FORTY-SECOND
CONVOCATION ADDRESS

BY

PROFESSOR MARK E. WELLAND, FRS, FREng.

UNIVERSITY OF CAMBRIDGE

CAMBRIDGE, U.K.

25th FEBRUARY 2008

INDIAN STATISTICAL INSTITUTE
KOLKATA

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Professor M.G.K. Menon, President of ISI, Professor Sankar K. Pal, Director of ISI, Professor Bimal K. Roy, Dean of ISI, Distinguished faculty members, students and guests.

Let me start by saying what a great honour and pleasure it is to be speaking at this important event. Convocation marks the start of a new phase in all your lives. You have completed years of hard study and are now set on the path to be the next generation of leaders and innovators that will shape both your own country and the world around you.

In talking to you today I wanted to share with you some connected but ultimately very different aspects of my experiences over the last 20 years. I want to say something about my field of research, nanotechnology, and I also want to provide you with some strong themes that have guided my life as my research developed.

When I arrived in Cambridge in 1985 as a fresh young lecturer the word nanotechnology was virtually unknown. Indeed, over the past two previous years whilst working at IBM in the USA, I had been researching into a new technique that eventually became the cornerstone of what has become nanotechnology without any sense of where it would lead. What made this technique unique was that the very first time it was possible to look at the surface of virtually any material and directly image the atoms and molecules that constituted that material. Nanotechnology, of course, is in essence simply about understanding, exploring, and ultimately exploiting the properties of matter at the atomic and molecular scale. This new technique opened the door onto a world that had never previously been accessible. I think that when I was appointed to my lectureship at Cambridge, that there was considerable incredulity as to whether this technique really worked or not. I can clearly remember giving a lecture during the interview process where I showed, almost certainly for the first time, images of individual silicon atoms arranged in a beautiful pattern on a surface. I am quite sure that some of the audience looked at those images and thought they were merely computer generated rather than the real atoms on the surface. The extent to which this incredulity reached only became clear to me when I finally arrived to take up my position only to find that I had no office, no laboratory and no funding. It was at this time that I learnt one of my most important lessons.

There were two major challenges. The first was obviously to find space and funding to establish my laboratory, but the second and perhaps more difficult challenge, was that I had to persuade the research community in the UK that nanotechnology was going to be an important area and that special funding should be set aside for it. In pursuing both these strands I needed at one level to convince my colleagues in Cambridge of my requirements and needs in respect of space and facilities and at a quite different level start to talk with senior academics and policy makers in order to provide the funding platform from which nanotechnology research could be initiated. Putting aside the detailed technical and strategic arguments that had to be made the lesson I learnt from this process was that in planning one's future one needs to have a mixture of short-term and long-term aspirations both of which needing to be strongly centred about cogent argument. I cannot stress too highly the importance of balancing short and long-term aspirations. Doing just one without the other would ultimately have been ineffective. Of course, my immediate colleagues who had to suffer this young upstart from the US coming and removing their laboratory space to make way for his own without question made me unpopular. Fortunately, Cambridge is well used to this approach and ultimately responds to well founded argument. As I said earlier, in respect of my local aspirations these have now been more than satisfied with the establishment of a purpose-built Nanoscience Centre at Cambridge. At a national level significant funding has now been provided both for basic research and for the commercialisation of research in nanotechnology. I would estimate that the UK government has probably invested the order of £200 million in nanotechnology over the past few years. Of course, this national success is down to many factors and my role was ultimately small. What it did mean however, is that there was significant funding available for me to bid against which in turn allowed me to expand my activities in Cambridge thus closing the circle.

I now wish to turn to talking rather more specifically about what nanotechnology is and why the annual international investment in it exceeds $1 billion per year. If one looks back at the history of technology one can see a number of significant trends. One of these is miniaturisation. Think of a clock or watch. In England we have an ancient monument called Stonehenge that is several thousand years old, 100 metres in diameter and made of massive stones arranged in a circle. This was effectively used to tell the time. Fast forward a few thousand years and the timekeeping element that is contained in your watch is just a few millimetres in size. This miniaturisation of technology is reflected in many products around us. The mobile phone, the digital camera, medical diagnostics, and of course, the ubiquitous computer. A single computer chip which measures only 2 cm across contains over one billion transistors, the building blocks of the computer. And within each of those transistors there are engineered structures that are in some cases only a few tens of atoms in thickness. It is quite logical to ask how much further can this miniaturisation process go. And this simplistically is where nanotechnology comes in. Nanotechnology represents the end of the miniaturisation road. It deals with technology on the scale of atoms and molecules, the building blocks of nature, and as such is the ultimate in science and engineering. It is important to recognize that everything around us; the buildings, the trees, life, televisions, are not only built from assemblies of atoms and molecules but that their very properties depend upon how those atoms and molecules are arranged and connected together. For example, whether a material is hard or soft, conducts electricity or not, what colour it has, or even whether it is magnetic, depend upon the detailed arrangements of the atoms. Nanotechnology therefore is not just about miniaturisation, but is also a technology that can design or change those very material properties upon which we depend. It is only by engineering on the scale of atoms and molecules that one can truly control the properties of materials. Finally, since atoms and molecules are the building blocks of nature, nanotechnology has potential application in all fields. It is perhaps most obviously relevant in computers, digital cameras etc, but also has implications in medicine, biology and materials in general. The combination of this ultimate in miniaturisation with application across all fields is ultimately why virtually every government around the world is investing in this technology.

