00:01.775 --> 00:06.379
[SPEAKER_00]: [Automatic captions by Autotekst using OpenAI Whisper V3. May contain recognition errors.]
Welcome everyone again to the fourth edition of Shaking Matters with me, Shibl Gill.

00:07.020 --> 00:12.044
[SPEAKER_00]: Today we are bringing you a fantastic episode all about functional materials.

00:12.645 --> 00:27.258
[SPEAKER_00]: And to talk about functional materials today, I am in the physics department at the University of Stavanger and I'm joined by four researchers from different departments who all have

00:29.139 --> 00:31.721
[SPEAKER_00]: a stake in the game for functional materials.

00:31.981 --> 00:41.847
[SPEAKER_00]: So they all come at the topic from different angles and they are highly regarded and respected researchers and we shall have an invigorating conversation.

00:42.747 --> 00:46.930
[SPEAKER_00]: Functional materials, as a concept, they've been around for a very long time.

00:47.990 --> 00:53.714
[SPEAKER_00]: Magnetic materials were discovered over 3,000 years ago around the Greek town of Magnesia

00:54.751 --> 00:57.932
[SPEAKER_00]: and their first use was in compasses used for navigation.

00:58.713 --> 01:14.720
[SPEAKER_00]: Of course since then they've enabled us to make a great technological leap after another, notwithstanding of course the digital revolution based on the silicone semiconductor which of course happens to be a functional material.

01:16.140 --> 01:17.221
[SPEAKER_00]: Nowadays they are found in

01:17.898 --> 01:22.600
[SPEAKER_00]: computers, cars, telescopes, solar panels and the like.

01:23.621 --> 01:33.746
[SPEAKER_00]: The properties of these materials are born out of the microscopic properties of the crystal structures that they come out of.

01:34.526 --> 01:48.280

[SPEAKER_00]: the crystal structure, electronic structure or the magnetic microstructure of these materials when looked at from a zoomed up perspective gives rise to these properties.

01:48.680 --> 01:55.206
[SPEAKER_00]: What these properties are and how they come about, we will be finding that out very shortly with our guests.

01:56.084 --> 02:04.366
[SPEAKER_00]: So now I would like our guests to introduce themselves and tell us what their connection with functional materials is.

02:04.967 --> 02:07.407
[SPEAKER_00]: So let's start with Professor Sachin.

02:08.288 --> 02:08.488
[SPEAKER_01]: Yeah.

02:08.628 --> 02:11.048
[SPEAKER_01]: Hi, my name is Sachin Chavan.

02:11.169 --> 02:15.690
[SPEAKER_01]: I'm associate professor at the Department of Chemistry, Bioscience and Environmental Engineering.

02:16.710 --> 02:21.372
[SPEAKER_01]: And my focus is material technology for sustainable energy and environmental application.

02:22.532 --> 02:22.812
[SPEAKER_01]: Welcome.

02:24.048 --> 02:33.013
[SPEAKER_02]: Hello, my name is Olena Zavorotynska, I am associate professor in materials physics and I work in the University Stavanger in the department of mathematics and physics.

02:34.254 --> 02:45.600
[SPEAKER_02]: My main focus in my research is the materials for hydrogen technology as well as advanced method of characterization of materials structures and processes in the materials.

02:46.618 --> 02:46.938
[SPEAKER_00]: Brilliant.

02:47.439 --> 02:47.839
[SPEAKER_00]: Sofia?

02:48.220 --> 02:50.202
[SPEAKER_03]: Hello, my name is Sofia Bercha.

02:51.082 --> 03:00.672
[SPEAKER_03]: I have a PhD in physics and now I'm doing my postdoc research at the University of Stavanger under the guidance of Professor Sachin.

03:01.473 --> 03:06.858
[SPEAKER_03]: I'm working on a project, MOFsorbMET, which is looking into

03:07.959 --> 03:13.122
[SPEAKER_03]: MOFs for collecting and recycling critical materials.

03:13.843 --> 03:20.346
[SPEAKER_03]: Previously, I've been working with biosensors and different kinds of functional materials.

03:21.727 --> 03:24.249
[SPEAKER_04]: Hi, I'm Jelena Popovic-Neuber.

03:24.369 --> 03:29.052
[SPEAKER_04]: I'm Associate Professor in Battery Technology in the Department of Energy and Petroleum Engineering.

03:30.029 --> 03:36.281
[SPEAKER_04]: I define myself as a physical chemist that is interested in ion transport, particularly in battery materials.

03:37.243 --> 03:41.091
[SPEAKER_04]: And I use electrochemical methods to investigate them.

03:42.849 --> 03:44.110
[SPEAKER_00]: Warm welcome to all of you.

03:44.511 --> 03:50.455
[SPEAKER_00]: So now getting into the meat of the matter, we're here to discuss functional materials.

03:51.136 --> 04:01.243
[SPEAKER_00]: So which one of you would like to take a stab at telling us from a very basic perspective and building up as to what a functional material is?

04:01.263 --> 04:04.325
[SPEAKER_01]: Yeah, I mean basically these are the

04:05.911 --> 04:14.518

[SPEAKER_01]: Materials in a way, but they are tailored to gain some functionalities, targeted functionalities, properties.

04:15.059 --> 04:28.491
[SPEAKER_01]: So it can be achieved by atomic level modification or molecular level modification, or you're engineering the material by making the mixtures of the material to harness some properties.

04:29.111 --> 04:32.874
[SPEAKER_01]: So these are the material, but they are tailored to gain some functionalities.

04:33.812 --> 04:44.040
[SPEAKER_00]: And these are materials that, through intervention by physicists or chemists, you can have them achieve certain characteristics.

04:45.600 --> 04:47.461
[SPEAKER_01]: I think it matters all.

04:47.581 --> 04:52.505
[SPEAKER_01]: I mean, we need to understand material at a different level before we conclude what it is good for.

04:53.186 --> 05:09.117
[SPEAKER_01]: And so I heavily rely on other scientists working in my field, on the application side, engineers who are testing, on the characterization side, physicists who can know them at atomic level to the bulk level characteristics.

05:09.878 --> 05:14.081
[SPEAKER_01]: And so very often as a researcher, we try to...

05:15.726 --> 05:24.730
[SPEAKER_01]: engineer the material for particular targeted application, but sometimes or quite often it end up that material is good for completely different.

