UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

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LG ENERGY SOLUTION, LTD.,	:	
Petitioner,	:	
-vs-	:	CASE NO. IPR2024-01011
	:	U.S. PATENT NO. 8,968,924 B2
MOLECULAR REBAR DESIGN, LLC,	:	
Patent Owner.	:	

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Deposition of YU ZHU, PhD, an expert witness herein, taken by the Patent Owner as upon Cross-Examination and pursuant to the Federal Rules of Civil Procedure and Notice via Zoom videoconference on March 21, 2025 at 10:51 a.m., before Jennifer K. Starner, RPR, a Notary Public within and for the State of Ohio.

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MRD EX. 2026
LGES v MRD
IPR2024-01013

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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

YU ZHU, PhD,

of lawful age, as having been duly sworn, as hereinafter certified, was examined and testified as follows:

CROSS-EXAMINATION

BY MR. ZINDA

Q Hi, Dr. Zhu.

A Hi.

Q Let me go back. I'm not going back through the introduction with you because we just went through that regarding breaks and all that stuff. In this deposition you're here to offer testimony on U.S. Patent 8,682,924, correct?

A Yes, that's correct.

Q You understand -- is it okay if I call that the '924 Patent?

A Yes, that's okay.

Q You've offered a sworn declaration in the proceeding regarding the '924 Patent, right?

A Yes.

Q Okay. So can I get you to first to turn to LGES 1001?

A Yes.

Q And if you go to -- can I get you to turn to Claim 1?

A I'm on the claim page.

Q Okay. And if you look at Claim 1, do you see that it says "Discrete carbon nanotubes"?

A Yes, I saw discrete carbon nanotubes.

Q Okay. You've already offered -- you've already been deposed in the proceeding on the '909 Patent and the '483 Patent, correct?

A Yes. Correct.

Q And you've -- do you recall that both of those patents also had claims that used the word "discrete carbon nanotubes," correct?

A Yes.

Q Is your understanding of the word "discrete carbon nanotubes" the same for the '924 Patent as it is for the '909 and '483 Patent?

A I -- that's the same question as I mentioned previously. This is the status of carbon nanotube in application of lithium ion battery electrode. So it's a status to describe how the nanotubes distributed in such a composite. And this discrete carbon nanotube provide information on the status that is those nanotube are not bundled, they are uniformly distributed and eventually forming a good electrical conductive network in those battery electrode nanotube to support the high conductivity of the electrode composite materials.

Q So that understanding of discrete carbon

nanotubes, you think that's the same in both the '909 and the '483 Patent as well, correct?

A I would rather call it very similar status of the carbon nanotube distribution in the electrode composite materials because they all refer to the similar application.

Q Got it. And then if you go down to Claim 5, do you see where it uses the term "uniformly dispersible oxidized carbon nanotubes"?

A I saw uniformly dispersible oxidized carbon nanotubes, yes.

Q And does that phrase, uniformly dispersible oxidized carbon nanotubes, have the same meaning to you as uniformly dispersed carbon nanotubes from the '909 Patent?

A Well, that could be carbon nanotube with a similar status. However, here it specifically states it's oxidized carbon nanotubes and uniformly dispersible. And if you just say discrete carbon nanotube just the same as carbon nanotube are separated, not forming a bundle, and it does not mention any status like oxidized carbon nanotube in this case.

Q Maybe -- maybe I can make it a little clearer because I understand why -- I mean, my question wasn't a very good question. Let me just phrase it this

way.

A Uh-huh.

Q Uniformly dispersible carbon nanotube have the same meaning as uniformly dispersed carbon nanotube from the '909 Patent?

A Yeah. As I said, they have -- those are similar description of the status of a carbon nanotube under the -- under the application of using battery electrode to forming a composite. Those discrete nanotube in '909 and uniformly dispersed oxidized carbon nanotubes in '924 refers to how those carbon nanotubes are distributed in composite used lithium ion battery electrode, yeah. That is description of the status of those nanotube in the composite. They share similar meanings, which is they are not bundled carbon nanotubes, they can form good electrical conducting network in the composite electrode.

Q Now, in your declaration in this proceeding, the '924 proceeding, you've offered the opinion that the claims -- that certain claims of the '924 Patent are invalid based on a reference called Cheng and a reference called Gan, correct?

A Yes. I refer to a reference Cheng and Gan.

Q Okay. And I'm going to ask you if you wouldn't mind pulling out the Cheng reference for me.

MR. ZINDA: And just for the reporter because I don't think she's heard this word before, it's C-H-E-N-G, Cheng.

Q And then that's LGES-1007. So if I could get you to pull that out for me.

A Yes, I open that reference.

Q Okay. And then if I could get you to turn to Paragraph 1.

A Yes.

Q And in this Paragraph it says, "The present invention belongs to the technical field of lithium iron battery" -- I'm sorry -- ion battery materials, and in particular relates to a carbon nanotube/lithium iron phosphate composite cathode material and an in situ preparation method thereof."

