person who opened the

company that from the next month they would either be unemployed, because I had stopped their contract, or start their own company and have all the support I could provide. This is the story of 2-DTech that eventually was taken over by Versarien. But those small companies did not want to grow.

One of the things this Select Committee should probably look at is what stimulus you should give to PhD and undergraduate students to start their own companies, but that is another story. There was also frustration not only about the big ones but from our own start-ups. Then the companies came. The first one was BGT with a history of making real graphene products: touch screens for phones, batteries and transistors. The company burned \$50 million trying to push those products to the market and went bust essentially. That was the predecessor of BGT. You obviously value a company with expertise, and that went bust. They learned something from that expertise, and they were the very first. Of course, there is some sort of special relationship with BGT and 2-DTech—we still have shares in both companies—from the simple fact that our students are working for those companies. That is also important. Let's build an ecosystem in which those companies can work. I would not say that with the new companies coming about, or even with some companies sitting in the NGI; that special relationship has been lost, but behind every question there is a history.

Q87 Jim Dowd: You would say that people's fear of a conflict of interest with university staff being on the board of a company is ill-founded.

Professor Georghiou: It is absolutely the norm. We have a number of academics who sit on the board, never in an executive position. They are there either to provide technical input or to take part in strategic level discussions. I would say it is quite desirable rather than something to worry about. In all cases, they have to go through a formal process of getting permission, in this case at the level of our board of governors. I looked for another example just to show that it is not a local practice. The lead graphene academic at Princeton University is on the board of a graphene material-producing company called Vorbeck, which was part-founded on IP developed at Princeton itself. It continues to license that intellectual property from that university. The company has set up a research centre in that university, and it works very happily with other companies. This is the pattern of driving technology.

Q88 Victoria Borwick: What a fascinating afternoon this has turned out to be. Can we go back a little bit to what you feel is the main role of the institute? Is it undertaking research or commercialising the technology?

Professor Georghiou: It is not really an either/or answer, in the sense that of course it has the principal role of undertaking research, but it is providing a bridging role. In the business case for our ERDF support, we undertook with the institute to increase the scale of graphene-related research, including applied research; to grow the talent pool, particularly of researchers; to collaborate with other universities and industry; to aid commercialisation; to support spin-outs and start-ups; and to promote the role of the north-west of England as a leading centre for this activity. That was the formal list we worked to.

Q89 Victoria Borwick: Could you clarify for us what you think is the role of the Graphene Engineering Innovation Centre? Is the innovation centre the vehicle? What is the separation between the different bodies?

Professor Georghiou: It is a clear separation.

Q90 Victoria Borwick: Between that and the institute.

Professor Georghiou: Yes, otherwise we would not have sought a different model. In terms of the technology readiness levels map, it forms the final part of the bridge. There was a celebrated report by this Committee's predecessor about that bridge. It allows the technology to be taken to demonstrator level, and in this case companies can work on the premises. The building design looks very fine from the outside, but it is fundamentally a large shed that can be configured so that you can do demonstration projects and scale up activities. That is its function.

Q91 Victoria Borwick: You said they had to be separate. Could you explain for the benefit of the Committee why they need to be separate?

Professor Georghiou: The Graphene Engineering Innovation Centre, as we have all politely called it this afternoon—in Manchester it is always called “the Geek”—is in a more commercial space. This morning, I saw a presentation on its construction; for example, it is liable for VAT, whereas at the National Graphene Institute, as a research place, the building was not liable for VAT.

Q92 Victoria Borwick: That is a physicality reason, but are there other reasons why they are separate bodies? Is it because one is research and one is development?

Professor Georghiou: Yes. One is development and more downstream activity. It will be expected to develop substantial consultancy contract income, so it is more in the catapult-type space.

Q93 Victoria Borwick: Is it available for a broader variety of people to use? Do people have to use one to use the other? Is there a distinction of users?

Professor Georghiou: We would be happy that you could graduate from one to the other, but it would certainly be open to those already at that scaled-up level to use the facilities.

Q94 Victoria Borwick: What progress has been made in getting the institute running at full capacity? Is it to do with the number of labs? Can you talk to us about how you see it?