05:25.531 --> 05:32.994
[SPEAKER_01]: And so once you have this whole picture in front of you, then you are not wasting the potential that the material has.

05:33.234 --> 05:34.495
[SPEAKER_01]: That's my take on it.

05:35.636 --> 05:37.957
[SPEAKER_01]: Anyone else?

05:37.997 --> 05:42.319
[SPEAKER_04]: Yeah, to kind of compliment Sachin, it's a highly interdisciplinary field.

05:42.936 --> 05:47.402
[SPEAKER_04]: And some materials, as you said, magnetic materials are known for 3000 years.

05:47.442 --> 05:55.072
[SPEAKER_04]: There are materials such as carbon that can be used almost everywhere from bio applications to energy storage applications.

05:55.653 --> 06:01.140
[SPEAKER_04]: So we have this really large diversity of materials that are also non-toxic around us.

06:01.795 --> 06:08.579
[SPEAKER_04]: and finding them and using them for really useful applications is quite fulfilling for many scientists.

06:08.999 --> 06:09.679
[SPEAKER_00]: Yeah, right.

06:09.939 --> 06:29.990
[SPEAKER_00]: So just to give our audience a sense of what sorts of functionalities we're talking about, could someone give us some examples of functional materials that we might already be using in our lives and in a day-to-day basis so that we can identify, okay, so this is what a functional material is.

06:31.448 --> 06:38.909
[SPEAKER_03]: Well, I would say that functional material is any material that responds to external stimuli.

06:39.730 --> 06:44.070
[SPEAKER_03]: So basically we talk about, for example, solar cells or semiconductors.

06:44.710 --> 06:48.051
[SPEAKER_03]: You shine light on them and it produces electricity.

06:49.891 --> 06:57.633
[SPEAKER_03]: There are very many different examples of functional materials all around us.

06:59.170 --> 07:21.787
[SPEAKER_00]: very good okay so nowadays of course we are in 2023 and we have achieved their digital revolution what are some of the functional materials that that you guys are looking at and what are some in demand functional materials and what sort of properties would you would you like them to have

07:24.326 --> 07:29.810
[SPEAKER_01]: Yeah, so I mean, I established a group at UIS, functional material and process chemistry.

07:30.530 --> 07:34.252
[SPEAKER_01]: And in my group, we work primarily with metal organic frameworks.

07:34.472 --> 07:43.218
[SPEAKER_01]: These are hybrid material where you take metal or metal oxy cluster, you connect with organic part, you generate a three-dimensional structure.

07:43.858 --> 07:51.423
[SPEAKER_01]: So you're kind of uniting the different domains that were maybe previously not connected in the same way.

07:51.863 --> 07:52.244
[SPEAKER_01]: So you've got

07:53.061 --> 08:06.052
[SPEAKER_01]: inorganic chemistry comes in organic chemistry comes in and when you generate a three-dimensional structure porosity comes in and the order periodicity comes in so you need a crystallographer we need a excess people we need to understand

08:07.310 --> 08:32.037
[SPEAKER_01]: can we tell of this material at a molecular level to build the properties we also work with the carbon that's coming from waste so it's called biochar any organic waste that is spiralized in absence of oxygen you can you can make a carbon which have which have different properties depending on what is the source so i've been working with the

08:34.275 --> 08:40.379
[SPEAKER_01]: porous hybrid materials and we try to manipulate them to get particular functionalities.

08:41.340 --> 08:50.286
[SPEAKER_00]: So in these metal organic frameworks that you are talking about, you have this unconventional coming together of metals on one hand and organic

08:51.104 --> 08:52.005
[SPEAKER_00]: molecules on the other.

08:52.545 --> 08:59.350
[SPEAKER_00]: What can you do with these metal organic frameworks and what sorts of applications might they be useful for?

09:00.611 --> 09:05.575
[SPEAKER_01]: I mean, like Jelena mentioned that carbon is existing for so many years and then zeolites came.

09:05.595 --> 09:07.856
[SPEAKER_01]: Zeolites are a revolutionised industry.

09:08.237 --> 09:10.498
[SPEAKER_01]: These are the class of porous material.

09:10.799 --> 09:17.884
[SPEAKER_01]: What I'm fascinated about MOFs is that one can think of a building unit

09:19.702 --> 09:32.387
[SPEAKER_01]: mathematically or even just in terms of shapes and then go into the lab and try to connect them to generate a 3D structure and first game, first experiment is a trial and error but once you make them

09:33.464 --> 09:36.046
[SPEAKER_01]: Then you have reticular design aspect.

09:36.666 --> 09:44.032
[SPEAKER_01]: So if I make one molecule and connect it with organic, I get surface area 3000 m2 per gram.

09:44.792 --> 09:50.416
[SPEAKER_01]: By simply extending the length of organic linker now, I can generate 6000 m2 per gram.

09:51.597 --> 09:57.601
[SPEAKER_01]: And that was something new in a way, controlling the properties at molecular level.

09:58.439 --> 10:01.782
[SPEAKER_01]: which is controllable, achievable.

10:02.302 --> 10:15.853
[SPEAKER_01]: With respect to zeolite and carbon, even in polymer chemistry, it's difficult to control the chemistry to that extent, where you can targetedly take a molecule, integrate and generate the property.

10:16.713 --> 10:22.297
[SPEAKER_01]: So we work with carbon capture, metal separations, so we are trying to modify these molecules

10:23.158 --> 10:31.889
[SPEAKER_01]: to develop a solid material that can do the separation job much more efficiently compared to conventional material.

10:32.510 --> 10:40.140
[SPEAKER_01]: And the idea is to use this molecular engineering to give the functionality to MOFs and carbons.

10:41.698 --> 10:42.479
[SPEAKER_00]: That's fantastic.

10:42.539 --> 10:49.642
[SPEAKER_00]: It sounds like you can engineer molecules and get functionality out of that.

10:49.902 --> 11:03.609
[SPEAKER_00]: For example, in this instance, you have a very small amount of matter, but the surface area exposed to air of that small amount of matter would be much, much larger than you would expect.

11:04.169 --> 11:07.431
[SPEAKER_00]: And that has applications in carbon capture.

11:08.451 --> 11:08.872
[SPEAKER_00]: Very good.

11:09.312 --> 11:09.612
[SPEAKER_00]: Jelena?