Let me give you two very different examples of work in nanotechnology in my lab at Cambridge. The first is related to harnessing sunlight to generate electricity. In a world where global warming and climate change are becoming ever more rapidly major issues, harnessing the sun's energy to directly produce electricity is high on the agenda of many countries research. The challenge is to produce a technology that is efficient, in other words makes most use of the sunlight falling upon it, but that is also cheap and easy to manufacture. The process we have developed relies on nanoscale hairs of zinc oxide that look very much like grass except on the nanoscale. In one square millimetre, about the size of the head of a pin, there would be approximately 400 million zinc oxide hairs. Zinc oxide, by the way, is a very common material that is used in cosmetics and sunscreens. Once we have coated the surface with the zinc oxide hairs we put a very thin layer of plastic over the top that melts down in between the hairs. Finally we put a very thin layer of metal on the top. The whole structure is far thinner than a piece of paper and can easily be produced over large areas, such as a sheet of glass. The principal is that light falling on the solar cell is trapped between the hairs of zinc oxide and in so doing a tiny electrical current is produced. The more light and the bigger the area of the cell the bigger the current. This cell only works because the zinc oxide hairs are grown on the nanoscale. If they were much bigger the cell would simply either stop working or become grossly inefficient. This is therefore a true nanotechnology-based product. In the lab this cell is still not efficient enough for commercial production but since we are a long way from the theoretical limit for its performance, we have great confidence that we will soon be able to explore commercial production.

My second example is that of trying to combine physics, engineering and medicine in a single project. In diseases such as Alzheimer's, Huntington's disease and

Parkinson's, material is deposited in the relevant organ in the body. The material itself is actually a protein that in a normally functioning body is used as part of cell metabolism. But in an ageing body, or in a body where some of the normal cellular processes have been compromised, the protein aggregates into long wires of material that slowly build up over time. Thus, in Alzheimer's disease the protein Abeta is deposited in the brain in the form of long wires called fibrils. Our interest was in trying to elucidate the mechanism by which the protein aggregates to form fibrils. We found a number of remarkable properties of these structures. Firstly, that they were incredibly perfect. If you imagine assembling a necklace from 50,000 individual beads each one connected perfectly to its neighbour in one long continuous string then this will give you a good idea of what the fibrillar structure is. In the case of Alzheimer's the bead is of course a single protein molecule so that the diameter of the protein necklace is just a few nanometres. In fact on average one would need to go 50,000 protein molecules before there was any defect in the structure at all. This incredible perfection has an immediate implication in respect of the stability of the fibrils once formed. It is more difficult to imagine altering or even reversing a perfect structure as opposed to a structure full of defects. A highly defected structure presents easy access for chemicals or even drugs to perturb and break up the structure. A perfect structure has fewer possibilities in this respect. This observation immediately gives an explanation as to why material once deposited in the brain is both difficult to remove and effectively irreversible. The second interesting property of the fibril is that we found it to be as strong as spiders silk. This is partly due to its perfection but also due to the strong atomic forces that assemble the fibril in the first place. This mechanical strength, actually amongst the highest of all biological materials, once again makes the structure almost indestructible once formed. By applying nanoscience tools in a laboratory environment we are able to both explain some of the properties and behaviour associated with diseases such as Alzheimer's and can even start to think about exactly how one might perturb the mechanisms by which such structures form.

The two examples above I hope give you some clear indication that nanotechnology has some potential impact in addressing issues that are of major concern to all countries. And these are just two examples. There are many such scattered across the commercial and medical sectors. We are, for example, working with Nokia, the mobile phone company, to research into what might be in our phones in 10 years time. Imagine a phone that could continuously monitor your health and remind you to take your medicine, or even automatically radio for help if required. Or a phone that could smell your food or drink and tell you whether it was contaminated or past its sell by date. These are all areas that we're actively researching into.

In all my nanoscience research over the past 20 years and in all the successes, small or great, that I have been involved in, there have been two further guiding principles that I think are especially relevant here today. The first is about setting oneself the very highest standards to aspire to. In everything I have done at Cambridge I have always looked over my shoulder to where ever I thought the very best work was being done. In some cases this might be elsewhere in Cambridge, more often than not outside the UK. Where is not relevant. All that matters is that one should constantly hold a mirror up to oneself and ask whether what you are doing could be done better and what might you learn from how it is done better elsewhere. This does not mean that in every facet of one's work that one can expect to be the best. On the contrary, it is actually rare to be the best but it can be commonplace and routine to aspire to the best. One consequence of such an attitude in a global context is that one builds long-lasting and incredibly fruitful relationships with other research groups across the world. I have collaborations across Europe, in the Middle East, in the USA, in Japan, Singapore and here in India. These collaborations are almost exclusively built around a desire to work to an even higher standard on a chosen topic and to learn from ones collaborator. In this sense, science is a truly global economy.

My last guiding principle comes back to the heart of what today is about. The greatest asset of any institution whether academic, commercial or governmental are the people that work in it. I am often asked what makes Cambridge a great university. It is tempting to list the 800 years of its history, it is tempting to cite the beautiful and ancient colleges in which we all work, and it is tempting to list the incredible facilities that we have at our disposal. But all of these become irrelevant without the excellence of the people that work and study in the University. And the most important of all those different people are the students themselves. Students that come from a whole range of backgrounds, religions, nationalities and political persuasions. They meet in Cambridge with those aspirations to excel that I have mentioned previously, they spark off each other, they challenge their teachers and they leave the place intellectually enriched. The prime minister of India, Dr. Manmoan Singh, who studied at Cambridge, was recently awarded an honorary degree and at the degree ceremony gave a truly impressive speech that, although far more eloquent than my own, resonated with some of the principles I have alluded to. The importance of being strategic about your future, aspiring to the very highest possible standards and valuing the people with whom you will work with henceforth.

And so here today at ISI it gives me the very greatest of pleasure to congratulate all of you who are graduating as this marks the point at which your skills, efforts and aspirations will truly begin to make their mark where ever your lives may lead.

Finally, I would like to thank the Director and the Institute for the invitation to speak today.