1 UNITED STATES PATENT AND TRADEMARK OFFICE

2 BEFORE THE PATENT TRIAL AND APPEAL BOARD

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4 LG ENERGY SOLUTION, :
LTD., :
5 :
Petitioner, :
6 -vs- : CASE NO. IPR2024-01013
: U.S. PATENT NO. 10,153,483
7 MOLECULAR REBAR DESIGN, :
LLC, :
8 :
Patent Owner. :
9

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11 Deposition of YU ZHU, PhD, an expert witness herein,

12 taken by the Patent Owner as upon Cross-Examination and

13 pursuant to the Federal Rules of Civil Procedure and Notice

14 via Zoom videoconference on March 14, 2025 at 10:00 a.m.,

15 before Jennifer K. Starner, RPR, a Notary Public within and

16 for the State of Ohio.

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MRD EX. 2024
LGES v MRD
IPR2024-01011

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S T I P U L A T I O N S

It is stipulated by and between counsel for the respective parties that the deposition of YU ZHU, PhD, an expert witness herein, called as upon Cross-Examination by the Patent Owner may be taken at this time and place pursuant to the Federal Rules of Civil procedure and Notice as to the time and place of taking said deposition; that the deposition was recorded in stenotypy by the court reporter, Jennifer K. Starner, RPR, and transcribed out of the presence of the witness; and that said deposition is to be submitted to the witness for his examination and signature, and that signature may be affixed out of the presence of the Notary Public.

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I N D E X

WITNESS:

YU ZHU, PhD

	Page
Cross-Examination By Mr. Zinda	5

1 YU ZHU, PhD,
2 of lawful age, as having been duly sworn, as hereinafter
3 certified, was examined and testified as follows:
4 CROSS-EXAMINATION
5 BY MR. ZINDA
6 **Q Good morning, Dr. Zhu. How are you?**
7 A Good morning. How are you?
8 **Q I'm doing pretty well. Thank you for**
9 **asking. I first want to ask you have you ever been deposed**
10 **before?**
11 A No.
12 **Q Okay. So this is your first deposition.**
13 **So I just want to lay out some kind of -- I'll call them**
14 **ground rules. And your counsel can chime in if he disagrees**
15 **with anything I'm telling you. If I ask you a question and**
16 **you don't understand the question I'm asking, can you let me**
17 **know so that we -- I can clarify the question for you?**
18 A Yes, I will.
19 **Q And if I ask you a question and you**
20 **don't ask me to clarify it, I'm going to assume that you**
21 **understand it. Does that make sense?**
22 A Yes.
23 **Q During the deposition, I'm sure there**
24 **will probably be at least some objections from your counsel.**
25 **And he probably already told you this. You have to answer**

1 the question unless he instructs you not to. Does that make
2 sense?
3 A Yes.
4 Q Are you under any sort of medication or
5 anything that would impair your ability to give truthful
6 testimony here today?
7 A No.
8 Q And I don't know how long the deposition
9 is going to last, but we will certainly take breaks. And
10 since you're the one being deposed, I'm open to taking
11 breaks whenever you would like. Typically -- since this is
12 your first deposition, typically breaks are, in my
13 experience, about 45 minutes to an hour or so. It's
14 typically when people want to take breaks, but I'm not
15 telling you you have to. I'm giving you a little bit of
16 guideline there since you've never been deposed. Does that
17 all make sense?
18 A Yes.
19 Q Okay. Great. So, Dr. Zhu, we're here
20 today -- you're here today to be deposed on the testimony
21 that you offered in the IPR challenging U.S. Patent
22 10,153,483; is that correct?
23 A Yes, that's correct.
24 Q And if I refer to that -- and I'm going
25 to refer to that patent as the '483 Patent; is that fair?

A That's fair.

Q And in your declaration, you offered opinions on the validity of the claims of the '483 Patent?

MR. IN: Objection. Form.

A Can you repeat that question again?

Q Sure. In your declaration, you have offered opinions on the validity of the claims of the '483 Patent?

A I offered a technical opinion on Patent '483 in the declaration.

Q And as part of your opinions, did you apply the language of the claims to the prior art?

A I studied the prior art and compared with the prior art and Patent '483 and I provided my evaluation.

Q And as part of that evaluation, did you interpret the language of the claims of the patent?

MR. IN: Objection. Form.

A I tried to understand the language of the '483 Patent and I studied the prior art and put my understanding to arrive at my declaration.

Q Okay. Can I ask you, Dr. Zhu, to pull out LGES-1001?

A So the patent?

Q Yes, sir.

A Yes.
Q That's the '483 Patent, correct?
A Yes, that's the '483 Patent.
Q If I could get you -- could you please turn to the end of the patent to Claim 1?
A I am at the end of the patent.
Q And do you see Claim 1?
A Yes, I see Claim 1.
Q And the first phrase there at the beginning of the claim says, "A composition useful for lithium iron batteries comprising discrete, non-agglomerated and exfoliated carbon nanotubes."
Did I read that properly?
A Yes.
Q What is a -- what is the meaning of discrete carbon nanotubes?
MR. IN: Objection. Form.
A Yes. The discrete, non-agglomerated and exfoliated carbon nanotubes are used quite often in the literature. And also the use is quite common in the community of nanotube research, battery research. So oftentimes they are used interchangeably. I also gave some descriptions in my declaration regarding the discrete, non-agglomerated and exfoliated carbon nanotube. And I believe from POSITA point of view, those are the words which

have similar meaning and can be considered as same status of carbon nanotube.

Q Okay. But what is -- I'm looking for your -- a clear definition of your -- what your understanding of what -- what is a discrete carbon nanotube. What is the definition -- well, let me strike that.

What is the definition of a discrete carbon nanotube in your own words?

MR. IN: Objection to form.

A Well, I think we don't really need to have a definition for this discrete because this is a common understanding for people working with carbon nanotube and they've referred to a carbon nanotube, that they have non-agglomerated status, they could have exfoliated status and it can be a uniformly distributed in the medium.

Q Can I get you to turn to LGES-1003, which is your declaration on the '483 Patent.

A I opened my declaration.

Q Okay. Could you please turn to paragraph -- or rather to Page 49.

A Page 49. I'm on Page 49.

Q If you go to Paragraph 83. Do you see Paragraph 83?

A Yes, I see Paragraph 83.

Q And you said, "Indeed a POSITA would

1 have understood a carbon nanotube that is, as shown below,
2 fully isolated from each other to be discrete,
3 non-agglomerated and exfoliated."
4 Do you see that sentence?
5 A Yes, I see that sentence.
6 Q And so you're interpreting -- your
7 understanding of discrete is it has to be fully isolated
8 from another nanotube; is that fair?
9 MR. IN: Objection. Form.
10 A Did you say fully oxidized?
11 Q No. No. Sorry. Turning back to the
12 sentence where you say, "As shown below, fully isolated from
13 each other." And my question is, is your understanding of a
14 discrete carbon nanotube is that it is fully isolated from
15 another nanotube?
16 A My understanding is discrete and
17 non-agglomerated and exfoliated are similar words to use to
18 describe a very similar situation, which means that the
19 nanotubes are dispersed as individual tubes intermedium. In
20 this case, it could be a resin.
21 Q Okay. But I want to -- I'm asking about
22 the word fully isolated. So if you go to figure -- do you
23 see the annotated figure on Page 50 of your declaration?
24 A I see the figure on Page 50. Do you
25 refer to Figure 1B?

1 **Q Correct. And do you see the -- you**
2 **added a red arrow. Do you see that?**
3 A Yes. I see that.
4 **Q And so you're identifying that nanotube**
5 **as discrete because it's fully isolated from the other**
6 **nanotubes?**
7 A Yeah. I say it is discrete,
8 non-agglomerated and exfoliated carbon nanotubes.
9 **Q Okay. Is it -- is it discrete because**
10 **it's fully isolated from the other nanotubes?**
11 A From the figures, it was separated from
12 other nanotubes that was joining on the figure.
13 **Q Okay. So I'm just trying -- I'm just --**
14 **you know, I'm not trying to play word games with you. I'm**
15 **just trying to understand how you're viewing the word**
16 **"discrete." And it appears to me that your understanding of**
17 **discrete is that the nanotube is separate from the other**
18 **nanotubes; is that fair?**
19 MR. IN: Objection. Form.
20 A No. I already said this is actually a
21 common understanding for the POSITAs because when you use
22 the carbon nanotube in lithium battery electrode
23 preparation, nanotube act as conducting filler materials in
24 this composite. So this conducting filler material is
25 needed to have good, uniform distribution in the electrode.