11:09.893 --> 11:19.141
[SPEAKER_04]: I'm interested in looking at kind of a variety of different materials that show property in which we can move ions really quickly.

11:19.742 --> 11:28.650
[SPEAKER_04]: So this is relevant, for example, for applications such as lithium ion batteries, where we are having a device in which we can move ions quickly.

11:29.167 --> 11:31.688
[SPEAKER_04]: quickly at room temperature, even in the solid state.

11:31.808 --> 11:45.535
[SPEAKER_04]: So these materials can be actually from liquid to solid state materials and depending on, of course, their molecular properties, as you said, we can kind of tune them to perform very well.

11:46.132 --> 11:55.698
[SPEAKER_04]: So there we are looking for different kind of solid-state materials with specific structures containing quite a lot of defects where ions can move.

11:56.338 --> 12:14.410
[SPEAKER_04]: Or we are looking at liquids with very specific molecular structure, specific type of ionic association, and trying to finally match them together and build new devices for kind of future energy storage as one of the biggest, I would say, challenges for

12:14.987 --> 12:16.568
[SPEAKER_04]: for mankind nowadays.

12:17.448 --> 12:18.028
[SPEAKER_00]: Fantastic.

12:18.048 --> 12:23.330
[SPEAKER_00]: So now we have at least two examples of very different kinds of functional materials.

12:23.810 --> 12:34.654
[SPEAKER_00]: Now, the question emerges, how do you ensure that these materials that you are engineering, that you are synthesizing, that they actually perform in the way that you intend them to?

12:35.394 --> 12:40.516
[SPEAKER_00]: Because, of course, such in the materials that you mentioned, they have a specific function of specific tasking.

12:41.016 --> 12:43.737
[SPEAKER_00]: Your materials, they need to do iron transport and better

12:43.854 --> 12:52.261
[SPEAKER_00]: How do you ensure, how do you test that your material is performing the task that it ought?

12:54.523 --> 12:58.226
[SPEAKER_04]: So maybe I start and then Olena continues.

12:58.763 --> 13:10.207
[SPEAKER_04]: I, as a physical chemist, I'm actually more on this characterization side, so really actually measuring the properties of materials, also synthesizing them, but that's not kind of the key focus.

13:10.247 --> 13:27.794
[SPEAKER_04]: The key focus is actually building characterization techniques and building actually procedures in order to test them properly and to be sure that these properties that we predict based on our theory and hypothesis

13:28.291 --> 13:33.253
[SPEAKER_04]: that they actually are there once we have the physical material in the lab.

13:34.073 --> 13:35.514
[SPEAKER_04]: So this is what I do.

13:35.574 --> 13:40.756
[SPEAKER_04]: And I guess people that do other types of characterization do that in a kind of similar way.

13:40.796 --> 13:45.698
[SPEAKER_00]: Could you give us a sneak peek into what sorts of techniques you're utilizing?

13:46.298 --> 13:52.501
[SPEAKER_04]: So as I said, I used electrochemical techniques, which means that we need to build different kinds of electrochemical cells.

13:52.841 --> 13:58.003
[SPEAKER_04]: And by using different electrodes and different measurement protocols, we can

13:58.584 --> 14:06.751
[SPEAKER_04]: get access to ionic conductivity, diffusion coefficients, electronic conductivity, et cetera, of specific materials.

14:06.791 --> 14:14.478
[SPEAKER_04]: So it's all about kind of building specific cell for your specific parameter that you try to actually measure.

14:17.617 --> 14:25.764
[SPEAKER_02]: Yes, I guess first I have to introduce the materials I'm working with because they are again very much different from what Sachin and Jelena were talking about.

14:26.325 --> 14:30.128
[SPEAKER_02]: So one of my main focuses of research is materials for hydrogen storage.

14:33.791 --> 14:34.372
[SPEAKER_02]: Where do I start?

14:36.073 --> 14:38.755
[SPEAKER_02]: So these are the materials that can pack hydrogen.

14:38.815 --> 14:50.561
[SPEAKER_02]: If you know that hydrogen can be used as one of the alternative fuels because it has a lot of energy in this chemical bonding in the hydrogen molecule.

14:51.341 --> 15:05.370
[SPEAKER_02]: The problem is that it's a smallest atom and smallest molecule and it's very difficult to keep it in place where you want to keep it and to transport and to use it where you want to use it.

15:05.951 --> 15:07.292
[SPEAKER_02]: So we have to pack it somehow.

15:08.172 --> 15:11.935
[SPEAKER_02]: The current ways of packing it is either to put it under very high pressure

15:13.253 --> 15:15.616
[SPEAKER_02]: 700 atmospheres or 300 atmospheres.

15:15.696 --> 15:19.902
[SPEAKER_02]: These are the standards or at very low temperature to make a liquid.

15:20.042 --> 15:23.226
[SPEAKER_02]: Liquid hydrogen is about minus 250 degrees Celsius.

15:24.227 --> 15:25.589
[SPEAKER_02]: So both of them are not very.

15:27.571 --> 15:29.354
[SPEAKER_02]: These are developed technologies and they work.

15:29.795 --> 15:34.760
[SPEAKER_02]: But we would like to have something less energy consuming and maybe more safe also.

15:35.902 --> 15:44.191
[SPEAKER_02]: So these materials that I'm working with, they take hydrogen molecules and in most cases they split them into two atoms and these two atoms are placed inside the materials.

15:44.311 --> 15:48.335
[SPEAKER_02]: And in this way, they're kept until we want to use this hydrogen.

15:51.435 --> 15:58.817
[SPEAKER_02]: And well, there are different types of this kind of metal hydrides with different bonding between hydrogen atoms.

15:58.957 --> 16:09.100
[SPEAKER_02]: This can be the atoms or hydrogen ions, and they can be bound in different ways, different energy to the matrix.

16:10.860 --> 16:14.261
[SPEAKER_02]: How do we ensure how do they perform this material?

16:14.301 --> 16:20.343
[SPEAKER_02]: So what we do that we have the material and then we set it in the atmosphere of hydrogen and we see

16:21.255 --> 16:26.859
[SPEAKER_02]: how much of that hydrogen was absorbed inside the material and at which condition, at which temperature and pressure.