Sir André Geim: As I said previously, I am not in any administrative capacity at the NGI, but I am an academic user of it. It was opened in April last year officially, but you will appreciate that there was a period of time during which academics moved in. Now it is over-subscribed. There are problems putting people into it. It is over-subscribed, and even

the places that were supposed to be there for companies and so on are now being moved around. To be fair, the labs are not at full capacity; it is just the normal process of commissioning equipment and so on.

Q95 Victoria Borwick: Currently, it is fully occupied with the research function.

Sir André Geim: It is fully occupied. If anything is reserved, it is reserved for equipment we are waiting for.

Q96 Victoria Borwick: To go back to the university, what is the strategy on intellectual property rights for graphene? Inevitably, when things are being developed—this was touched on in the earlier session—that is what comes first. Is your strategy different from those of other universities and organisations? How do you see your role?

Professor Georghiou: In general terms, it would be the same as for other universities. We develop intellectual property in collaboration with companies. The normal situation would be that they have the full rights, usually by their sector, but we always keep the right to use it in further research, and sometimes to apply it in other sectors as well if any public funding has been involved, and we have not been bought out altogether, which is a rare situation.

In terms of the intellectual property that ends up owned by the university, the royalties principally go to the staff who invented it. I think we have one of the most generous deals. The starting position is that 85% would go to those staff. They might trade some of that share in return for assistance in securing patents and so on. That is how it would work.

I suppose that what would be different from what you might see if you were doing graphene research anywhere else is that we have the capacity to invest in early stage graphene propositions ourselves. We have two dedicated graphene intellectual property business managers in the institute, and we now have specialist staff in our IP company who understand graphene and related materials and are able to work on that.

We previously developed 2-DTech as a vehicle but sold it to Versarien; it is now used in social media by Innovate UK as a frequent example of an excellent innovative start-up company. We have just started a new translational business model, which we call Graphene Enabled Ltd. We head-hunted an experienced executive to work in that. It will be a bit more of a demand-pull approach. The company will identify opportunities for graphene and seek to match that with available intellectual property.

Q97 Victoria Borwick: Are you involved with the intellectual property on all the things produced there, or in some cases are people just using your space and, therefore, they have the IP?

Professor Georghiou: There are not many external people using it. Of course, academic collaborators, if they come, will own their IP. As far as I know, there is one company based in the NGI—Morgan Advanced Materials, a large British materials company. They work with us on a joint IP project.

Q98 Victoria Borwick: You have some IP rights on almost everything that is produced there.

Professor Georghiou: Yes. Normally, when we work with a company we have some rights on the IP to ensure that the national interest is safeguarded. They would have all the rights in their sector based on what they paid for.

Q99 Victoria Borwick: In your view, how robust is the institute's IP strategy? Have you had any way of stress-testing it, or testing it against other organisations?

Professor Georghiou: Absolutely. We cannot really say it is the institute's IP strategy; it is the university's IP strategy. The institute is simply a part of the university. We carry out international benchmarking every year, and have our strategy reviewed by an international intellectual property lawyer every two years. There have been two commissioned reviews specifically about graphene IP strategy. We wanted to nail the very ill-informed comments made about early patenting on graphene. These were done by extremely senior people in the world of IP. Both of them endorsed our general approach and made some small and very useful suggestions, which we have adopted.

Q100 Victoria Borwick: In a fast-moving field like graphene, is every two years sufficient?

Professor Georghiou: To look at the system rather than at the portfolio itself, yes. All individual IP decisions also involve external consultants and IP lawyers.

Q101 Chris Green: Professor Georghiou, are you aware of criticisms of the National Graphene Institute's approach to seeking patents?

Professor Georghiou: Is this about the "whether graphene could have been patented at the beginning" story? My colleague was there before anybody.

Sir André Geim: That is a very long discussion. To answer shortly, at no point could graphene be patented before our first publication in 2003. Patents do not improve academic careers. Some academics publish too many patents, but in this particular case a patent was drafted. Then I had a communication from a multinational company that said essentially, "We are not interested in supporting this patent." If I quote it correctly—it is written somewhere in the *Financial Times*—it said, "If this material turns out to be as good as it promises to be, after 10 years 100 patent lawyers will write 100 patents every day, and you will spend the rest of your life and the GDP of your little island"—I remember that part—"trying to sue us." It was rude, but the point of view of that multinational was very educative, because it was clear that the material had applications; we could possibly envisage them at that moment, but not those that would come 20 years from then.