1 Therefore, I think it's quite a general understanding for
2 the POSITA that all the conducting filler such as carbon
3 nanotube needed to be uniformly distributed and needs to be
4 non-agglomerated. And, therefore, all the descriptions like
5 discrete, non-agglomerated and exfoliated pointing to the
6 same status of the nanotube distribution in the electrode,
7 which means that they are uniformly distributed and they are
8 not aggregated and bundled in a specific location.
9 **Q So is it your opinion that a discrete**
10 **nanotube has to be separate from other nanotubes?**
11 MR. IN: Objection. Form.
12 A I do not think of discrete and
13 non-agglomerated and exfoliated as having a significant
14 difference in terms of describe the status of the nanotube
15 distribution in the context of Patent '483 and the use in
16 the carbon nanotube within a lithium iron battery electrode.
17 **Q Okay. Well, that wasn't my question.**
18 **So I'm going to strike the response -- as nonresponsive. Or**
19 **object as nonresponsive.**
20 **My question is quite simple. Does a**
21 **discrete nanotube have to be separate from another nanotube?**
22 A The discrete nanotube is a status of the
23 nanotube, which means that they are not aggregated, not
24 agglomerated and they are exfoliated as they -- they are
25 not -- they are not bundled to other carbon nanotubes. So

when the carbon nanotube was produced as a -- as a raw material, they will grow under gas-based conditions and gas-based grown carbon nanotube are bundled carbon nanotube. So they are basically apparently carbon nanotube, like, bundled to each other. So this is the status, I believe, different from discrete, non-agglomerated and exfoliated status in which there is no bundled carbon nanotubes. And the nanotubes have been separated from each other and forming a uniform distribution in the medium. So that's the status of the discrete, non-agglomerated and exfoliated. This is regarding to the status as grown carbon nanotube, which is bundled, yeah, forming bundles.

Q And so you testified that a discrete nanotube is a non-bundled -- non-bundled -- or I'm sorry.

Your testimony was that discrete carbon nanotubes are non-bundled nanotubes that are separate from each other, correct?

MR. IN: Objection. Form.

A Yeah. I think more accurately, the -- what I said in the declaration is discrete, non-agglomerated and exfoliated nanotubes are nanotubes that are uniformly distributed in the medium.

Q Okay.

A That's what I wrote in the -- in the declaration.

1 **Q Okay. And does that mean the nanotubes**
2 **have to be separate then from one another?**
3 A From what I write over there, that just
4 means it's uniformly distributed.
5 **Q Going back to LGES-1001, going back to**
6 **the Claim 1 again.**
7 A Yes.
8 **Q Do you see in the second line of Claim 1**
9 **it says "non-agglomerated"?**
10 A Yes. I saw that one.
11 **Q From the perspective of a person of**
12 **ordinary skill in the art, what is a non-agglomerated carbon**
13 **nanotube?**
14 A That means it was uniformly distributed
15 in the medium, yeah, as compared with the initial status of
16 the carbon nanotube.
17 **Q And if you turn back to Claim 1, if you**
18 **look at the next two words, it says "and exfoliated." Do**
19 **you see that?**
20 A Yes.
21 **Q From the perspective of a person with**
22 **ordinary skill in the art, what is an exfoliated carbon**
23 **nanotube?**
24 A That's what I mentioned. Its initial
25 status of the carbon nanotube as grown nanotube. They are

bundled to the carbon nanotube. So when they are uniformly distributed, which means they do not form any bundled structure by themselves, and they can be considered as exfoliated carbon nanotube.

Q Is it your -- is it your testimony that the words -- that the words discrete, non-agglomerated and exfoliated in Claim 1 have the same meaning?

MR. IN: Objection. Form.

MR. ZINDA: Let me strike the question.

Q Is it your testimony that a person of ordinary skill in the art would understand the words discrete carbon nanotubes, non-agglomerated carbon nanotubes and exfoliated carbon nanotubes to have the same meaning?

A I think it's not only my thoughts. It's actually the thoughts from the people in the community. It's the thoughts of the POSITA who have been working on carbon nanotube and batteries, has experience with electrochemistry and carbon fillers. They understand the meaning of a uniformly distributed carbon fillers in the electrode materials distributed in lithium iron batteries. So they understand the meaning of discrete, the meaning of non-agglomerated and the meaning of exfoliated carbon nanotube. They represent a status that is desirable of lithium iron battery in actual fabrication.

Q If I could get you to turn to Claim 8 of

1 **the '483 Patent.**
2 A Claim 8 of '483.
3 **Q Correct. And then if you -- if you --**
4 **you see it goes over to the next column, Column 8?**
5 A Yes.
6 **Q Do you see there's a phrase in the**
7 **middle of that -- kind of in the middle of the top of Column**
8 **8. It says, "Wherein, the carbon nanotubes are uniformly**
9 **dispersed without clustering on a dimension scale of less**
10 **than about 1 micrometer."**
11 **Do you see that?**
12 A Yes, I see that.
13 **Q As a person of ordinary skill in the**
14 **art, what is your understanding of the meaning of that**
15 **phrase?**
16 A My understanding is -- and also the
17 POSITA's understanding is that is a description of a status
18 that the nanotube is not bundled. So they have significant
19 distance between each other.
20 **Q Is it -- is it your -- would a person of**
21 **ordinary skill in the art understand that phrase to mean**
22 **that the discrete nanotubes have to be at least 1 micrometer**
23 **apart?**
24 A From the POSITA's point of view, if they
25 have significant distance from each other it can be regarded

as dispersed. And oftentimes it does have significant distance as compared with the length of -- of the carbon nanotube, which is in the range of the microbes. So it is quite common for the POSITAs to consider that dispersed carbon nanotube actually have a distance of around 1 micrometer.

Q And then if you go down to -- well, let me go back to that same phrase where it says -- we just talked about it. Claim 8 says, "Wherein the carbon nanotubes are uniformly dispersed without clustering."

My question to you is from the perspective of a person of ordinary skill in the art, what does uniformly dispersed mean?

A Uniformly dispersed means there is no aggregated status, particularly as compared with initial status of as grown carbon nanotubes. Those nanotube are bundled. So the uniform distribution means that the nanotube does not form any initial bundled structure. Instead they will disperse in the medium with certain distance between nanotube rather than bundled each other as the initial carbon nanotubes. That's the opinion of the POSITA, yeah.

Q And the claim states that that distance is about 1 micrometer, correct?

A That distance, about 1 micrometer for

1 you to a range that can be considered that carbon nanotube
2 are not bundled.
3 **Q So, Dr. Zhu, in your declaration you**
4 **offered testimony on two prior art references. One prior**
5 **reference is referred to as Ohata. Do you remember that?**
6 A Yes, I remember.
7 **Q And do you have Ohata handy? That's**
8 **LEGS-1004.**
9 A Let me open it. Yes.
10 **Q And then there was another reference**
11 **that you provided testimony on called Kavan. Do you**
12 **remember that?**
13 A Yes, I remember that.
14 **Q And Kavan is LGES-1005. If you could**
15 **open that up as well.**
16 A Yes, I opened it.
17 **Q I'm going to try to minimize going back**
18 **and forth between the documents if I can. Sometimes it's a**
19 **little hard, but let's start with your declaration. If you**
20 **could go to LGES-1003, Paragraph 29. Or actually let me**
21 **give you the page. I think that would be better.**
22 A Do we need to go to the declaration?
23 **Q Declaration, yes, sir. LGES-1003. And**
24 **that's Page 19.**
25 A I'm on Page 19.

Q Okay. Paragraph 28.
A 28. Yes, I saw that paragraph.
Q And it says -- the first sentence says, "Kavan describes performing oxidative 'functionalization' on the MWNTs to produce MWNT-ox." Did I read that correctly?
A Yes.
Q And MWNT, is that an abbreviation for multi-walled carbon nanotube?
A Yes.
Q And MWNT, that's an abbreviation for an oxidized multi-walled carbon nanotube?
A MWNT-ox means oxidized carbon nanotubes.
Q Does oxidizing a carbon nanotube result in the carbon nanotube getting shorter?
MR. IN: Objection to form.
A It is possible to have shorter carbon nanotubes after oxidation.
Q And can you explain how the carbon nanotubes become shorter when it's exposed to oxidation?
A So when oxidation reaction happens, the oxidant chemicals such as the nitric acid and other oxidant reagent would react with the carbon atoms on the surface of the carbon nanotube. And during this reaction, some of the carbon atoms on the carbon nanotube would be oxidized and form oxygen-containing functional group. If oxidation level

is very high and this can cause the circular oxidation of carbon atoms on the carbon nanotube, which can potentially result in a shorter of the carbon nanotube. However, this is really depending on the condition of oxidation. And depending on the oxidation reaction conditions, the nanotube can be shortened. It can also be comparable length as the original carbon nanotube. So this is not a certain answer in this case whether it will be always get shortened by oxidation reaction.