16:28.200 --> 16:34.085

[SPEAKER_02]: The most positive thing is, of course, that these materials store hydrogen at much higher temperatures.

16:34.105 --> 16:36.566
[SPEAKER_02]: We don't go to minus 250 degrees Celsius.

16:36.626 --> 16:38.368
[SPEAKER_02]: They mostly work in the ambient

16:39.508 --> 16:59.382
[SPEAKER_02]: conditions which is minus 20 plus 40 something that we have in our everyday life on our planet and the pressure is also much less than the 700 atmospheres even though we work with much

17:01.480 --> 17:24.130
[SPEAKER_02]: milder conditions we can still pack that hydrogen much more efficiently than it is packed in liquid so we have at room temperature we have hydrogen packed in these metal hydrides much more efficient than in liquids we need of course to characterize how much efficiently that hydrogen is packed that's why we carry out these experiments on seeing how much of hydrogen is absorbed

17:25.227 --> 17:31.948
[SPEAKER_02]: Or we can also shine at this material by X-ray, for example, or by neutrons and see as well.

17:32.008 --> 17:41.450
[SPEAKER_02]: We can see in one or another way how much of hydrogen is inside of the material and where does it sit exactly in the structure of the material.

17:42.110 --> 17:42.470
[SPEAKER_01]: Brilliant.

17:42.730 --> 17:43.050
[SPEAKER_01]: Thank you.

17:44.631 --> 17:51.232
[SPEAKER_01]: In my opinion, to me, at least, it's boiled down to understand everything about the material.

17:51.872 --> 18:01.514
[SPEAKER_01]: And so when, because I have this belief that sometimes if I focus the material for carbon capture and maybe it doesn't work there, so I just throw it away.

18:02.195 --> 18:04.115
[SPEAKER_01]: But the material maybe was good for something else.

18:04.835 --> 18:15.358

[SPEAKER_01]: And there has been many technological stories, breakthroughs, where a person who invented was trying to do something for a particular purpose, but it ended up in a completely different way.

18:15.918 --> 18:36.912
[SPEAKER_01]: scenario useful so that's where dependency on trying to understand at atomic level trying to understand that the structural textural level and then performance so lots of characteristics it does take time it does take time and knowing if we can do in real time in the sense in situ or operando

18:37.870 --> 18:41.873
[SPEAKER_01]: That's where maybe you get much more deeper understanding of what has happened.

18:42.493 --> 18:44.174
[SPEAKER_01]: And that interests me a lot.

18:44.294 --> 18:51.179
[SPEAKER_01]: And that's where we collaborate with the physics department, where they can help us to do some in-situ studies.

18:51.879 --> 18:55.722
[SPEAKER_01]: So MOPS are there for a long time.

18:55.742 --> 18:56.643
[SPEAKER_01]: 1999 was the first game.

18:57.243 --> 19:03.667
[SPEAKER_01]: More than 70,000 MOPS are reported, but you will find only a handful of papers are talking about how the things are made in a solution.

19:04.588 --> 19:07.590
[SPEAKER_01]: How did these building blocks come together from 3D structure?

19:08.187 --> 19:10.328
[SPEAKER_01]: And some of them happens in five minutes or so.

19:10.948 --> 19:22.014
[SPEAKER_01]: So with the physics group now, with Olena and Sofia, we are trying to learn using X-ray absorption spectroscopy, how things grow in a solution.

19:22.774 --> 19:23.915
[SPEAKER_01]: So shading the light on

19:24.992 --> 19:31.456
[SPEAKER_01]: nucleation and crystal growth and then maybe it will help us to develop a new functional material.

19:31.516 --> 19:31.816
[SPEAKER_01]: Right.

19:32.877 --> 19:33.497
[SPEAKER_00]: Fantastic.

19:34.117 --> 19:45.244
[SPEAKER_00]: So we've spoken about functional materials that are being used for hydrogen storage, for carbon capture, for improving battery technology.

19:45.784 --> 19:50.186
[SPEAKER_00]: And you hinted on this earlier, Sachin.

19:51.307 --> 19:51.907
[SPEAKER_00]: It seems that

19:53.308 --> 20:02.533
[SPEAKER_00]: there is a big problem out there in the world and then it seems like there is a functional material that is going to solve that problem.

20:02.953 --> 20:09.817
[SPEAKER_00]: Now, are you starting with usually a functional material and then finding a problem that it can solve?

20:10.037 --> 20:17.041
[SPEAKER_00]: Or are you starting with the problem and then looking at your arsenal of functional materials that can solve the problem?

20:18.462 --> 20:22.864
[SPEAKER_04]: For me, it's always actually looking at the problem and then picking the material.

20:23.462 --> 20:27.885
[SPEAKER_04]: Maybe that has to do with how ripe certain technologies are or not.

20:28.325 --> 20:33.169
[SPEAKER_04]: At least in batteries, we really kind of know the materials are really known.

20:33.709 --> 20:45.037
[SPEAKER_04]: So we can actually pick the ones that are really good for that specific application and actually try to tune that one, to tune a specific parameter of a known material.

20:46.018 --> 20:52.523
[SPEAKER_04]: I think that's also kind of good if we think about sourcing of materials because the known materials are kind of easy to

20:53.160 --> 20:58.663
[SPEAKER_04]: to get a hold of and kind of easier to parameterize and improve.

20:59.643 --> 21:07.748
[SPEAKER_04]: But of course, there is, I think in particular for synthetic chemists, is a kind of a really broad playground of making materials.

21:07.848 --> 21:19.954
[SPEAKER_04]: And as Sachin said, you never know as a researcher if what you found in one specific field will be found by someone else from a very different field and will be found useful.

21:20.074 --> 21:21.635
[SPEAKER_04]: And I think in that sense, we are...

21:22.552 --> 21:44.751
[SPEAKER_04]: um we can be kind of happy to work on that knowledge that will be found as a kind of uh hidden a gem by someone else from a different field so that's kind of this is what i like about doing science is that you do not control the future right it's in in the hand of the future generations and how do they use the knowledge that we collect at this moment

21:45.689 --> 21:50.693
[SPEAKER_03]: Lots of times you come across a paper that was already published.

21:50.713 --> 22:02.765
[SPEAKER_03]: So you screen the literature, you go to the conference and you get inspired from the investigations of other people because it's not everyone is working on the functional materials right now.

