Going Against All Odds In The Discovery Of QuasiCrytals

— Interview with Nobel Laureate Prof Danny Shechtman

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Professor Danny Shechtman rose to fame when he was awarded the 2011 Nobel Prize in Chemistry for his discovery of quasicrystals. He was sabbatical at the U.S. National Bureau of Standards in Washington, D.C., when he discovered the icosahedral phase. His findings on quasi-periodic materials have since drastically changed the way scientists today look at states of matter and the way atoms are arranged in a structure. In 2011, Prof Shechtman was the fourth Israeli to win the Nobel Prize in Chemistry in under a decade. He has done significant research in microstructure and properties of rapidly solidified metaliic alloys and titanium aluminides, nucleation and growth of CVD diamond films and development of new magnesium alloys.

Prof Shechtman was in Singapore to attend the inaugural Global Young Scientists Summit 2013 which was organised by the National Research Foundation. In this interview, the man who overcame years of resistance on his discovery shares his journey and his thoughts on scientific research.

Tell us how you came to be involved in the scientific field.

When I was young, I used to read many books. One of them was by French author Jules Verne, called "The Mysterious Island", a story about five people who were stranded on an island. The main character, whom I admired was an engineer named Cyrus Smith and he could do everything and anything. He could make tools from iron ore on the island, create proper living conditions and I wanted to be like him. So I decided from a young age that when I grew up I would become an engineer. I went to study Mechanical Engineering in Technion, the Israel Institute of Technology, but when I graduated, it was during the 1966 recession in Israel and I had difficulty finding a job. I decided to take two years to do my Masters in Materials Engineering and that was where I fell in love with Science. I continued on to do my PhD in Materials Engineering, but I wanted a position in academia, hence I had to go abroad to the United States of America to do my postdoctoral study. I stayed there for three years, doing work for the United States Airforce. Thereafter I was offered a position at the Technion in 1975 and I have been a member of the faculty at Technion ever since. That was how I became a scientist.

What are your current research interests?

I am working on several projects right now, but the main project is research in the development of new magnesium alloys. Some of the alloys are used for body implants and some are used in car parts for the car industry.

You have won several notable awards like the Wolf Prize in 1998 and the Israel Prize in 1999. What is significant about your 2011 win of the Nobel Prize in Chemistry?

The Nobel Prize is a class of its own. It is second to no other and it is the summit of all prizes. When I got the other awards, people say, "Wow, you have done this and got this prize", but when I won the Nobel Prize it is a different thing. You did not invite me to Singapore when I won those other prizes, but you did when I won the Nobel, so that is something really special about the prize.

The Nobel Prize is recognised worldwide and is very unique. It is like a fairytale to win the prize, with the ceremonies (that have been conducted for the past years) and along with the prize money that you get.

Speaking of the prize money, how do you intend to use it and will you be using it for your future research work?

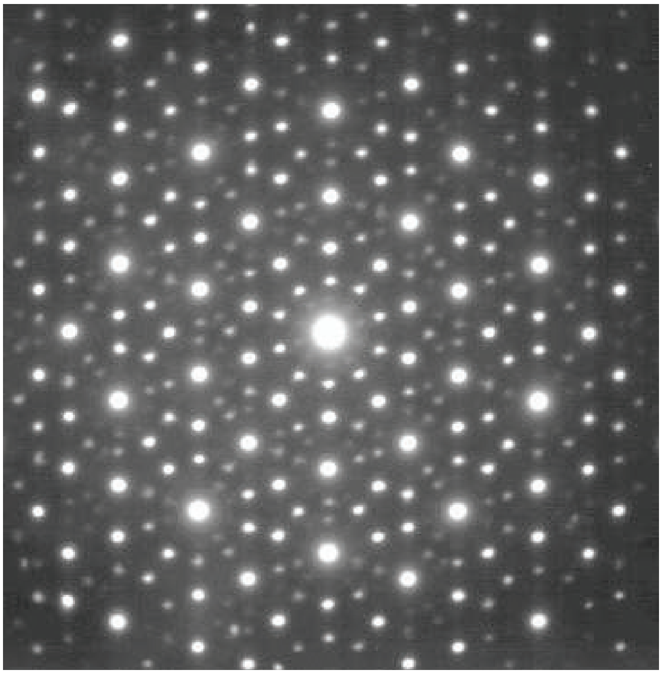
I will use it for one important thing, which is education. For my children as well as my grand children..

Can you tell us about your groundbreaking discovery?