Q And you mentioned that this shortening of a carbon nanotube can occur if the oxidation level was high; is that correct?

A In principal, with more oxidation the chance of getting shorter carbon nanotubes is higher.

Q Is the nanotube always going to get shorter when it's oxidized or is it depending on the degree of oxidation?

A As I just said, it is not always getting shortened. So if the oxidation happened on the surface and if the oxidation happened across the length of the carbon nanotube, it does not necessarily result in the shortening of the carbon nanotube. But if the reaction happens in a circular direction, it probably can shorten the carbon nanotube.

Q If you go back to Paragraph 28 of your

declaration, do you still have that open? Do you see that final sentence of Paragraph 28?

A Paragraph 28 on Page 19 in my declaration, right?

Q Right.

A So which sentence you want me to look?

Q I can just read it to just put it on the record. It says, "Moreover, the amount of atomic oxygen present on the MWNT-ox surfaces was also analyzed by X-ray photoelectron spectroscopy and gave a value of 7%."

Did I read that correctly?

A Yes, you read that correctly.

Q Would you expect there to be a shortening of a carbon nanotube that is oxidized with -- at a value of 7 percent?

A That's -- that's what I -- that's what I just said. It's really depending on how the oxidation condition is controlled. The percentage of oxygen with atomic percentage does not necessarily result in a definite shortening of the carbon nanotubes because the oxidation functional group can be along the longitude and direction of the carbon nanotube. It could be across the circumference direction of the carbon nanotube. So it's not necessary to be definitive condition that will result the shorten of the carbon nanotube at this level.

Q Can oxidizing carbon nanotubes have a negative effect on the intrinsic properties of the nanotubes?

MR. IN: Objection. Form.

A This is depending on how do you define what is intrinsic property of the carbon nanotube. The oxidation will certainly change the chemical structure of carbon nanotube. And typically the oxidation will attach oxygen-containing functional group on the surface, on the end of the carbon nanotube. And those functional group -- oxygen-containing functional group will change some of the property of carbon nanotube. So it's depending on what intrinsic property you are referring to that -- that -- that property can be changed either in a -- in a good way or in a bad way depending on how you use those properties as well.

Q If you're relying on the carbon nanotubes to increase electro conductivity through an electrode, does oxidation have -- can oxidation have a negative effect on that property?

MR. IN: Objection. Form.

A So the impact would be quite complicated. So certainly there are some impacts on the intrinsic property of the carbon nanotube. And once you put oxygen functional group on the carbon nanotube, the intrinsic conductivity of the carbon nanotube will be

1 decreased. However, if you consider the carbon nanotube
2 used in lithium iron battery electrode, it's not solely
3 depending on the intrinsic conductivity of carbon nanotube.
4 It also depending largely on how the carbon nanotube was
5 distributed in the electrode materials, which contain both
6 active materials, contain part of the binder materials as
7 well as carbon fillers such as carbon nanotube. So the
8 conducting network can be viewed better if the dispersion is
9 better. So this will result in a better conductivity in
10 terms of the electrode as a whole. So this really depending
11 on how nanotube and electrode materials will be used
12 together in the electrode.
13 So, as I said, oxidation can have some
14 impact on the intrinsic conductivity of nanotube, which
15 leads to lower conductivity as compared with the pristine
16 carbon nanotube. However, generally, oxidized carbon
17 nanotube leads to a better dispersion in the medium, which
18 counted for a better conducting network viewed up in the
19 lithium iron battery electrode. In this case, the
20 conductivity of the electrode as a whole will be actually
21 better if you do not have good dispersion of carbon nanotube
22 in the electrode. I think this is actually very well
23 explored even by that time for all the battery industry and
24 battery researchers and POSITA have a well understanding of
25 what is the importance of dis -- well distributed carbon

1 fillers in the electrode versus how good the intrinsic
2 conductivity of the filler is and their impact on the
3 electrode formation as a whole.
4 **Q So, Dr. Zhu, I want to ask you about --**
5 **do you see Paragraph 29 of your declaration?**
6 A Yes.
7 **Q And the first sentence it says, "In**
8 **Kavan, oxidized nanotubes were mixed with a powder material**
9 (titanium dioxide, lithium manganese phosphate or lithium
10 iron phosphate) as were non-functionalized nanotubes as a
11 control." Do you see that?
12 A Yes.
13 **Q I want to ask -- do you see that you**
14 **cite Page 2 of Kavan?**
15 A Kavan, Page 2. Yes, I'm on Page 2 of
16 Kavan paper.
17 **Q Okay. And if you go to the second**
18 **paragraph it starts with, "Nanotubes were dispersed." Do**
19 **you see that?**
20 A Second paragraph?
21 **Q Yes, sir.**
22 A The surface of oxidation carbon nanotube
23 starting from this one.
24 **Q We're on the same page? You're on**
25 **Page 2 of LGES-1005?**

A Yes.
Q And you see the second paragraph that says, "Nanotubes were dispersed in water." Do you see that?
A So you are talking about Kavan?
Q Kavan, yes, sir.
A Kavan's literature, Page 2?
Q Right.
A The second paragraph?
Q Yes.
A My document is, "The surface oxidation of carbon nanotubes by nitric acid represented levels." That's the sentence on the second paragraph. I just wanted to make sure we're on the same document.
Q Oh, no, no. I'm sorry. I should be more clear. The right column. The second paragraph on the right column. Sorry. My mistake. I didn't --
A Right column. So you're saying, "Nanotubes were dispersed in water"?
Q Yes, sir. Second sentence.
A Okay. So which sentence you want me to go --
Q Let's focus on the first sentence. It says, "Nanotubes were dispersed in water under short sonication in an ultrasonic bath."
Did I read that correctly?

A Yes.

Q What is sonication?

A Sonication is a use of a -- is the using of sound wave, basically the mechanical vibration of the tip to vibrate the materials, which is a common technique to disperse aggregated materials, powder materials in solution.

Q And what is the purpose of sonicating the carbon nanotubes in Kavan?

A So in this -- in this sentence Kavan is carrying out experiment to disperse a solid powder, nanotubes into -- into a solution. So this is to disperse nanotubes in water in this case.

Q And then in the next sentence it says, "To this solution of powder material (titanium dioxide, lithium manganese phosphate or lithium iron phosphate) was added (in a proportion of 1-10 wt% of nanotubes in the mixture) and stirred overnight. The suspension was subsequently evaporated to dryness."

Do you see that?

A Yes.

Q So the first step is dispersing the nanotube under sonication of water; and then the second step is further mixing the active material with the nanotubes, correct?

A Yes.

Q And why are the -- why the -- why is the dispersion of the nanotubes in water mixed with the active material?

MR. IN: Objection. Form.

A I do not fully understand your question. So you're asking why they put these two together? Is that your question?

Q Yes. Why are they mixing the powder material with the nanotubes that are dispersed in water?

A I think you needed active materials in nanotube to be dispersed uniformly in the slurry and the slurry will be used to cast electrode and, therefore, they needed to put together uniformly. That's why they carry out this experimental step to prepare the slurry, which is the active materials and the carbon nanotube dispersed in water for casting electrode.

Q And when the nanotubes are -- when the nanotubes, water and powder material were mixed together, does -- does the active material anchor to the nanotubes?