22:02.805 --> 22:04.647
[SPEAKER_03]: They are very important for research.

22:05.007 --> 22:09.690
[SPEAKER_03]: renewable energy for environmental reasons, green transition.

22:10.391 --> 22:18.757
[SPEAKER_03]: So sometimes you just get inspired or you just see what somebody does and you add a little bit on top of that and you got a new functionality.

22:19.237 --> 22:27.963
[SPEAKER_03]: So that's one of the things, how you can come up with new functional material or improve something that already exists.

22:30.618 --> 22:33.879
[SPEAKER_02]: I think that depends quite a lot on whether you're a physicist or chemist.

22:35.760 --> 22:36.560
[SPEAKER_02]: Or a physical chemist.

22:38.161 --> 22:46.144
[SPEAKER_02]: Because physicists tend to like to work with a very basic and very exemplary systems and very perfect ones also.

22:46.804 --> 22:58.069
[SPEAKER_02]: And that's basically only basic systems can be perfect where we can explore the properties and explain the properties, for example, magnetic properties or similar of these materials.

22:58.189 --> 22:58.689
[SPEAKER_02]: And then we...

22:59.429 --> 23:12.155
[SPEAKER_02]: kind of send this information to the world where chemists can pick it up and then think how to use it afterwards to invent the material based on this kind of property or structure.

23:13.473 --> 23:18.336
[SPEAKER_03]: Also, on the other hand, sometimes we're doing something very small scale.

23:18.436 --> 23:25.760
[SPEAKER_03]: And when you want to do this functional material perform on a big scale and put it in a device, it's a completely different topic.

23:25.800 --> 23:33.125
[SPEAKER_03]: So lots of work has to be put to bring something from the lab to the actual device.

23:34.005 --> 23:35.666
[SPEAKER_04]: Which is what the engineers maybe do.

23:35.826 --> 23:42.010
[SPEAKER_04]: Maybe as a kind of physical accountant slash engineer, I have big respect towards scale-up.

23:42.506 --> 23:48.008
[SPEAKER_04]: This is a big engineering problem, which is how do we make those materials in a kind of organized way?

23:48.048 --> 23:51.269
[SPEAKER_04]: But how do we make devices that from small scale to big scale?

23:51.890 --> 23:54.991

[SPEAKER_04]: This is a non-trivial task.

23:56.011 --> 24:03.694
[SPEAKER_04]: And in many of the fields, including battery field, it's one of the most important tasks actually to be done.

24:03.714 --> 24:08.376
[SPEAKER_04]: And it's reflected in particular, for example, in the battery field.

24:08.772 --> 24:15.733
[SPEAKER_04]: by the fact that Nobel Prize for batteries has been given to chemists, of which two are, as I always said, chemists and one is an engineer.

24:16.434 --> 24:21.915
[SPEAKER_04]: So the engineering aspect of things becomes more and more important, I believe, in time to come.

24:21.995 --> 24:28.936
[SPEAKER_04]: And, you know, the natural scientists were always kind of treating engineers as someone that is executing.

24:29.036 --> 24:36.598
[SPEAKER_04]: But now that this gap is closing out, the engineering aspects get more and more fundamental.

24:38.275 --> 24:40.776
[SPEAKER_04]: kind of implications for fundamental knowledge.

24:41.236 --> 24:46.057
[SPEAKER_04]: So I think this is a shift that we are now seeing also in this decade.

24:46.297 --> 24:47.498
[SPEAKER_01]: I think that's very important.

24:48.018 --> 25:03.322
[SPEAKER_01]: It's like what you said, like when you have a problem defined, then you understand the limitations, constraints, and this is where engineering aspect is taken into fundamental research, which will not have, whatever you are doing, which will not have show stoppers during the engineering part.

25:04.019 --> 25:14.990
[SPEAKER_01]: So then this is all the research is in a way, even in my lab, when we think of hydrogen purification, metal separation, carbon, we know the constraints given in a problem.

25:16.151 --> 25:19.334
[SPEAKER_01]: But we are still open to investigate whatever

25:19.614 --> 25:49.169
[SPEAKER_01]: we make in our product lab because it is created something that we have made and maybe it's for the first time or somebody has already done it's a derived research but we want to know everything is it totally useless material or it has somewhere the needs that it can work but today I mean nowadays it's computational chemistry is contributing huge to reduce the burden on investigating

25:49.366 --> 25:50.486
[SPEAKER_01]: material in the lab.

25:51.246 --> 26:08.270
[SPEAKER_01]: So if I make up the first MOF that was came but then there are hypothetical morphs generated in computer there are millions and they can study carbon capture property in computer without even going to the lab and it is speeding up the research.

26:08.290 --> 26:16.552
[SPEAKER_01]: So then I know that okay they have found in silico this computationally the structure property relationship where the

26:16.809 --> 26:18.851
[SPEAKER_01]: water will bind very strongly.

26:19.832 --> 26:25.456
[SPEAKER_01]: Then as a synthetic chemist I would go into the lab and see how can I engineer those into the material.

26:26.257 --> 26:31.141
[SPEAKER_01]: Sometimes nature is inspiration where you want to mimic the nature, that's where we start.

26:31.561 --> 26:38.327
[SPEAKER_01]: But I think the computational chemistry is doing impressive work in accelerating material research in a way.

26:40.447 --> 26:52.731
[SPEAKER_00]: I think this discussion is really highlighting how important interdisciplinarity is within this field, that so many disciplines coming together to sort a problem.

26:53.191 --> 26:59.473
[SPEAKER_00]: And of course, one of the biggest, perhaps the biggest problem that we are facing currently is the climate crisis.

26:59.913 --> 27:03.975
[SPEAKER_00]: Now, each of the functional materials that we have spoken about here,

27:05.395 --> 27:11.160

[SPEAKER_00]: somehow fits in with the puzzle of trying to help solve that crisis.

27:11.740 --> 27:18.685
[SPEAKER_00]: How front of mind is that motivation for all of you when you are going about your day-to-day work?

27:18.745 --> 27:30.514
[SPEAKER_00]: And in addition to that, I'd like to ask what non-scientific challenges do you think still block the roads in bringing these technologies to the market, to the front?

27:32.185 --> 27:33.446
[SPEAKER_04]: For me, that was the key.