The conventional paradigm of crystals was that they are all ordered and periodic in their atomic structure. This applied to hundreds and thousands of crystals studied for 70 years from 1912 to 1982.

To understand what periodicity is, you can look at tiles on the floor. You will see that there is order and periodicity (meaning that they are the same distance from each other, hence easy to predict where the next one will be). If I give you a few tiles and ask you to lay them on the floor, you will know how to do so because you can predict where the next tile should be, so there is order and periodicity in this formation. This applied to all crystals in the normally understood paradigm, which was before I made a new discovery.

In 1982, I found a crystal that is ordered, but not periodic, and this went against the conventional belief that all crystals are ordered and periodic. Because people thought such quasicrystals did not exist, there was a lot of resistance to my findings. Prominent scientists raised objections to my discovery. But they were wrong. Parts of the scientific community that were close to me and away from me did not believe that quasiperiodic materials could exist. These were not just verbal objections, they were objections documented in articles.



Electron diffraction pattern of an icosahedral Ho-Mg-Zn quasicrystal.

My discovery changed peoples' understanding of the nature in which atoms are arranged in a solid matter. People thought all crystals are periodic, but now we know of two kinds of crystals. One is periodic, and one is non-periodic. Non-periodic crystals are not rare. This non-periodic arrangement of atoms can actually be found in hundreds of crystals out there.

Tell us about the paper you published with J. Cahn, I. Blech and D. Gratias and the impact it had on the scientific community.

Well, at the time in 1982, I was on sabbatical at the US National Bureau of Standards (NBS) near Washington, D.C. and that is when the discovery was made. In 1984, I wrote a paper on the discovery, along with my colleague Ian Blech who had a theory about how such quasiperiodic materials formed. The paper was rejected by the Journal of Applied Physics; on grounds that they believed the community of physicists will not be interested in it. Then again in 1984, along with two more colleagues, John Cahn and Denis Gratias, we wrote another paper and it was published by Physical Review Letters. It created an explosion as many scientists around the world started to work on quasicrystals and it was this paper that started the field.

What kind of resistances did you face with your findings on quasi-periodic crystals?

It was an internal crystal property and I discovered it, not only in aluminium manganese but in other crystals. But there was a range of reactions to the discovery ranging from encouragement to total rejection. John Cahn challenged me to find out the meaning of my discovery, but the Head of my Research Group came into my office one day, put a book on my table and said, *"Danny please read this book and you will understand that what you are talking cannot be."* I said I do not need to read the book because I was sure of what I had discovered and there were no twins (intergrown crystal forms that display a twin boundary). He said that I was a disgrace and told me to leave his group. I did that, but it did not mean much to me, I just had to find another group to join. In the end, through a friend I knew, I managed to find one.

The rejection continued for two years from 1982 to 1984. But as of 1984 there was a group of avant-garde young scientists from Europe, US and China who started doing work on quasi-periodic materials. They were like my troops who believed in me. There were many of them and it was a growing community. Still, at that point there was great rejection from scientists and the international community of crystallographers. In 1987, the International Union of Crystallography accepted the existence of the Quasiperiodic structures.

From 1987 to 1994, resistance continued because of one man, a prominent scientist of the 20th century Linus Pauling. It was about 12 years after my discovery but he still claimed I was wrong and that quasi-periodic materials cannot exist. He was a single person but he was a great leader and behind him was the American Chemical Society, which had thousands of scientists. He passed away in 1994 and all the rejections subsided with that.

The lesson to learn here is that science should always be open to new techniques, new discoveries; new scientists and should never be blocked from any direction.

How did you overcome them and why did you not give up?

Well, when I did my research, I used an electron microscope. I was a professional at using it. I knew how to use it and what I was doing with it. The people that objected my findings did not come up with hard evidence, but I did. When I was sure that what I had discovered was right, I did not give up; it was in my character to press on with my findings.