A Well, in this case, it will rely on what is the surface of the carbon nanotube and the materials particles. So in this case, because the nanotube used in this process is already oxidized, so the nanotube mentioned in this step has been oxidized before. And at the surface of those nanotube and end of the nanotube, there are more

1 oxygen-containing functional groups such as carboxylic acid
2 group and hydroxy group. And those functional groups will
3 provide hydrophilicity of the carbon nanotube. That is why
4 this carbon nanotube can be very well dispersed in the
5 water, which is certainly a hydrophilic medium. And then
6 the powder materials of titanium dioxide, lithium manganese
7 phosphate and lithium iron phosphate, were dissolved -- were
8 not dissolved -- were dispersed in such a medium which
9 already have a uniform distribution of carbon nanotube in
10 the water. And this will help the interaction of carbon
11 nanotube and dispersed active materials, particles. So
12 there are a number of possibilities to forming strong
13 interaction between the surface of carbon nanotube, which
14 have different oxygen-containing functional group, and the
15 surface atoms of those active materials, which contain
16 positive charged nano ions and negatively charged oxygen
17 ions. Yeah.
18 **Q How does the surface of the -- how does**
19 **the surface of the oxidized carbon nanotubes attach to the**
20 **active material in Kavan?**
21 A So in Kavan's description, I mentioned
22 Kavan has mentioned the surface of carbon nanotube contain
23 at least carboxylic acid functional group, which has been
24 identified by the titration experiment. And those
25 carboxylic acid functional group, it's a connective charged

1 functional group. So they will have some interaction with
2 positive charged functional -- a positive charged ions,
3 right. So the negative charged carboxylic acid group and
4 the positive charged ions can be associated with ionic bond.
5 So the bond forming -- formed in this process can be
6 potentially an ionic carbon due to the charging status
7 between -- between the two materials. One is oxidized
8 carbon nanotube. The other is a different type of active
9 material, powder.
10 **Q Does -- would a -- do unoxidized carbon**
11 **nanotubes have Van der Waals forces attraction with active**
12 **material like -- well, let me strike that.**
13 **Would the unoxidized carbon nanotube**
14 **have Van der Waals force of interaction with the titanium**
15 **dioxide, for example?**
16 A Well, the non-oxidized carbon nanotubes,
17 the major property is you have also interaction force
18 between the nanotube itself. So they are competing with the
19 conduction force between the nanotube and the other active
20 materials. As I mentioned, the non-oxidized carbon
21 nanotube, they tended to aggregate if you do not have a good
22 way to disperse them. And the aggregation of the nanotube
23 is due to the pi pi interaction on the outside wall of the
24 carbon nanotube, which is a force between the Kavan bond and
25 the Van der Waals force. And this interaction happens when

the two tubes are very close to each other. So if the tube are bundled to each other, then there will be no chance for -- or very little chance for external active materials/particles like a titanium oxide, a lithium iron phosphate, particles to interact with the surface of the carbon nanotube. So, therefore, the Van der Waals force probably will not be competing with the interaction force of the nanotube itself. And that is why the oxidized carbon nanotube, which disrupted the pi pi stacking force of the nanotube, will intrinsically have better interaction with the oxide particles including iron phosphate, including titanium dioxide and so forth.

Q Okay. So I want to make sure I understand what you're saying. I think I do, but let me -- I'm going to try to explain my understanding of what you said. And you can correct me if I'm wrong.

So basically what you're saying is that when you oxidize the carbon nanotubes in Kavan and then you mix it with the active material, the functional groups allow you to have interaction between the active material and the carbon nanotubes; is that fair?

A The functional group on the carbon nanotube -- on the oxidized carbon nanotube will be beneficial for forming strong interaction between carbon nanotube surface and active material particles.

1 Q Okay. But if you have -- if you don't
2 have an oxidized -- strike that.
3 If the carbon nanotubes are not
4 oxidized, then you're saying the active material wouldn't
5 really attach to it because of the competing forces?
6 A The attachment -- I would say the
7 attachment would be much weaker as compared with the one
8 have oxidative functional group.
9 Q Okay. I understand. So I want to go to
10 the other -- the rest of the process described -- or the
11 steps described in that paragraph of Kavan. So when I say
12 "that paragraph," I'm referring to the paragraph we're
13 talking about where it begins -- in the middle there it
14 says, "The electrodes were prepared as follows." Do you see
15 that?
16 A In the same paragraph?
17 Q Yes, sir.
18 A Carbon nanotube -- I did not see -- oh,
19 "The electrodes were prepared as follows." This is what
20 you're referring to?
21 Q Right.
22 A Yes.
23 Q So it says in full, "The electrodes were
24 prepared as follows: Powder precursor material, either pure
25 or carbon-containing (see above) was mixed with 5wt% of

1 **polyvinylidene fluoride (PVDF) dissolved in**
2 **N-methyl-2-pyrrolidone."**
3 **Do you see that?**
4 A Yes.
5 **Q Okay. So first off, what is PVDF?**
6 A PVDF is a particle -- a fluorinated
7 particle which is commonly used as a binder for the casting
8 materials. It's polyvinylidene fluoride, yeah. It's a
9 several plastic polymer. It's a vinylidene polymer with a
10 fluorine group on the side chain.
11 **Q And when you use the word "binder," what**
12 **is a binder in an electrode?**
13 A The binder in the electrode is a
14 polymer, which you have as an active material, which is a
15 powder to be attached on the current connector, which is
16 usually an aluminum current collector for cathode and a
17 copper aluminum collector -- a copper collective for the
18 anode. And if you only have a powder active material so
19 they don't attach on those current collector very well, so
20 you needed to have something which function as a -- like a
21 glue and to help those active materials be attached on the
22 metal collector.
23 **Q Is PVDF a resin?**
24 A Yes. PVDF can be produced as a resin.
25 **Q And what is a -- for laypeople like me,**

what is a resin?

A It's just a technical term. So the PVDF is a polymer and a polymer can be prepared in different formats. So when we talk about a resilient polymer industry, they are referring those bead-like particles of polymer product. So you can basically use it for a lot of processing tubes like extrusion, ejection molding. So they always use something like a bead-shaped starting material. And it will be typically softened by raising the temperature and using shear force to mix with another component.

Q So you said -- you said you increased the temperature to soften it. Is that because it's a viscous -- or I guess it's a solid or semisolid material that you have to make viscous. Is that why you heat it?

A So the PVDF is somewhat passed as polymer. So when you heat it, the interaction between the PVDF or polymer molecular will become weaker. And then the polymer molecular started to flow and, therefore, the materials become a little bit soft from the appearance. And in this case, you can deform it and you can shear it, yeah.

Q And you mentioned before -- I think the word you used was it acts like a glue; is that fair?

A Yes. The PVDF is used as a binder material in lithium iron battery electrode and their big function is a glue. It's like a glue to adhere all the

1 materials together to the current collector.
2 **Q Okay. And then that same sentence that**
3 **we're talking about that mentions PVDF also states -- it**
4 **also mentions N-methyl-2-pyrrolidone. Have you ever**
5 **heard -- that's -- that's -- is that commonly referred to as**
6 **NMP, correct?**
7 A Yes, you are right.
8 **Q What is the purpose of NMP?**
9 A NMP is a solid which is used to cast
10 electrode slurry. So the electrode was prepared by
11 preparing the slurry first. The slurry means your solid
12 content was not completely dissolved in the solvent. And
13 the solvent in this case can be different materials. The
14 common one used on the cathode is NMP and it's a poly
15 solvent, but it's organic solvent. And it is actually one
16 of the few solvent that can dissolve PVDF very well. And
17 that is why it was chosen as a solvent to prepare the
18 cathode material slurry. And in this case, polyvinylidene
19 fluoride will be completely dissolved in NMP once they were
20 mixed together. So the polymer PVDF was completely
21 dissolved in NMP and they formed -- pretty much they
22 themselves formed a solution. So you can have atom
23 materials like nanotube, active materials. Those are the
24 materials which will not be dissolved by NMP. Therefore,
25 you will have something like a slurry. And the slurry has a

solution base, which including the dissolved PVDF in NMP, and a solid base, which it has common fillers such as carbon nanotube, and the active material, which are powder materials.

So once you have this slurry, you can actually cast a carbon collector -- or an aluminum collector in this case for the cathode. And once the film was casted -- it's a white film. So then you needed to evaporate all the solvent, which is NMP. So once the NMP was completely evaporated -- and the PVDF itself will not be evaporated. It will stay -- it will come back to -- to the solid status. And in this case, the PVDF basically mixed uniformly with carbon filler and active materials. So they were very tightly binded to each other and binded onto to the current collector which is aluminum. This is how they prepare coated electrode, yeah.

Q Okay. And then Kavan, the first step is mixing the nanotubes with water, correct?

A Yes.

Q Okay. And the mixing of PVDF doesn't occur until after you've already mixed the active material with the oxidized nanotubes, correct?

A You are right.

Q If you were to mix the nanotubes with the PVDF in the first step instead of water, would that --

that would prevent the functional groups of the nanotubes from attaching to the active material, wouldn't it?

A Can you say that again when you first --

Q Sure. Sorry. That's a poorly phrased question. So, I mean, the nanotubes are dispersed in water first, correct?

A Yes.

Q But if you were to disperse the nanotubes in the PVDF, because it's a glue-like substance that would prevent the functional groups of the carbon nanotubes from attaching to the active material; is that correct?