27:33.806 --> 27:44.910
[SPEAKER_04]: It actually was what hooked me with doing this job is feeling that maybe I can contribute to that part, to the sustainability in the direction that we were kind of taking.

27:45.791 --> 27:55.995
[SPEAKER_04]: So it is the only motivation that I have to do the kind of research that I do, is to think that, you know, in decades to come, we will be using

27:56.812 --> 27:58.093
[SPEAKER_04]: more sustainable materials.

27:58.253 --> 28:03.958
[SPEAKER_04]: We will be doing something for the planet with the knowledge that we've collected.

28:04.618 --> 28:13.366
[SPEAKER_04]: But of course, many other things are going in parallel and it's not only the burden of researchers to take.

28:13.726 --> 28:20.652
[SPEAKER_04]: And in many of these fields, including my field, there have been sustainable materials for decades already.

28:21.269 --> 28:22.650
[SPEAKER_04]: but they have not been used.

28:23.211 --> 28:38.001
[SPEAKER_04]: So it was not on the burden of the science that we have not been prolific in producing those materials, but it was rather the industries that were too slow to accept those movements.

28:38.542 --> 28:49.610
[SPEAKER_04]: So if we look in my field, it's always the cost of materials and the supply of those that is kind of guiding to what is being used at the moment.

28:50.652 --> 28:55.619
[SPEAKER_04]: And in a kind of bizarre way, nowadays we have cost and supply.

28:55.639 --> 28:58.703
[SPEAKER_04]: So one is diminishing and the other one is rising.

28:58.783 --> 29:02.067
[SPEAKER_04]: That is triggering also to sustainable development.

29:02.307 --> 29:04.009
[SPEAKER_04]: So it's a positive aspect.

29:04.089 --> 29:04.790
[SPEAKER_04]: Is it too late?

29:05.151 --> 29:05.732
[SPEAKER_04]: I do not know.

29:07.352 --> 29:14.954
[SPEAKER_00]: Yes, of course, business and politics, they have to play their parts in helping solve the crisis.

29:15.014 --> 29:20.096
[SPEAKER_00]: Of course, the scientists are doing what the scientists do.

29:20.816 --> 29:23.296
[SPEAKER_01]: Non-scientific challenges are there.

29:23.356 --> 29:28.518
[SPEAKER_01]: I mean, they have to contribute in a way in acceptance of technology and making sure that

29:29.355 --> 29:55.343
[SPEAKER_01]: even see hydrogen is coming now hydrogen economy coming again we talked about it has been coming and going and coming and going there are reasons for that and so if the transportation regulation safety there are technical challenges but governance and policy around it is very important social acceptance will be it's interesting to see how lithium ion batteries

29:56.345 --> 30:24.136
[SPEAKER_01]: were accepted even though there was a time gap since its discovery then the first e-vehicle then nothing was happened then new expensive car came it got accepted the risk associated with the car's supply and all these different challenges but the safety around it is when I see how it is accepted when we know that whole waste incineration plant in forest got burned because of one lithium-ion battery got fired

30:25.302 --> 30:27.965
[SPEAKER_04]: But it's also very culturally dependent, I would say.

30:28.085 --> 30:31.949
[SPEAKER_04]: So one of the first technologies in lithium batteries was lithium metal.

30:32.109 --> 30:40.237
[SPEAKER_04]: And it was abandoned because people, users, were not willing to take the risk.

30:40.978 --> 30:45.543
[SPEAKER_04]: While the users in Asia, for example, in Japan, were very willing to take the risk.

30:45.583 --> 30:48.546
[SPEAKER_04]: So if we look at the market, we still have

30:49.079 --> 30:53.042
[SPEAKER_04]: lithium metal products in Asian market, but we do not have them in other markets.

30:53.142 --> 30:55.624
[SPEAKER_04]: And that's a kind of a product development.

30:55.824 --> 31:03.289
[SPEAKER_04]: And how do we as cultures perceive safety, which is also related with nuclear energy and other things.

31:03.909 --> 31:06.251
[SPEAKER_04]: So it's a kind of very social and

31:08.030 --> 31:16.636
[SPEAKER_04]: phenomenon that is beyond natural science and very difficult to tackle in which cultures it will go in which direction.

31:16.736 --> 31:19.178
[SPEAKER_04]: And I guess for hydrogen it's a really big topic.

31:19.198 --> 31:22.020
[SPEAKER_04]: Yes, hydrogen for some reason it's a technology that the society still has to accept.

31:22.100 --> 31:23.461
[SPEAKER_02]: Just as an example I can give a

31:36.167 --> 31:42.952

[SPEAKER_02]: a recent hydrogen conference here in Stavanger that I've been to, which was a bit different from the usual conferences I go to.

31:42.992 --> 31:49.556
[SPEAKER_02]: This was a conference for businesses, industries and insurance companies and stuff.

31:51.014 --> 32:01.561
[SPEAKER_02]: And, well, first of all, the moderator all the time was stressing after almost each talk how dangerous and flammable hydrogen is for some reason.

32:01.641 --> 32:15.771
[SPEAKER_02]: And then when we actually had a talk on the risk associated with hydrogens, the speaker mentioned two accidents in the history of hydrogen industry, which one happened in 1975 and the other one in 2019,

32:21.191 --> 32:24.272
[SPEAKER_02]: what we've learned from 1975 was not used in the 2019.

32:25.073 --> 32:34.916
[SPEAKER_02]: Think of how many big explosions happened on oil platforms in the time, just in one particular country.

32:38.838 --> 32:50.182
[SPEAKER_02]: Yes, but if you think about the oil spills and the fires on the oil platforms and all the mines and the fires and disasters and how many people were killed in all these disasters,

32:51.081 --> 33:01.629
[SPEAKER_02]: And yet hydrogen technology somehow is considered to be much more risky than the other burning matter technology, let's say.

33:01.689 --> 33:05.051
[SPEAKER_02]: So this is something that one has to think about.

33:06.532 --> 33:16.960
[SPEAKER_02]: Also, one can check, of course, if you yourself are ready for hydrogen technology by thinking whether I would board a plane which is powered by hydrogen.

33:18.658 --> 33:21.780
[SPEAKER_02]: Or whether I would go by car, which is powered by hydrogen.

33:22.761 --> 33:23.422
[SPEAKER_02]: And so on.