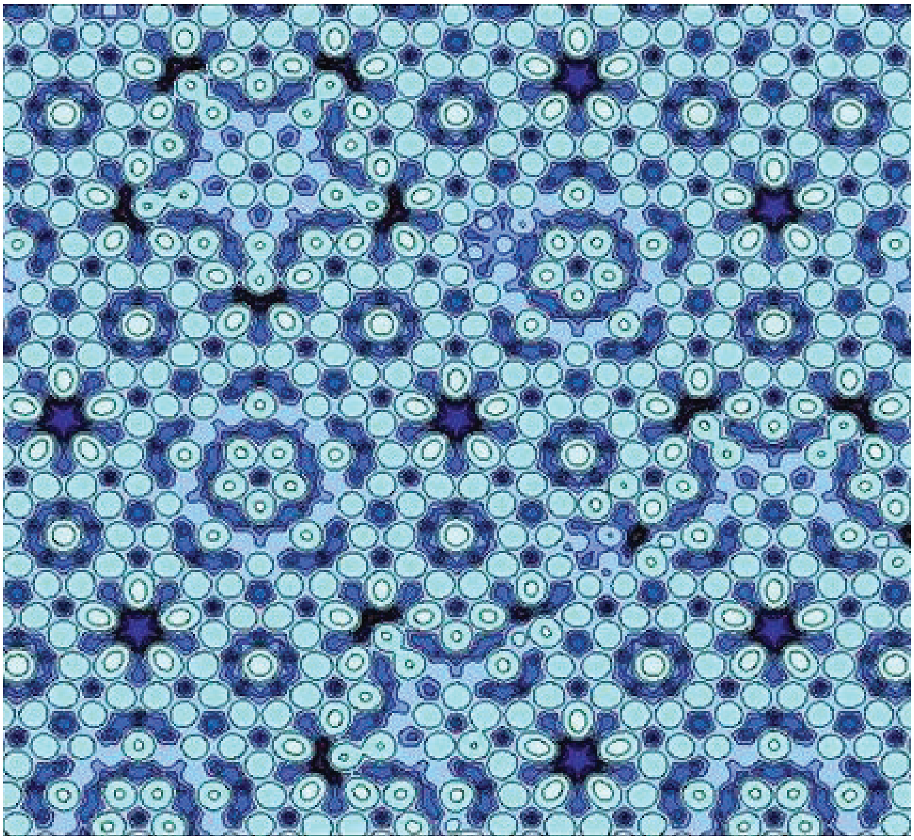
Can you describe what happened on the day you made the discovery?

The date was April 8, 1982. I was working with my electron microscope and studying an alloy of aluminium and manganese. I looked at a series of images of crystals, as well as several diffraction patterns. I spotted a very unique diffraction pattern, which indicated that either the material is full of defects, twins, or that the crystal is something unique.

I spent a day looking for those twins, but could not find them. They were not there. I knew then that I had something unique on my hands. I did not think I would be winning any prize, let alone a Nobel. It was really interesting to me then. I quickly ran out of the room, to see if there was anyone in the corridors that I could tell the interesting news to, but there was no one there.

What is your motivation when you conduct research?

My motivation is curiosity. I am very curious and want to understand how things work. I think that curiosity is the main nature of a scientist. Trying to understand nature is a challenge and that is what motivates me.



Shechtman's Nobel Prize winning work was in the area of quasicrystals, ordered crystalline materials lacking repeating structures, such as this Al-Pd-Mn alloy.

What roles do quasicrystals play in our daily lives?

There is a Swedish steel company that has developed one of the strongest steel in the world using quasicrystals. The steel is ductile and sold in large quantities to produce everything that touches the body, like electric shaving machines. The steel is ideal for that because it is strengthened by quasicrystals.

Quasicrystals have a low coefficient of friction, which means nothing sticks to it. Quasiperiodic coated frying pans can replace Teflon coating, so omelettes do not stick. Cutting anything on such pan is also not advisable, as it will destroy the knife. At the frontier of optics, a lot of progress has been made with quasi-periodic arrays and what they will do to optical rays. Architects also use quasiperiodic properties to design five-fold pentacities.

In your opinion, should research be done for theoretical (like your discovery) or practical purposes?

I did not win a Nobel for the applications of quasicrystals, but for the fundamental discovery of quasi-periodic crystal structure. You never know where a fundamental scientific discovery can lead to something useful and productive like what I have mentioned for the roles quasicrystals play in our lives.

The scientists who won a Nobel Prize in Physics discovered that the universe is not only expanding but also accelerating. I definitely consider that as something useful. Whenever something new is discovered, you never know where science will take it.

Einstein's equations made the GPS system useful today, not just for our own cars but for surveillance purposes as well. So research has to be both theoretical and practical. But it is the hard evidence that makes science useful.

If you have a word of advice for people aspiring to be good scientists out there, what would it be?

Have a broad knowledge but also become an expert. Choose a subject that interests you. Learn all about it and become an expert at it. It will bring you great benefits for your career. You can change your subject later on and that is when you become a professional in something. As a scientist, you must also believe in yourself, have tenacity and courage to get to the bottom of your findings.