A Well, the dispersion steps can be -- can be quite -- can be different from -- different from different people. So the carbon nanotubes can be dispersed in water very well, which usually require the carbon nanotube have good hydrophilicity. And then you can disperse carbon nanotube directly in water, which is dispersed carbon nanotube in medium and forming uniform distribution of carbon nanotube in that medium. And, therefore, you can take that -- take that step.

And you can also disperse carbon nanotube in other medium other than water, right. So if you can find a way that carbon nanotube can be very well dispersed in another medium -- for example, you can see the

1 PDVF as the medium. And this is a large portion in the
2 mixture. And carbon nanotube is the one you would like to
3 distribute in such a medium, right. So in this case
4 because -- because your metrics of PVDF is a solid and your
5 nanotube is also a solid, so it's a solid dispersed in a
6 solid. So in this case, you really needed to have a shear
7 force to help one solid material to be widely -- to be
8 uniformly distributed in another medium. That is why if you
9 directly combine nanotube and the PVDF, then you needed to
10 use the shear force to make sure this too was -- this too
11 was uniform mixed and nanotube was uniformly distributed in
12 PVDF, yeah.
13 So the processes will be slightly
14 different, but the purpose is the same. The purpose is to
15 achieve a uniform distribution of carbon nanotube in medium.
16 And then in the next step, if you want to mix with some
17 active materials, you can mix the active materials with that
18 medium which already have uniform distributed carbon
19 nanotube. The overall purpose for all those processes --
20 different people may use different processes, but the
21 overall purpose of all these procedures is to making sure
22 that the carbon nanotube can be uniformly distributed at the
23 end in the -- in the final mixture that you use to cast the
24 electrode, which can be active materials and carbon fillers,
25 binders and a solvent.

1 **Q Okay. But in Kavan doesn't he teach**
2 **that another purpose other than just uniform dispersion is**
3 **to have a better attachment between the active material and**
4 **the CNTs?**
5 A Yeah. I think this is quite common
6 because, as I just mentioned, you can have different
7 approach to achieve the initial pre-dispersion of carbon
8 nanotube in your medium. And this is actually well
9 established understanding for all the battery researchers,
10 for all the nanotube dispersion work. So you can choose
11 different medium. In Kavan's case, he choose to use water
12 to pre-disperse all those carbon nanotubes. So you have
13 carbon nanotubes distributed in water very well. And then
14 you start to mix with the casting solvent, which is NMP, as
15 well as the active materials, the titanium dioxide, the
16 lithium manganese phosphate, lithium iron phosphate and so
17 forth, right. And in another case in Ohata, he choose to
18 mix nanotube directly with PVDF and get a uniform
19 distribution of the carbon nanotube within PVDF. And he
20 didn't use water because his carbon nanotube is not
21 hydrophilic. It's not an oxidized carbon nanotube. So in
22 his case, he used the carbon nanotube mixed with PVDF, which
23 is also a medium, and he achieved a uniform distribution of
24 the carbon nanotube in a -- in a PVDF and everything. And
25 then the PVDF resin, which has uniform distributed carbon

nanotube, was then mixed with active materials as well as the dispersion medium, which is a solvent, NMP, and achieve eventually the same status. When they casted the materials -- when they casted the materials and slurry on the electrode, the material is casted to pretty much the same.

Q Okay. But in Kavan, he uses water in his first step, correct, under sonication?

A Kavan used water to disperse, yes.

Q If you were to put those nanotubes of Kavan in -- the oxidized nanotubes of Kavan into, like, the PVDF, right, that would cover -- that would cover the nanotubes in resin. And then how the -- the functional groups of the nanotubes couldn't then attach to the active material, could they?

MR. IN: Objection. Form.

A So this is a -- it should be understanding this way. So in Kavan's -- in Kavan's case, the nanotube is already exfoliated and dispersed after they were treated with acid. And once they collect solid powders of those oxidized carbon nanotubes, those oxidized carbon nanotubes are not really a bundled carbon nanotube as compared with the pristine, non-oxidized carbon nanotube, which are typically bundled. So they can be mixed in within a resin such as PVDF. And you can also shear them using a

1 shear force to shear them and achieve some dispersion.
2 In my opinion, in the POSITA's opinion,
3 it will be easier to achieve a better distribution as
4 compared with the bundled carbon nanotube. So he can also
5 choose water as a medium to distribute the oxidized
6 Nanotube, which is what he did in his paper since the
7 nanotube can even be directly dispersed in water. So he
8 just choose water as a different dispersed medium. But at
9 the end they were all dissolved in -- they were all
10 dispersed in NMP. They were all dispersed -- put together
11 with active materials. So the end of status, whichever
12 approach you take, will be the same because even you use the
13 resin approach, the resin you use is PVDF. It's actually
14 the same type of the binder materials you used for -- in
15 Kavan's case when they mixed together with NMP solvent
16 system, yeah.
17 **Q And the NMP, that helps disperse the**
18 **PVDF throughout the mixture?**
19 A Yes. NMP can dissolve PVDF forming
20 solution.
21 **Q I think you used the word "matrix"**
22 **before. What is a PVDF matrix?**
23 MR. IN: Objection. Form.
24 A I -- I think what I mean in the -- in
25 describing the PVDF is I describe a PVDF as a binder

1 material in the -- in the electrode. And at the end of the
2 binder -- the binder molecular so it will bind all the
3 active particles and carbon fillers in forming good
4 adaptation to the current collector.
5 **Q Okay. But when you -- when -- I just**
6 **want to be clear, though, that when you use the word**
7 **"dissolve" -- and if we go back to -- let me strike that.**
8 **Let me go back to that sentence. It**
9 **says, "5wt% of PVDF was dissolved in NMP."**
10 A Yes.
11 **Q That doesn't mean that the PVDF is**
12 **removed from the mixture, correct?**
13 A No. It's not -- it doesn't mean the
14 PVDF was removed from -- from one mixture. So which mixture
15 are you referring to?
16 **Q Well, it says, "The electrodes were**
17 **prepared as follows: Powder precursor material, either pure**
18 **carbon-containing (see above) was mixed with 5wt% of PVDF**
19 **dissolved in NMP."**
20 **Do you see that?**
21 A Yes. So no, it was not removed from the
22 mixture. It was still inside the mixture. The mixture
23 containing all the carbon nanotubes -- containing all the
24 active materials -- active materials, powder and PVDF as
25 well as NMPs. So there are four components in this mixture.

MR. IN: Counsel, we've been going for an hour now. Would this be a good time for a quick break?

MR. ZINDA: Yeah. How about ten minutes, does that work for you?

MR. IN: Yeah.

(Whereupon, a brief recess was taken.)

Q Dr. Zhu, I want to turn -- so we last ended our discussion -- we talked a lot about the Kavan reference. I would like to turn now and talk about the Ohata reference. But before I have you pull that up, can I get you to turn to Page 16 of your declaration which is LGES-1003?

A Page 16 of my declaration?

Q Yes, sir.

A Yes, I am on that page.

Q Okay. So do you see that the first sentence says, "Ohata prepares" -- I'm sorry. The first sentence of Paragraph 24 says, "Ohata prepares its composites by first producing a masterbatch by blending at least carbon nanotubes with a resin such as a fluorocarbon resin, e.g., PVDF."

Do you see that?

A Yes, I see that.

Q What is the purpose of the masterbatch

in Ohata?

A So the masterbatch is basically a precursor, which outputs the dispersion of minor component, in this case carbon nanotubes. So in Ohata's approach, it's mixing carbon nanotubes and a resin, which is a PVDF. So they first achieve uniform distribution of carbon nanotube in a resin, which is the -- which is a PVDF. And then they use this -- which is called a masterbatch -- to prepare the final slurry for coating. And the next steps that will be taking this masterbatch to mix with active materials and solvent.

Q Okay. And so the purpose of the masterbatch in Ohata is to unravel and straighten the carbon nanotubes?

A Yes, to disperse carbon nanotubes.

Q Is there any other purpose for the masterbatch other than the dispersion?

A Masterbatch can have many, many advantages. Here certainty I would consider one of the very important reasons to use masterbatch is to disperse nanotube in a resin, which will later on achieve better dispersion in the final slurry including active materials and solvent.

Q Okay. But in -- you said there could be other uses for a masterbatch. But in Ohata, is it your opinion that the only use is to unravel and straighten the

nanotubes?

A I wouldn't say only. I would say that one of the important purposes is to disperse nanotube in the resin.

Q What are the other purposes that you're aware of?

