Sue Nelson
Hello, I'm Sue Nelson and welcome to the Create the Future podcast brought to you by the Queen Elizabeth Prize for Engineering, celebrating engineering visionaries, and inspiring creative minds.
[Music]
Today's podcast is rather special, as it features the winner of the 2022 Queen Elizabeth prize for Engineering. An engineer from Japan, whose innovation has changed and improved the way we live in so many ways. Dr Masato Sagawa invented a high strength permanent magnet that is ubiquitous, but whose presence in everyday devices is usually hidden. Before we hear from the winner himself. Here's what a few of the prestigious judges on the panel had to say about Dr Sagawa and his achievement.

Ilya Marotta
Magnets have existed since the 18th century. So, Dr Sagawa discovered a way to make magnets a lot more affordable and a lot more powerful.

Jim Al-Khalili
This particular magnet is essentially made from a type of metal called neodymium, which is what's known as a rare earth metal. And it has the property that it can be magnetized. But, by itself, it's not stable, the magnetism isn't reliable enough. But mix it with other elements, in this case with iron and the element boron, you get this neodymium-iron-boron magnet, which is hugely versatile.

Paul Westbury
This is one of those incredible jewels that sits inside other things. And without magnets and without these really powerful, small efficient magnets, we wouldn't be able to have around us an enormous number of things that we take for granted every day.

Alan Finkel
It's used in MRI for medical imaging, it's used in industrial robots, it's used in the motors that make the hard disks of computers work. It's used in wind turbines, it's used to produce incredibly powerful electric vehicles, the little speakers in your phone, the speakers in your laptop, the motors that last for ages and ages and ages in those portable vacuum cleaners. They're enabled by this kind of high strength permanent magnet.

Lynn Gladden
Motors lie at the heart of the transition to electric and hybrid electric vehicles. And therefore, the ability to deliver that transition to electric vehicles is hugely important.

John Anderson
He went from the invention to the development to the manufacture and that is I think, sort of the epitome of the highest level of engineering.

Sue Nelson
You heard there judges, Ilya Marotta who led the Panama Canal Expansion Project, physicist and broadcaster Professor Jim Al-Khalili, Paul Westbury from the Madison Square Garden company, Australia's former chief scientist engineer Dr Alan Finkel, chairman of the judges Professor Lynn Gladden, and president of the US National Academy of Engineering John Anderson. Now on to the winner himself. Dr Sagawa has a degree and master's in electrical engineering, and in 1971, he went on to gain a doctoral degree in material science. He began working on the challenge of creating a new magnet privately while working for an electronics company, before leaving to join Sumitomo Special Metals Company. A few months later, in 1982, he announced a new high performance permanent magnet, and in 1988, founded his own company Intermetallics. Speaking via a

translator, I began by asking Dr Sagawa how he felt about winning the 2022 Queen Elizabeth Prize for Engineering.

Masato Sagawa
I feel very happy and honoured to have received such a prestigious engineering prize and I have nothing but respect and gratitude to the people of the UK for having such an award.

Sue Nelson
Now your work has changed the world we live in, do you reflect on what a difference you've made to so many people's lives?

Masato Sagawa
After I had made my announcement of my finding, I found that all across the world who are in the field of magnets and not only magnets but magnetism have come forward with the academics to give me some accolades in regards to my findings, and through that, I started receiving invitations to hold lectures at international conferences, at not only that, a lot of the magnet manufacturers have also invited me to their premises to visit their factories and plants. And a lot of the people who are working in those manufacturers have also expressed their gratitude.

Sue Nelson
That's lovely. Is there an application of your work that's surprised you, or perhaps please do the most?

Masato Sagawa
What I found surprising the most is in the area of the hard disk. And before the invention of the neodymium magnets, they've had to use magnets that weighed 30 kilograms, which you couldn't possibly carry around. But because of the invention, we've been able to have the same performance through neodymium magnets that you can carry in the palm of your hand. So that's one happy outcome through the invention of the neodymium magnets. And then another one is in the area of air conditioning. And because of the invention of the magnet, the efficiency of air conditioners has increased greatly, halving the electrical consumption. And this has been now widely adopted around the world. I don't know how it is in Europe, Japan certainly is very hot. So, there'll be a use of air conditioning. And perhaps in the in Europe, maybe it's not so hot, so it won't be used as much, but I'm really happy that this outcome has allowed the magnet to be used widely across the world.