Did I read it correctly?

A Yes. That's correct.

Q What is a composite cathode material for a lithium ion battery?

MR. IN: Objection to form.

A So the composite cathode material for lithium ion battery I already described in my declaration. So the lithium ion battery cathode materials are not a single-component material. It consists -- it consist of several typical ingredients including the active materials,

which in this case is lithium iron phosphate. And also, the carbon conducting fillers and in this case can be carbon nanotube, and it can contain additional materials. Typically will contain polymer binder materials. And when you prepare the slurry, you need also a dispersion medium, which is a solid. And there may be some additional additive materials that can be added into this mixture in order to forming a composite cathode, yes. So the composite cathode contained several different type of materials in the lithium ion battery.

Q Okay. The cathode comprises active material, correct?

A Yes.

Q And it will comprise a binder typically?

A Yes.

Q And it will also sometimes include a conducting agent such as carbon black?

A Yes, a lot of times.

Q Okay. And then I want to just to discuss at your higher level -- a high level your understanding of how these composite cathode materials are typically made.

Is it common to mix a conductive agent such as carbon black with a solvent or a dispersing agent as part of that process?

A Yes. That is one common approach.

Q Is it common to mix -- to then mix the conductive agent with an active material such as a lithium iron phosphate?

A Yes. It is one common approach to mix them with active materials and conducting fillers.

Q Is it common to use a mixing medium such as deionized water as part of that process?

A Yes. Deionized water is one of the solvent or dispersion medium used, but it is not the only one, yeah. So in some cases deionized water was used.

Q And is it common to apply a heat treatment to the mixture?

A That depending on how you refer the heat treatment. In general, you can evaporate a solvent by slightly heat it. And to -- to remove the wall entire apart and then you can conduct in solid material. But in some approach this can be some -- let's say you call it in situ preparation. So there will be some reactions related to those heat treatment to forming the right materials. So the situation of heating is relatively complicated. There are different approach, different purpose, yeah, used in the lithium ion battery electrode preparation.

Q And if we could go to Paragraph 5 of Cheng.

A Paragraph 5?

Q Yes, sir.

A Yes, sir.

Q Yes, Paragraph 5. And I'll read it. It says, No. 1, "Carbon nanotubes have good electrical conductivity, and the fibrous structure thereof can better connect electrode active materials into a continuous 'network' that is electrically conductive, thereby improving the electrical conductivity of the electrode and the utilization rate of the active material."

Did I read that correctly?

A Yes, that's correct.

Q So is -- is Cheng describing the goal of trying to achieve an interconnected network of carbon nanotubes?

A Cheng is describing here is ideal situation, that a carbon nanotube forming good network because the carbon nanotube has good electrical conductivity as intrinsic properties. It will be ideal to have this conduct -- electrical -- electrical conductive network, which is beneficial for the lithium ion battery electrode. However, this is an idea situation it referred in this case.

Q Okay. Understood. But in this paragraph, Cheng is stating that one of the goals is to have a continuous network of connected carbon nanotubes, correct?

A Yes.

Q Okay. No. -- if we could go down to Paragraph 6. In Paragraph 6 Cheng states, No. 2, "The carbon nanotubes have good mechanical properties and the added carbon nanotubes provide high toughness to the electrode sheet, so that exfoliation caused by a change in the volume of material during charging and discharging can effectively be suppressed, and particles of the active material can always maintain good electrical contact during charging and discharging, thereby improving the cycle life of the electrode."

Did I read that right?

A Yes.

Q And so here is -- when Cheng refers to good mechanical properties, can you describe in your own words what he means?

A So in this Paragraph, Cheng mentions that carbon nanotubes not only have beneficial for improved electrical conductivity, but also provide a good mechanical property for the electrode as a whole. So the change of the volume, which oftentimes happens during the charging and discharging process, will not cause a dramatic change on -- on the material's pathology. Therefore, the electrical contact can be maintained during repeatedly charge and discharge. Therefore, the cycle lifetime of the battery

electrode will be improved.

Q So if I'm understanding you correctly, when he's talking about mechanical properties, he's saying that because during charging and discharging it will cause expansion and contraction of the material, this -- these nanotubes are actually better at addressing that problem?

MR. IN: Objection. Form.

A Yeah. The procedure here is -- so you have electrode active materials, which is active materials such as lithium iron phosphate or some other things like graphite. And what happens during the lithium ion battery operation is the lithium iron -- we use lithium iron phosphate as an example, right. So the lithium irons inside the lithium iron phosphate is actually movable. So you can take it out and move it in during the charging and discharging process. And when you take it out and move it in, there will be slightly more change for this active materials. So you add one lithium iron into it, it will generally cause a little bit expansion on the solid material itself. And even though it's very little expansion, a few percentage or even less, it can actually repeatedly happen and cause some stress between the electrode active materials and the current collector, which was the base where the electrode material was coded during the preparation procedure.