A Other purpose I'm aware of is based on the general industrial procedure. So if you have a masterbatch, it will be much easier to scale up. So you can use this masterbatch to mix with different active materials. For example, in this batch is an iron phosphate. In other batch I want to cast an ion material. And I could cast another carbon materials other than lithium iron phosphate. But regardless of which active materials I incorporate into the electrode slurry, I always can use the same masterbatch I prepared. So this is typically the purpose to prepare a masterbatch, yeah, for other than the dispersion reason I mentioned.

Q Okay. Any other reason that you would use a masterbatch in Ohata?

A I think the major reason I already mentioned is to disperse nanotube.

Q Okay. If I could get you to go to LGES-1004, which is the Ohata reference.

A Yes, I'm on that reference.

1 Q Okay. And if you could go to
2 Paragraph 6.
3 A You mean Paragraph 6 on Page -- on
4 Page 4?
5 Q Do you see the last sentence there?
6 A So you said Paragraph 6 on which page?
7 Q We'll go with the bottom page numbers.
8 Page 4, Paragraph 6.
9 A Okay. Yes.
10 Q And it says at the end there, the last
11 sentence, "The proper amount of the carbon nanotubes
12 contained in the masterbatch is 5 to 20 parts by weight per
13 100 parts by weight of the resin."
14 Do you see that?
15 A Yes, I see that.
16 Q And in Ohata, one of the resins it uses
17 is a fluorocarbon resin such as PVDF, correct?
18 A Yes.
19 Q Do carbon nanotubes -- are carbon
20 nanotubes and PVDF attracted to one another?
21 A As far as I know, not very strong,
22 special interaction was described between nanotube and PVDF.
23 Q Would you expect there to be stronger
24 attraction between oxidized carbon nanotubes and PDVF?
25 A I -- I do not think any comparison has

1 been done academically or industrially regarding the
2 comparison of interaction force between PVDF and oxidized --
3 non-oxidized and oxidized nanotubes.
4 **Q Well, to your knowledge, do oxidized**
5 **carbon nanotubes and PVDF attract to one another?**
6 A You -- your question is: Does PVDF and
7 oxidized carbon nanotube attracted to each other?
8 **Q Correct.**
9 A I do not recall any specific mention
10 between the interaction of these two.
11 **Q All right. So the answer is you don't**
12 **know as you sit here?**
13 A Well, what I mean is it could be any
14 other different type of polymer versus carbon nanotube.
15 **Q I want to go to -- if you could turn to**
16 **Paragraph 2 of Ohata, which is in the left column of that**
17 **same page.**
18 A Uh-huh.
19 **Q If you could just read Paragraph 2 to**
20 **yourself. You don't have to read it out loud. I just want**
21 **to ask you a few questions. Just let me know when you're**
22 **finished.**
23 A So the paragraph starting, "An
24 electrolyte of non-aqueous secondary batteries," right?
25 **Q Right. Sure.**

A Yes, I finished reading this paragraph.
Q Okay. So this paragraph is discussing uniformly dispersed -- pre-dispersing a conductive material in a binder; is that correct?
A Yes, it mentions it.
Q And the conductive material that's referenced in this paragraph is carbon black such as furnace black or acetylene black and powder graphite; is that correct?
A I think it mentioned -- let me just doublecheck it.
Q Sure. Take your time. I'm not trying to --
A Yeah. Yes. This paragraph mentions three -- three conductive materials, carbon furnace, acetylene black and powder graphite.
Q And we talked before about how the binder acts as a glue between the active material, correct?
A Yes. That is the electrode, yeah.
Q And an electrode. What is the purpose of pre-dispersing a conductive material in the binder of an electrode?
A So this serves the purpose of eventually to disperse the conductive materials in the electrode. So regardless of how you disperse the conductive materials,

1 regardless of which step you use to disperse the conductive
2 material. The ultimate purpose is to disperse the
3 conductive materials in your electrode, coated electrode
4 uniformly. That is the final purpose. And in order to
5 achieve that final purpose, you can take different steps.
6 So you can first disperse conductive materials in one of the
7 component and then mix the other component with a
8 pre-dispersed conductive material.
9 So in the final electrode material, it
10 included -- in a slurry it included a solvent, which is also
11 called a dispersed medium, and conductive fillers and active
12 materials and binder polymers. But you can choose a route
13 to mix the conductive fillers with one of the components in
14 the previous -- in the first step to build up something,
15 which is called pre-dispersed medium, and then mix the rest
16 of the things in the following steps. So this is the
17 purpose. So here they are talking about to mix conductive
18 materials including either carbon black -- either furnace
19 black, acetylene black or powder graphite with one of the
20 component finally will be used in the electrode. That
21 component in this case is PVDF, which is a binder polymer.
22 **Q Okay. So in the background here in**
23 **paragraph 2, it's describing a process where a conductive**
24 **material such as carbon black is pre-dispersed within the**
25 **binder and then the binder would later be dispersed with the**

active material; is that fair?

A And a solvent.

Q And a solvent. And then in -- let's go back to Kavan. In Kavan, that process is different because in Kavan he starts by mixing the oxidized carbon nanotubes with the active material and then he adds the PVDF after; is that fair?

A Well, in Kavan, the dispersion is the carbon nanotubes is dispersed in water. So the water is also a medium. So the water is the medium used to disperse carbon nanotubes. It's just like the PVDF resin is the medium to use -- to disperse the unoxidized carbon nanotubes within Ohata's case.

Q Right. But in Kavan, he's taking the nanotubes and active material and mixing them together, right? Whereas, in Ohata, he's taking the -- he's first creating the masterbatch and then adding the active material to it?

A Kavan also added the active material in the later stage. You can consider his mixing of water and carbon nanotubes is pretty much the same step as Ohata's approach to mixing PVDF and carbon nanotubes. Carbon nanotubes had different property they use. Therefore, the first -- the first mixing step was the using different materials.

Q And can water be used as a binder for an electrode?

A Water can be used as a solvent, so it can be one of the components in the final -- in the final slurry.

Q But can water be used as a binder?

A No. Water is not a binder material. But as I said, the final -- the final slurry prepared will have the content including active material, binder, carbon fillers and dispersed medium. It's not necessary to mix in a specific order. And this is where understanded by other people who do mixing. It's also where understanded by battery researchers who prepare the electrode slurry. So you can have four components, A, B, C, D, right, and you can mix A, B first and then add C, D, and eventually you have A, B, C, D together. Or you can mix A and C first, and then you add B and D, and then you will have eventually A, B, C, D together to cause the slurry.

So whether the person choose to mix those components in which order, it's generally based on the experience of the people in the field. I think people will understand very well when they're working with lithium iron batteries which two component can be mixed first, which two component can be added later on. So there is no definitive order in the industry saying that which one has to be

1 mixed -- which two has to be mixed first and which two has
2 to be added later on. So that is a general, I would say,
3 something like common sense about anybody working with
4 mixing, yeah.
5 **Q So when you go back to Kavan, if we talk**
6 **about -- we talked about the steps earlier that one of the**
7 **first steps is you disperse the nanotubes in water, right,**
8 **under sonication, and then you -- and then you further add**
9 **the powder material which has your active material, correct?**
10 A Yes.
11 **Q And when that happens, there are --**
12 **there's two forms of attachment to the -- between the active**
13 **material and the -- and the oxidized nanotubes. One is --**
14 **one is going to be the anchoring between the functional**
15 **groups of the nanotubes and the active material, correct?**
16 A Yes.
17 **Q And the other is going to be the Van der**
18 **Waals forces that exist in the composition?**
19 A So you are comparing two force
20 between -- between what?
21 **Q Well, no. My question is when you**
22 **mix -- when you follow the first two steps of -- here in**
23 **Kavan, which is first disperse the nanotube in water under**
24 **short sonication, and then adding the powder material, which**
25 **is the active material, will the active material be attached**

1 **to the nanotubes via Van der Waals forces?**
2 A It will be attached with the functional
3 group under carbon nanotubes. We have discussed this
4 because carbon nanotube has an active charge on the surface,
5 which is an oxidized functional group, an oxygen containing
6 functional group. And then it will impact with the metal
7 oxide, which are different type of active materials,
8 positive charged ions, and there will be some ion force
9 between them for sure. And there are also potential Van der
10 Waals force, which is quite uniform between oxide materials
11 and the carbon nanotubes regardless whether the carbon
12 nanotube has been oxidized or not, yeah. But ionic force is
13 something which -- which due to the charge difference
14 between the surface of oxidized nanotube and the charge of
15 metal oxide materials that will be likely forming between --
16 between those -- yeah, between those two materials.
17 **Q Okay. So that's how the active material**
18 **and the oxidized nanotubes attach to one another?**
19 A Yeah.
20 **Q I want to go back. We were talking**
21 **about Ohata. I got a little sidetracked there. I apologize**
22 **I was trying to keep us on one person at a time. I want to**
23 **go back to the background of Ohata. And if we go to**
24 **Paragraph 3 -- and I'll just read this into the record.**
25 **It's not too long. It says -- tell me when you're there**