Sue Nelson
And when did your interest in permanent magnets begin?

Masato Sagawa
My interest really started, after my PhD at the University, I joined a company and after a few years, I got a role to try and improve the strong magnet that was available and the magnet then was samarium-cobalt. So that was really when I started taking an interest in these permanent magnets.

Sue Nelson
Why did these magnets need improving then, what were their limitations?

Masato Sagawa
The issues with the samarium-cobalt magnets is that we had to use a substantial amount of cobalt in those magnets, up to about 70% of the total and that also lends itself to its availability in resource. And because it was very scarce. And the second point is that if you have a look at the magnetic moment of cobalt, this is

substantially smaller than what you would see for iron, the cobalt magnetic moment is 70% less than iron. So, we knew that if we could use iron, we would have a much better magnet, but we didn't know how to address this issue.

Sue Nelson
So what were the engineering challenges then for producing a stronger permanent magnet?

Masato Sagawa
First of all, if we have a look at the samarium-cobalt, the samarium part is the rare earth portion. And what I needed to do was to find the rare earth and iron compound which would be appropriate for a magnet because the rare earth portion didn't have to be samarium, there are 17 types of those. But I just needed to find the iron being the main component, with a combination of another rare earth. So that's what I needed to find. Plus, the second point was that having this compound as the main component, we would need to have this compound have a microstructure and give it an alloy construction that's appropriate for magnets. Furthermore, I had to find out a way to produce those magnets and compounds that I would find.

Sue Nelson
And how did you go about solving these problems?

Masato Sagawa
What I needed to do was to find a good compound between rare earth and iron. And I had also known that the existing rare earth and iron compounds were not good. And at the time I was able to attend a lecture which touched upon why the currently available rare earth iron compounds were not good. And there, the lecture stated that because the interatomic distances between the iron atoms were too small and that's why it wasn't giving the magnetic performance that it needed, but if there was a way to increase the internal atomic difference between the iron atoms, then this will give a substantial improvement to the magnetism, I took that as a hint, and I started looking into introducing atoms and elements like carbon and boron in-between the iron atoms-because they had a small atomic radius-and tried to come up with a compound which has these carbon and boron atoms to make it into a more appropriate magnet. And taking that as the initiative, I started performing experiments repeatedly and after going through such endeavours, I was able to discover the compound. I discovered the compound within a year, but what I also needed to do to make it into an appropriate magnet was to have the appropriate microstructure of the compound to make it into an appropriate material for a magnet and I went into trial and error after discovering the compound and it took me another three years to come to that alloy microstructure.

Sue Nelson
And it involved something known as a sintering process that you used. Could you explain this process and why it was different?

Masato Sagawa
I had discovered the neodymium-iron-boron compound, and I was able to make the alloy microstructure with this compound. But in the process, I had known that sintering might be appropriate for making this magnet and through a series of trials and errors and trying to come up with the best composition. Why sintering is good? Well, if I go through the process, first we have the alloy, and then we pulverize it, and then we put it through a metal dye, we press the material in a vacuum and then we heat it up, which gives you a sintered body and then that turns into the most appropriate neodymium magnet. It is a process which is pretty similar to what was used for the samarium-cobalt magnets, but the composition of the neodymium-iron-boron magnet is 31% neodymium, 61% iron, and 1% boron. And we came up with this composition after a series of trial and errors. But

after having come up with this competition, we were able to create the world's number one magnet. And we filed for the patent in July of 1982.

Sue Nelson
And how did this new magnet compare to existing permanent magnets? What made them so much stronger and better than the ones that had been around up until then.