Therefore, in a sense my personal decision to withdraw from patenting on the basis of the Nobel prize acknowledgment or paper was right. It probably saved the taxpayer £50,000. I have 10 patents or so at the moment for very specific applications that are defensible. They are not broad. If one patent can cover everything, why are there 10,000 around the

world? You have to think about the cost of patents. Each patent costs £50,000 to support over its lifetime. You have to take a very specific decision about whether it is worthwhile; whether it is within 20 years, or whether it is defensible. That decision was completely right.

Patenting is a very painful subject for me, not just this particular graphene patenting. Patents are a very inaccurate and artificial measure of success. Because it is so easy to get the number of patents, journalists quote how far the UK is behind China. We heard from companies what they think about Chinese patents. We are not behind; we are more selective in publishing. Maybe we have 1%, but using patenting as a measure of success is absolutely ridiculous.

Q102 Chris Green: How do you judge the quality of a patent? How do you judge that British patents are of a higher quality than those from other countries?

Sir André Geim: History will tell us later. There is pressure from the media and politicians to measure the success of industrialisation and commercialisation in terms of patents. We experience this pressure; all universities do. I have experienced it enormously over the last 10 years. I am human; I cannot resist all the pressures. If you asked me how many of those 10 patents I should have had, I would probably say three or four. I have 10. I doubt that six of those are really going to play anyway. Many universities experience that pressure. If this Committee held a special session about patenting by public funding bodies rather than hearing about it in this session, it would save taxpayers millions of pounds every year. Patents by public bodies are by definition a bit of an oxymoron. Patents are a defensive mechanism to defend your commercial product. Universities by definition do not produce commercial products. There is a contradiction. Many people say we need patents to protect our IP, but the pressure now is such that the pendulum is in the wrong place. That is what I am trying to say.

Q103 Chris Green: There is another aspect. Rather than going down the patent route, if you keep the knowledge in-house and keep it under wraps, so to speak, that knowledge within an institute or university builds up and it is very valuable to the university, but that means that perhaps the knowledge is not shared as much as it could or should have been.

Sir André Geim: Absolutely, but a university does not produce commercial products. To keep knowledge within the university and not give industry an opportunity to access it is self-contradictory as well. We have know-how and expertise, and that is what companies on one side appreciate in their interactions; other companies also appreciate it and want to use it. Around the NGI there is a unique ecosystem where we can help small companies and entrepreneurs to start graphene businesses. There are many graphene enthusiasts around, sometimes with science fiction ideas; they have heard that graphene is 200 times stronger than steel and 1,000 times thinner than hair, so let's make a transatlantic bridge, or a hammock that will catch falling airplanes. That is what we want to be there for, but I return to the point I raised previously: there is no support to do this for the community of enthusiasts and entrepreneurs; it is all done voluntarily at the expense of the university and other funders.

Q104 Chris Green: When you say voluntarily, I wonder about the differences between the approach in Britain and the approach around the world. If you look at the number of patents around the world, is there more political pressure in some countries to demonstrate that the institutes and universities are doing something good, and it is a numbers game more than anything else?

Sir André Geim: Absolutely. We saw this scandal in terms of academic publications. At one moment the number of published papers was considered an example of how successful an academic was. It was pressure. Now quality counts more. In China, a respected company told me—not my words—that there are too many useless patents. This goes way beyond that. We do not want to take China as an example, but even in this country there is misunderstanding of the nature of defensive patents. This kind of contradiction in university patenting wastes a lot of taxpayer money.

Professor Georghiou: Some research has been done that shows a surge in patenting among certain Asian universities in the month before their annual report comes in, because any indicator is feeding back and disturbing behaviour. Some years ago I visited the research establishment of one of the best known US companies. They told me that they had not placed huge emphasis on patents until it started being reported in their shareholder briefings. From then on, they were under pressure simply to increase the number. As soon as you measure something, you affect people's behaviour.

To add a point about the initial patent—there is a further part to the story to complement what my colleague told you—there were in existence US patents that had completely anticipated this approach. The patent would not have passed the test at that time in any case, had we pursued it. It is interesting to note that the judgment is borne out, because those patents have not been commercialised; they were uncommercialisable.