1 **actually.**
2 A In Paragraph 2 and 3?
3 **Q Paragraph 3.**
4 A 3. Okay. "The primary particle of the
5 carbon black"?
6 **Q Correct. "The primary particles of**
7 **carbon black or powdered graphite are linked to a chain to**
8 **form a conductive path."**
9 **First I want to ask you about what**
10 **exactly does that mean? I'm sorry. Let me strike that.**
11 **What is your understanding of what that**
12 **sentence means?**
13 A That sentence means -- that sentence
14 actually describe the status of how the conductive pathway
15 was built in the composite material, right. So you have two
16 materials mixed together. One of the components, which is
17 carbon black or some other carbon-containing species, is
18 conductive. The other one is non-conductive. And in order
19 to have these two materials form a mixture that have overall
20 conductivity across the entire mixture, then the conductive
21 materials need to form a path, which means the conducting
22 component in this mixture needed to be conducted across the
23 entire mixture in order to achieve the -- above the
24 conductivity. That is how it is described here. So those
25 graphite powders are forming a link, then chain, which

1 indicate that there is a connected pathway from the bulk
2 point of view from one end of the material's composite to
3 another end of the materials of the component, yeah.
4 **Q Okay. So let me -- let me back up a**
5 **little bit. So you mentioned the, I guess, network through**
6 **the -- so basically, in layman's terms, you're trying to**
7 **form a network through your -- between your active material,**
8 **correct?**
9 A Between your conductive material.
10 **Q Between your conductive material. Okay.**
11 **Can you -- can you have any gaps in the connective -- into**
12 **the chain of conductive material between your active**
13 **material or does it have to be, like, a complete closed**
14 **connection? Do you understand what I'm saying?**
15 A So what do you mean "the gap"? So there
16 are somewhere probably some broken piece, but in case it was
17 connected -- I don't know. How do you define gap?
18 **Q Sure. Sure. Let me -- let me try to**
19 **clarify my question. So the way I picture this is you've**
20 **got -- let's imagine you've got two -- I know this is**
21 **simplistic. We're talking in the abstract conceptual world**
22 **right now just to help me understand this better. But**
23 **you've got two circles of active material, right?**
24 A Uh-huh.
25 **Q And then between the active material you**

1 have the binder, correct? Or you can? You can have binder
2 between --
3 A So you are talking about a conductive
4 material or active material?
5 Q Oh, I'm talking about active.
6 A You're talking about a conductive
7 material, right? So let --
8 Q Let me back up. Let me back up. Let me
9 get a little more high level.
10 So in these electrodes you have an
11 active material, correct?
12 A Yes.
13 Q And then you have a binder, correct?
14 A Yes.
15 Q And then you can also -- you don't have
16 to, but you can include a conductive agent within the
17 binder, correct?
18 A Usually you will have conductive filler,
19 yes.
20 Q So when you have the active material
21 that is glued together by the binder, right, and you have
22 the conductive agent within that binder, does that
23 conductive agent have to connect all the way from one side
24 to the other? Or can there be any physical space between
25 the network?

A So you want to have a good connection between your conducting filler and active materials and build up the conducting pathway across active materials, across conducting fillers, and you want those paths to be as robust as possible, so which means you have many, many channels to actually tunnel -- tunnel the electrodes.

Q Do you mean, like, many channels -- many -- I'm trying to think of -- when you say many channels, do you mean like a network of connected CNTs that all go to -- some of them go to the same location, so you have two or three conductive paths or --

A So as I -- as just suggested in this paragraph says -- in the third paragraph says, the graphite linked into a chain. So this is something I mean.

Q Okay. And then it says -- if you look at that same paragraph, the second sentence says, "Shearing force is applied to the conductive material during the masterbatch process."

What is -- excuse me. What is the purpose of that shearing force?

A The shearing force is required when you mix two polymer components. So you leave a powder, which is graphite, and a resin, which is like a bead, right. So you start heating them in the developer and then you mix them together. So you cannot mix them together without applying

any shear force. They don't automatically merge to each other because there's no liquid. So they do not move by itself. So you have to apply external force in order to mix two solid compounds.

Q So you take the solid resin, you heat it and then you mix it with the carbon black and powdered graphite and then you shear it to mix it all up?

A Yes. You can understand how that mixing is, yeah, carried out in this way.

Q And so when it -- and then it goes on to say in the last sentence of Paragraph 3 of Ohata, "For this reason, the use of the masterbatch process to uniformly disperse the conductive material in the binder does not yield an electrode superior connectivity."

So if we go back to the first sentence -- or first two sentences, it talks about how that linked chain that's formed by the carbon black, powdered graphite is damaged by shearing. Can you kind of describe in your own words what exactly that means?

A So those sentence means the ideal situation in a -- in a carbon particle distributed in a resin should be forming a chain by those carbon particles. Therefore, you can have a conducting pathway for the resin to move and when -- but, however, you also needed to mix the resin with the powder. And when you mix the resin with a

1 carbon powder when they are small particles, the strong
2 shear force can disrupt those existing chains and which
3 leaded to the ideal situation for the entire conductivity,
4 yeah, as a whole.
5 **Q And when -- in the background it's**
6 **talking about preparing the masterbatch by mixing the carbon**
7 **black with resin. So that's essentially taking the carbon**
8 **black and embedding it within the resin matrix and then**
9 **mixing it up?**
10 A Yes. My understanding, yeah.
11 **Q Okay. So you have like -- you**
12 **essentially have -- in layman's terms, you have, like, this**
13 **glue material that actually has chains formed in it of**
14 **graphite and carbon black that you then use for your active**
15 **material so that you have better connectivity, electrical**
16 **connectivity; is that fair?**
17 A I think that what they mention here and
18 what they want to say in this patent is they wanted this
19 carbon particles to forming a chain-like structure. And
20 they wanted them forming a chain-like structure in the
21 resin. And, therefore, after the resin was mixed with other
22 components, which are active materials and as a solvent,
23 those chain-like structures can be maintained in the final
24 electrode, therefore, can provide good conductivity. I
25 think that's what they mean in this description.

1 Q And when you said -- and I asked you if
2 the carbon black is embedded in the resin, correct?
3 A Carbon black is mixed with resin, yes.
4 Q And the same -- if you -- and if you mix
5 the CNTs with the resin, just like you're embedding carbon
6 black in resin, you're embedding the CNTs within the resin
7 as well?
8 A So I do not know if that is a question.
9 I mean, CNT can be mixed with resin in a similar manner in
10 this patent. That's what they disclose.
11 Q So I guess my question is, is in the
12 background it's talking about mixing carbon black with a
13 resin to create a masterbatch, right?
14 A Yes.
15 Q And then in the actual -- you know, what
16 Ohata believes he invented, he says, oh, now we're going to
17 take the resin and we're going to mix CNTs with the resin
18 instead of carbon black, right?
19 A Yes. This is what he described in his
20 patent.
21 Q Right. So just like you have carbon
22 black embedded in the resin in the background, in his
23 invention you would have CNTs embedded in the resin as part
24 of the masterbatch? That's all I'm asking.
25 A So he described two different approach.