33:25.263 --> 33:30.967

[SPEAKER_02]: However, I mean, yes, every new technology has its risks, of course, associated risks.

33:31.088 --> 33:41.776
[SPEAKER_02]: And now there is a lot going on in this field for making the hydrogen technology safer and acceptable by the society.

33:41.796 --> 33:42.736
[SPEAKER_02]: But this is one of the...

33:45.055 --> 33:51.541
[SPEAKER_04]: Just to say something to Olena and the listeners, the first cars were electric cars.

33:51.941 --> 33:56.906
[SPEAKER_04]: I think that's the reason why it's so easy to accept them because they have been there from the very beginning.

33:57.586 --> 34:05.233
[SPEAKER_04]: Many of the things that are related with battery technology are reinventing the wheel because we very early on had them.

34:05.754 --> 34:09.017
[SPEAKER_04]: Sodium batteries were there at the same time as lithium batteries.

34:09.574 --> 34:13.898
[SPEAKER_04]: the layered sodium cobalt oxide were discovered in the same year as lithium cobalt oxide.

34:13.958 --> 34:18.842
[SPEAKER_04]: It's just that the investments took us in another direction for many, many years.

34:19.463 --> 34:26.890
[SPEAKER_04]: So that's why it's so easy to accept the battery technologies in comparison to some others that would be a kind of a paradigm change.

34:27.470 --> 34:33.756
[SPEAKER_04]: With batteries, we have no paradigm change since the moment we kind of discovered interconnection in materials.

34:35.094 --> 34:44.582
[SPEAKER_00]: I think it's worth mentioning the elephant in the room, the fact that we are sitting here in Stavanger, which is the oil capital of Norway.

34:45.322 --> 34:57.572

[SPEAKER_00]: So in order to transition from the fossil fuel economy, of course, we can naturally imagine that there might be some pushback there.

34:57.952 --> 34:59.874
[SPEAKER_00]: However, if I

35:00.011 --> 35:05.514
[SPEAKER_00]: I was to play devil's advocate, for example, Jelena with battery technologies.

35:06.834 --> 35:10.136
[SPEAKER_00]: There is some talk of responsible research in

35:10.213 --> 35:30.947
[SPEAKER_00]: innovation example we hear that the mine tailings from lithium mines and other precious metal mining that the environmental cost of these precious metals might be just as bad the naysayers say as

35:32.187 --> 35:34.388
[SPEAKER_00]: mining fossil fuels.

35:34.908 --> 35:36.969
[SPEAKER_00]: What would you say to that point?

35:37.049 --> 35:41.911
[SPEAKER_00]: And in general, how do you think about responsible research within the work that you do?

35:42.991 --> 35:48.513
[SPEAKER_04]: Yeah, I think it's a really important topic, but I think it's kind of an internal topic for every researcher.

35:48.713 --> 35:49.614
[SPEAKER_04]: Of course, there is

35:50.595 --> 35:59.262
[SPEAKER_04]: kind of a movement trying to organize that in certain lists and kind of explanations, guidelines, we would say.

35:59.283 --> 36:04.147
[SPEAKER_04]: But I think it's something that we, as researchers, have to internalize.

36:05.488 --> 36:07.650
[SPEAKER_04]: And for me, that was always important.

36:08.170 --> 36:15.316
[SPEAKER_04]: The sourcing, the safety aspects, the toxicity aspects of materials, they were always important.

36:16.177 --> 36:16.437
[SPEAKER_04]: And then

36:17.635 --> 36:24.717
[SPEAKER_04]: At the end of the day, it is a kind of a balance act, trying to understand that, and that's very complex.

36:25.137 --> 36:31.358
[SPEAKER_04]: The techno-economical models are really complex, and that's beyond also understanding of a natural scientist, right?

36:32.058 --> 36:45.181
[SPEAKER_04]: But what I try to do for myself is be in permanent contact with people that know things that I do not know, in particular in batteries, to understand the pathways of materials.

36:46.294 --> 36:48.796
[SPEAKER_04]: that do investigate processes.

36:50.237 --> 37:08.153
[SPEAKER_04]: And even in the situations where it's really difficult because many industries or companies do not openly talk about these sourcing, still to try to get the information from knowledgeable people and kind of try to work for the best of it.

37:09.814 --> 37:10.475
[SPEAKER_04]: And yeah.

37:11.294 --> 37:18.440
[SPEAKER_04]: I think this is really relevant for me personally, and I think for many people that are in my field, it is becoming more and more relevant.

37:19.973 --> 37:28.956
[SPEAKER_01]: So sustainability for the energy technology, energy become like one of the essential needs for our generation now.

37:29.656 --> 37:48.443
[SPEAKER_01]: And I've been always telling in my class like, if we want to avoid repeating the mistake, the ignorance to what is the fossil fuel are doing, and if we just adapt the new technology because it's zero CO2, only CO2 tunneling, we need to look at the whole environmental impact.

37:49.460 --> 37:55.447
[SPEAKER_01]: That's what, because otherwise we create another problem, which we will discover maybe next.

37:56.087 --> 38:04.136

[SPEAKER_01]: I don't know if I will be there to discover it, but 20 years later, we will be talking about different environmental crisis, not the global warming and other thing.

38:04.857 --> 38:08.261
[SPEAKER_01]: So new technologies, when they are coming out, I think this...

38:09.759 --> 38:14.545
[SPEAKER_01]: Life cycle analysis, life cycle assessment, this is becoming an important part to think about.

38:14.926 --> 38:25.559
[SPEAKER_01]: When we integrate these things in our research, we look at what is non-toxic, what is easily available, what is available in a larger scale, if you have something developing for larger scale.

38:26.317 --> 38:31.340
[SPEAKER_01]: But at the end, it's the question about fossil fuel and those companies.

38:31.360 --> 38:33.521
[SPEAKER_01]: I don't think they are stopping that.

38:33.701 --> 38:35.822
[SPEAKER_01]: They are actually supporting it differently.

38:36.422 --> 38:40.104
[SPEAKER_01]: At the end, they will be the change makers in the energy scenario.

38:40.465 --> 38:46.828
[SPEAKER_01]: I was talking to an economist in Bergen University, and he says, when you think like economists, they are really different.

38:47.308 --> 38:48.409
[SPEAKER_01]: Who is going to do that?

38:48.529 --> 38:49.589
[SPEAKER_01]: Who is going to buy that?