Masato Sagawa
The new magnet that we came up with is really strong. And if you compare it with what was available then, the strongest magnet was the samarium-cobalt. And what's important to know is that the main constituent is the iron. And the advantage over the samarium-cobalt is that it's much cheaper to get the iron. So, the magnet itself will be much, much cheaper, it's readily available. And the second point is that the iron has a much larger magnetic moment. So, any magnet that's made from iron has a magnetic property 1.5x to 2x better than the samarium-cobalt magnets. And the neodymium that's in the compound is quite elastic in nature so the magnet resulting from that has very high durability.

Sue Nelson
The judges were also impressed not just by the engineering and technology advances that this new permanent magnet enabled but also the tenacity that Dr Sagawa had in order to get it produced. He's now worked on permanent magnets for 40 years, and continues to do so. And this is what the judges, former VP of IBM Research Josephine Cheng, Amazon's Research Manager Abdigani Diriye, and the chairman of India's National Innovation Foundation Dr Ramesh Mashelkar**,** had to say.

Ramesh Mashelkar
To me, he's an icon. To me, he's a role model. And the reason is a very simple one. You know, in life, what matters is purpose, perseverance, and passion.

Josephine Cheng
The prize for Dr Sagawa represents a long journey of innovation, from discovery to resolving all the problems with a lot of innovation, to manufacturing. And that whole journey is really amazing.

Abdigani Diriye
And I think what really speaks to me is his perseverance and decade's worth of experimentation, trial and error, and his commitment. And I think it's a great lesson for many of us, especially those who are looking for a career in engineering and science.

Sue Nelson
Now, we heard that several of the judges admiring your perseverance in getting your innovation made and then manufactured on a large scale, what qualities do you think an engineer needs to have in order to be successful?

Masato Sagawa
I would say that I really like experiments. And I really like making samples and repeating those experiments. Whatever substance I have at hand or materials, I would think about how those materials are working inside my head, I perform experiments. And once I come to a viable idea, then I try to make samples and measure what we can do with those materials, and I really like this cycle of making samples and measures. And I think that was one of the keys that led me to my success.

Sue Nelson

What's your future aim for neodymium magnets?

Masato Sagawa
Currently, I'm consulting for Daido Steel and what I'm working on is the neodymium magnets that will be used for the traction motor that is to be used in the electric vehicles. And I'm involved in the research together with the team. And our goal is that the current neodymium magnet uses an element called dysprosium. And we want to have the magnet use less of this element to improve its performance. And what we want to do eventually, is to have a magnet used for electric vehicles, which has the world's highest performance in magnetic properties and find a way for us to produce them in factories. So, I'm getting together with Diado Steel, with the aim of trying to achieve this magnet to be used in electric vehicles and to be mass produced.

Sue Nelson
Is there another potential application for your magnet?

Masato Sagawa
What I want to do is to have the neodymium magnets be used in the motors of the electric vehicles across the world. And we can foresee that there will be more electric vehicles across the world and we're hoping that all of those will eventually have the neodymium magnets that they use in the electric vehicles.

Sue Nelson
What's your advice for young engineers or anyone considering a career in engineering?

Masato Sagawa
What I would say to the younger engineers is to have a look around you. There are needs that are within society, what people need. There are those needs that are unmet. Find those and try to think of a way to find solutions and realize that. Think over how, and what you can do. Try to come up with some kind of an idea., because if you can get this idea, then that can become a research theme. And it will be something that would be worthwhile for your research. When you do that though, try to set a concrete goal on how to try and achieve that. And when you try to think about how to try to achieve that, then you will come up with many more ideas. So, keep thinking and thinking and once you get these ideas, experiment, and try to realize those goals because once you are able to go through, there will be a moment when you thought 'I am so happy that I went through the engineering journey and became an engineer'. There is no greater joy in the world. And so I'm hoping that the younger engineers can pursue this kind of path and become such a researcher and engineer.

Sue Nelson
Dr Masato Sagawa thank you for joining us...

Masato Sagawa
Thank you very much.

Sue Nelson
...on the Create the Future podcast. And thank you Yosuke Shinokubo for translating. Find out more about the Queen Elizabeth Prize for Engineering by following @qeprize on Twitter and Instagram, or visit qeprize.org. Thanks for listening and join me again next time.