Q105 Chris Green: Because of the cost of monitoring and enforcing patents, do you want to reduce the number?

Professor Georghiou: We try to be very selective in the ones we patent. We think the ones we have patented are important. Currently, it is costing the university £500,000 a year to maintain the graphene 2-D material patent portfolio. This will rise to £750,000 with the ramping up through the NGI. We have a fund to support universities in those activities—the Higher Education Innovation Fund—which is very important to us. Even though we are one of the biggest beneficiaries of it, because it is done on past performance, none the less it is a burden for us to carry. You could say that if we are spending this much on graphene IP we are probably spending less on other things that we should be looking after as well.

Q106 Chris Green: If the Higher Education Innovation Fund made more funds available, do you think it is likely that you would do more patents, or would you judge pretty much on the same criteria?

Professor Georghiou: At the moment we are spending everything that is needed on graphene because we feel we have a real duty there. You would probably see it more in biomedical patents or some other area.

Q107 Chris Green: Simon Howell left the university. What was the reason for that?

Professor Georghiou: Of course, it is up to him to say what his reasons were, but he—

Sir André Geim: I know the gentleman quite well. We agreed that he should start working for me from next week.

Professor Georghiou: He has moved from one organisation to another.

Sir André Geim: He is now coming back to the University of Manchester.

Q108 Chair: There are different cultures around patenting from nation to nation. I understand they have quotas for patents in China, but it is also a measure of academic success alongside citations and funding, whereas in the UK we do not really measure it. We measure citations and funding but we do not measure patents. I appreciate the points you have made, Sir André, about the political and journalistic pressure for patents, about misunderstanding and about the need to focus on quality. Is there something missing in our system that means that getting patents is too hard and too expensive for people who should get them? Are people who should be trying to get patents missing out because of something that is dysfunctional in the system? Do you think that is so, or is the system right and the correct number of patents is being filed at the moment? Are we or are we not missing opportunities?

Professor Georghiou: It is difficult to know what the right number is.

Q109 Chair: It is not the number; it is quality. Are we getting the opportunities? Is it easy enough? Are there players who are essentially priced out of the market?

Professor Georghiou: They are probably not priced out. Many institutions lose money on their intellectual property activities—as many in the US as in the UK. Probably our academic incentive systems are still not sufficiently rewarding those who produce valuable impacts by their research, which could be via patents or via other means. In that sense there are people who could probably take their work and push it more in that direction but who are not as incentivised to do that as they could be. The real reason why we have far fewer patents in the UK than in other countries is the fact that our three leading patent holders in graphene are all universities: ourselves, Oxford and Cambridge in that order. We might ask why business is not taking out more patents in the area. As discussed earlier, I would not say it is necessarily a measure of the quality of our graphene businesses—those we have are very good—but it probably is some indicator of activity or general level of interest.

Q110 Chair: Why do you think that level of activity is present in the UK compared with other countries?

Professor Georghiou: It is probably true for the wide front of high-technology sectors. If we look at other areas, the proportions would probably be similar. The exception is pharmaceuticals, where the whole existence of the area is dependent on patents.

Q111 Chair: In your written evidence you wrote that “income from industry has increased...as a direct result of anticipating the NGI coming on-line.” I know that the NGI had its formal opening last year. What is the timetable for its coming online, and what will that mean in practice? In addition, what is the timetable for the GEIC? It is hotly anticipated by the industrial witnesses who were here before you. Many are keen for graphene applications to get as much of a push as possible. What are those timetables?

Professor Georghiou: The NGI is now online. We could not wait for somebody to come to open the building, if you like, so collaboration started in other places and then moved in. The Graphene Engineering Innovation Centre—I may have to correct this answer afterwards—has passed design stage 1. We have also demolished a derelict building on the site where it is to be built. I believe construction will start later this year or early next year, and I think the online date is 2019. I am not absolutely sure, and I may have to correct that afterwards.

Chair: I thank both of you for coming to give evidence, and for your patience as we abandoned you for a big chunk of the session. You have helped us to try to understand some of the issues at hand, and taken us through questions with great patience. We might have a few follow-up questions. This is obviously a technical area, but it is a very important one for this area of growth in our science and technology sector. I hope you will be kind and reply to our questions and help us as we try to investigate how we can properly harness a very exciting technology for the United Kingdom. Thank you both for your time.