38:50.870 --> 38:52.031
[SPEAKER_01]: And they have this approach.

38:53.422 --> 38:57.727
[SPEAKER_01]: energy market is established in certain areas by fossil waste.

38:58.087 --> 38:59.428
[SPEAKER_01]: These are the big players.

38:59.889 --> 39:08.398

[SPEAKER_01]: If they adopt their vision and they adopt integrating, you cannot cut down the business and somebody else will not establish new industry.

39:08.938 --> 39:14.624
[SPEAKER_01]: So these are the existing strong players and they are going to bring this change.

39:15.145 --> 39:15.585
[SPEAKER_01]: By wind,

39:16.536 --> 39:18.598
[SPEAKER_01]: Going from Statoil to Equinor is one change.

39:19.399 --> 39:27.869
[SPEAKER_01]: By adopting wind energy as a biggest portfolio, investing in solar cell, and looking at hybrid energy technologies, they are contributing.

39:28.527 --> 39:50.356
[SPEAKER_00]: however critics might argue that these big energy players that you are talking about they have a vested interest in continuing on with the status quo as it is that is the model that they exist to serve it would not be to a naive person it would not be in their best interest to pivot their whole

39:51.036 --> 40:08.162
[SPEAKER_00]: strategy for the sake of helping avoid a crisis that looms over the horizon that is as of yet not even accepted by perhaps some sectors of the current energy industry.

40:08.902 --> 40:15.564
[SPEAKER_00]: So when you say that these companies are going to have to take a lead, of course they are the ones in those positions.

40:16.001 --> 40:31.132
[SPEAKER_00]: But what makes you certain that they will take this noble step and, in fact, cease enriching themselves, in fact, take financial hits by pivoting to these newer technologies?

40:32.069 --> 40:37.312
[SPEAKER_04]: I think they will not take the financial hit because the legislative is already there.

40:37.872 --> 40:42.495
[SPEAKER_04]: So these companies are also pressured by EU and its new legislatives.

40:42.595 --> 40:47.197
[SPEAKER_04]: So it actually, at this moment, it pays off to be sustainable.

40:47.718 --> 40:50.219

[SPEAKER_04]: So in that sense, I think we're going in the right direction.

40:51.380 --> 41:00.605
[SPEAKER_04]: Also in terms of political momentum that this moves, it's just really important to see where are the boundaries of it.

41:00.842 --> 41:08.645
[SPEAKER_04]: And as you said, we do not end up in the next crisis in 10 or 20 years.

41:09.206 --> 41:12.587
[SPEAKER_04]: But I think politically, now the question is, is it too late or is it not too late?

41:12.627 --> 41:16.429
[SPEAKER_04]: But politically, we do have the critical changes.

41:17.789 --> 41:23.932
[SPEAKER_04]: At least in my field, they are very clear in the sense of in which direction the materials should go in the future.

41:23.952 --> 41:29.294
[SPEAKER_04]: And there is a big pressure also in the research to attain that sustainability.

41:29.954 --> 41:48.229
[SPEAKER_04]: So if we just follow the legislative that is now this year, very quickly kind of pointed out by EU, we will have to, and Norway is always being a part of that legislative too, we will profit also from actually following it.

41:48.649 --> 41:53.233
[SPEAKER_04]: So I think it's a kind of, it could be a win-win situation also for the local

41:54.268 --> 42:10.656
[SPEAKER_04]: And I have another maybe opinion, and that is that Norway has been, in comparison to many other countries, kind of taking out fresh ideas more quickly, and in that sense, kind of more adaptive to modernization.

42:11.837 --> 42:16.819
[SPEAKER_04]: And I think that's a positive aspect and could be also in terms of sustainability, a positive aspect.

42:16.859 --> 42:22.042
[SPEAKER_04]: So I think the Norwegian culture is the one that opens up and takes up good things

42:22.739 --> 42:31.465
[SPEAKER_04]: So I think that's, and for many other, like if I talk with colleagues around the world, many say, who would do it if not Norway?

42:31.745 --> 42:37.990
[SPEAKER_04]: Because you need also a certain wealth in order to be able to make these kind of decisions.

42:38.070 --> 42:39.751
[SPEAKER_04]: And this is how I feel about it too.

42:40.411 --> 42:41.732
[SPEAKER_04]: Who if not Norway?

42:41.752 --> 42:43.894
[SPEAKER_00]: Yeah.

42:44.134 --> 42:48.297
[SPEAKER_00]: Any other confusing remarks before we end today's episode?

42:49.514 --> 42:58.238
[SPEAKER_02]: Maybe not counter polluting yet, but I'd like to add also, so you were mentioned like why the industries would take the hit, right?

42:58.278 --> 43:00.439
[SPEAKER_02]: Something like this.

43:00.459 --> 43:14.265
[SPEAKER_02]: And again, from the same conferences where we had some as well presentations from industries and those industries who actually adopt the green technologies such as steel production.

43:15.724 --> 43:18.487
[SPEAKER_02]: And these are very energy consuming industries.

43:18.567 --> 43:24.872
[SPEAKER_02]: And they do say that we do see that there are customers who prefer more expensive, but greener product.

43:25.193 --> 43:28.455
[SPEAKER_02]: And the number of those customers are growing, is growing.

43:29.536 --> 43:39.565
[SPEAKER_02]: So this is something that has been changing in the, as Jelena was mentioned, of course, pushed a lot by the legislation or global legislation.

43:42.681 --> 43:51.344
[SPEAKER_02]: but as well maybe something is changing in the the paradigm of the big industry looking in the future of our planet.

43:52.765 --> 43:57.147

[SPEAKER_00]: Well let's hope that those changes take place as quick as possible because

43:58.445 --> 44:01.428
[SPEAKER_00]: I think we would all agree that time is running short.

44:01.928 --> 44:05.412
[SPEAKER_00]: And time is also running short for the end of today's episode.

44:05.452 --> 44:09.716
[SPEAKER_00]: So I'd like to thank all of our participants for joining us.

44:10.156 --> 44:12.739
[SPEAKER_00]: And thank you to you, dear listener, for joining us.

44:13.199 --> 44:13.880
[SPEAKER_00]: We'll catch you again.

44:14.221 --> 44:14.481
[SPEAKER_00]: Goodbye.