1 One is mixing with CNT. The other is mixing with carbon
2 black in the resin.
3 **Q Right. And under either approach, the**
4 **result is you have this conductive agent embedded within the**
5 **resin, correct?**
6 A There is a conductive -- yeah, there is
7 conductive materials embedded with resin in both cases.
8 **Q So I want to go -- if could I get you to**
9 **turn, Dr. Zhu, to paragraph -- let me do it this way. I**
10 **always say paragraph and then I realize I've got to give you**
11 **the page number. Makes it a little easier. If I could get**
12 **you to turn to Page 29 of your declaration.**
13 A Page 29?
14 **Q Correct. And if you look at**
15 **Paragraph 47, do you see that?**
16 A Yes.
17 **Q And you say, "It is my opinion that a**
18 **POSITA would have been motivated to use oxidized nanotubes**
19 **in the Ohata-Kavan electrode material mixture paste for at**
20 **least the following reasons."**
21 **Did I read that right?**
22 A Yes.
23 **Q And the first reason begins on**
24 **Paragraph 48. And you say, "The first reason for using**
25 **oxidized nanotubes for the specific case when the electrode**

1 **material mixture paste is a positive electrode material**
2 **mixture paste having a phosphate olivine as the active**
3 **material. (See LGES-1005 (Kavan), 2), is that**
4 **electromechanical performance of the electrode is improved**
5 **by the presence of oxidized nanotubes."**
6 **Did I read that correctly?**
7 A Yes. In Kavan's paper, they disclose
8 that oxidized nanotubes mixed with phosphate olivine
9 achieved good electrical mechanical performance.
10 **Q And is that because the functional**
11 **groups added to the CNT via oxidation provide anchoring**
12 **points for the phosphate olivine?**
13 A There are a number of reasons. I think
14 one of the reason provided by Kavan says there are certainly
15 interaction between carbon nanotube and phosphate olivine,
16 which significantly improved the electrochemical performance
17 of the electrode.
18 **Q Is that tied to the ability -- I guess**
19 **is that tied to the improved attachment of the oxidized CNT**
20 **to the active material because of the functionalization?**
21 A It is. The attached active materials
22 and the oxidized carbon nanotubes can be one of the
23 functions that enhance the electrochemical performance of
24 the carbon nanotube.
25 **Q And then if we go down to Paragraph 49,**

1 which is on Page 30, you say, "The second reason for using
2 oxidized nanotubes is because it is consistent with, and
3 helpful for achieving, Ohata's goal to have well-dispersed
4 nanotubes in the composite."
5 Do you see that?
6 A Yes.
7 Q And that -- is that -- is improved
8 dispersion a result of the active material attaching to the
9 functional groups of the oxidized nanotubes?
10 A As I said, oxidized carbon nanotube has
11 oxygen-containing functional groups on the side wall of the
12 carbon nanotube. Therefore, it will -- it will prevent the
13 formation of the pi pi stacking of pristine carbon nanotube.
14 As a result, those functional carbon nanotubes will have
15 better dispersion to prevent forming -- forming clumps.
16 Q And one of the -- in Paragraph 51 you
17 cite to a reference. I honestly don't know how to say that.
18 Gojny. I don't know. I'm probably saying that wrong.
19 G-O-J-N-Y. Which you quoted as stating, "The presence of
20 carboxylic acid groups on the surface enables a better
21 dispersion of CNTs and shows images of oxidized multi-walled
22 carbon nanotubes that are completely dispersed in the epoxy
23 resin matrix due to the carboxylic groups on the surface."
24 Do you see that sentence?
25 A Yes.

1 **Q So this -- you're citing this reference**
2 **as evidence that you get improved dispersion when you**
3 **oxidize nanotubes, correct?**
4 A I cite this reference because they
5 specifically mention the function of carboxylic acid group
6 on the surface of the carbon nanotube will help the
7 dispersion.
8 **Q And this cited reference, which is**
9 **LGES-1014, it's mixing its nanotubes in a resin similar to**
10 **how Ohata is mixing its nanotubes in a resin, correct?**
11 A The polymer difference we use as a
12 reference because they are mixing between the oxidized
13 carbon nanotube and a polymer.
14 **Q And in -- but in Ohata is it -- PVDF is**
15 **a polymer, correct?**
16 A PVDF is a polymer.
17 **Q Okay. And when you mix -- this**
18 **reference, LGES-1014, when you mix the oxidized CNTs in the**
19 **resin matrix, does that completely cover the CNTs for resin?**
20 A Can you explain your question a little
21 more?
22 **Q Sure. So the reference that you cited,**
23 **LGES-1014, it teaches that it's dispersing oxidized**
24 **multi-walled nanotubes in a resin matrix, correct?**
25 A Yes.

Q And when you do that, would you expect that the resin would cover the CNTs completely -- or I'm sorry. Would you expect the resin to cover the carbon nanotubes completely?

A I do not think there's any mention about the resin needing to cover the entire surface of the CNT in my declaration.

Q Okay. What I'm asking you -- what you state here, "Oxidized multi-walled carbon nanotubes are completely dispersed in epoxy resin matrix," would that result in the CNTs being completely covered with the matrix?

A As I just said, the CNT was uniformly distributed within this resin. I didn't say the resin needed to cover the surface of the CNT completely.

Q That's not my question. My question is: Would the carbon nanotubes be completely covered with the resin matrix if you mixed them the way that LGES-1014 teaches?

A I think this is how you define what is completely -- what means to completely cover the bio resin. So the carbon nanotube inside this mixture can also contact each other. It's not necessary to be a completely bundled status, which are like unoxidized carbon nanotubes. But they can have contact between carbon nanotubes. So I do not know what is criteria of completely covered by the polymer

matrix in your -- in your -- yeah -- in your statement. So I do not know how to describe that because I don't know what is meaning of completely cover carbon nanotube with a polymer resin.

It's also related to -- to the -- to the content we discussed here, which we discussed about how the nanotube is distributed in the -- in the polymer medium.

Q I want to go back. I want to go to Exhibit 1014. Or I'm sorry. LGES -- or LGES-1014. Sorry. Math is not my strong suit. Apparently reading numbers isn't either. Let me know -- have you found it?

A Under what specific --

Q If you could just turn to Page 2 under the heading "Experimental."

A Page 2, under heading "Experimental."

Q If you could just read those two paragraphs to yourself under "Experimental." And then I'll ask you the question again. Just let me know when you're ready?

A Yep.

Q So my question is, Under the experimental steps disclosed in LGES-1014, would you expect the resin to be completely -- I'm sorry -- would you expect the oxidized carbon nanotubes to be completely covered with the resin matrix?

A Well, it just says here the nanotube was mixed with the resin. I think, as I said, depending on how you define what is -- what is the criteria for the complete coverage of carbon nanotubes with resin. Yeah.

Q When you mix resin with carbon nanotubes, would you agree that the resin covers the carbon nanotube surface?

A I would agree the resin cover significant amount of the surface of the carbon nanotube.

Q And would you agree that the resin is a viscous substance?

A As compared with what?

Q Well, let's say is a resin typically a solid, semisolid or viscous substance?

A Resin is a solid and it could be a flow, but whether it's viscous depending on what you compare it with.

Q Well, compared to water it's viscous, correct?

A Yes. It's more viscous than water.

Q And once you covered -- once you covered a carbon nanotube in resin, how can you remove the resin from the nanotube?

A If the resin can be dissolved in dispersing medium, then it can be removed, and it can be

also partially removed depending on your treatment, depending on the exact experiment procedures, conditions.

MR. ZINDA: All right. I have no further questions.

MR. IN: Sorry, Stephen. Just to confirm, you're saying no further questions for --

MR. ZINDA: Yes. I'm passing the witness.

MR. IN: Thank you. Could you give us maybe ten minutes?

MR. ZINDA: Yeah.

MR. IN: And then we can get back on the record. Would that be okay?

MR. ZINDA: That works for me.

MR. IN: All right. We'll be back in ten minutes. Thank you.

(Whereupon, a brief recess was taken.)

MR. IN: No further questions. Thank you.

A C K N O W L E D G E M E N T

STATE OF OHIO :
: SS:
COUNTY OF HAMILTON :

I, YU ZHU, PHD, have read the transcript of my testimony given under oath on March 14, 2025.

Having had the opportunity to note any necessary corrections of my testimony on the errata page, I hereby certify that the above-mentioned transcript is a true and complete record of my testimony.

_____

YU ZHU, PHD

(DEPOSITION CONCLUDED AT 12:40 P.M.)

C E R T I F I C A T E

STATE OF OHIO :
: SS:
COUNTY OF HAMILTON :

I, Jennifer K. Starner, the undersigned, a duly qualified and commissioned Notary Public within and for the State of Ohio, do hereby certify that before giving of the aforesaid deposition, the said YU ZHU, PHD was by me first duly sworn to depose the truth, the whole truth and nothing but the truth; that the foregoing deposition was given at the said time and place and was taken in all respects pursuant to Notice; that the deposition was taken in stenotypy by me and transcribed into typewritten form under my supervision; that the transcribed deposition is to be submitted to the witness for his examination and signature, and that signature may be affixed out of the presence of the Notary Public; that I am neither relative, attorney, nor employee of any party or their counsel and have no interest in the result of this pending action.

IN WITNESS WHEREOF, I have hereunto set my hand and official seal of office at Cincinnati, Ohio, this 18th day of March, 2025.

Jennifer K. Starner

My commission expires:
March 7, 2029

Jennifer K. Starner, RPR
Notary Public

CHANGES AND SIGNATURE

WITNESS NAME: Yu Zhu, PhD, 03/14/2025

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I, Yu Zhu, PhD, have read the foregoing transcript and hereby affix my signature that same is true and correct, except as noted above.

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Yu Zhu, PhD Date

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