So this repeatedly ball and chain can cause the denomination of what he says here is exfoliation, which is the electrode was peeled off from the current collector in this case. Most of that situation happened in this one. And, therefore, you lose contact -- the electrode lose contact with the current collector and with the carbon nanotube because they can -- they can provide stronger mechanical properties. They can hold those active materials better.

So during this slight warning, expansion and contraction, which happens during the charging and discharging process, this will not cause significant denomination of the materials, which is exfoliation of the materials from the current collector. If you have exfoliated those materials from the current collector, then those materials lose the electrical contact with the external circuit, and then those active materials will be lost during the cycling. Therefore, the battery does not detect all those active materials that was exfoliated. Therefore, the cycle has become worse because you have lower capacity after a certain number of cycles. So this is actually what he discussed in this paragraph what is the function of nanotubes in terms of intense mechanical property of the electrode and why that is important for the electrode.

Q And then Paragraph 7 -- and I'll quote it again. No. 3, "Uniform dispersion of carbon nanotubes can also significantly improve infiltration of the electrolyte in the electrode material."

Did I read that correctly?

A Yes.

Q And so what is this referring to?

A So the electrode prepared in the lithium ion battery is a porous structure, right. So this is actually a reaction needed to happen in several medium. So on the solid state, the electrode active materials is electrode transfer. And the iron transfer will be intercalation and de-intercalation from those solid active materials like lithium iron phosphate. And after the iron was de-intercalated from those solid materials, they have to have somewhere to go. Okay. So the place they go is actually the electrolyte. So those lithium iron de-intercalated from the electrode materials will enter into the electrolyte. And the electrolyte is a liquid medium that carry out all those irons from one electrode to the oxidated electrode, right. From the cathode to the anode, from the anode to the cathode. So, therefore, you have to have an interpenetrated structure for all those solid medium which contain all the active material, and a liquid medium, which is the liquid electrolyte.

So in this case, what he said here is uniform distribution of the carbon nanotube will also improve the infiltration of electrolyte, which means they will help to attribute this interpenetrated porous structure, allowing the electrolyte actually wetting everywhere of the electrode materials. Therefore, the de-intercalated lithium iron can be easily infiltrated into the -- can be easily moved into the liquid medium electrolyte and carry a charge and moving to the other opposite electrode. Yeah, that's the mechanism of how it works.

Q And then if we go to -- okay. I appreciate that. Thank you for that helpful explanation.

A Yeah.

Q I'd like to go to Paragraph 13 of Cheng.

A 13. Yes, I'm here.

Q Okay. So give me one second. If you scroll up a little bit more to Paragraph 10.

A 10.

Q Do you see the heading above it that says "Summary"?

A Summary?

Q Yeah. If you look at just above Paragraph 10 there in the middle of the page, it says "Summary." Just to be clear, above Paragraph 10 there's a

title --

A Above. So you are talking about the words above summary?

Q No. Right at summary. So you see Paragraph 10 is under the word "Summary," correct?

A Yes, I saw Paragraph 10. So which part do you want me to look?

Q Sure. So my first question is, Starting on Paragraph 10, this is Cheng's summary of what his invention is, correct?

A Yes. Correct.

Q Okay. And then if you go down to Paragraph 10, and about midway through the sentence -- I mean, of the paragraph, it says, "Uniform dispersion of carbon nanotubes in the bulk phase and on surfaces of lithium iron phosphate is achieved by means of an in situ solid phase reaction process, thereby, solving the problem in the prior art in which carbon nanotubes are distributed only on the surface of the electrode material and cannot form a continuously connected three-dimensional electrically conducted electric structure both in the interior and on the surface of the material."

Do you see that?

A Yes, I saw those words.

Q So Cheng -- again, Cheng is trying to

achieve a continuously conductive three-dimensional network of carbon nanotubes in his composite, correct?

A Yes, in this -- in this -- yeah, description.

Q And then if you go down to Paragraph 13, that is him describing -- providing a summary of the first step of his process, correct?

A Yes. 13 provided some details about his process.

Q Okay. So if I -- I'm going to refer to this Paragraph 13 as his Step 1; is that fair? Because if you look, he labels it 1, 2, 3 going down.

A Yeah. The Paragraph 13 is first step.

Q Okay. So in Step 1 of Cheng, as disclosed here in Paragraph 13, can you walk me through exactly what is happening in this step?

A Okay. So this step is basically dispersed carbon fillers which include carbon nanotubes. And in this case, they also have acetylene black, which is -- which is another filler. So it's actually quite common in the lithium ion battery actual preparation to use multiple carbon fillers. And they can serve as different functions. And so you needed to also control the quantity of the carbon nanotube eventually in the cathode and anode material. So you needed to weigh the exact quantity of

carbon nanotube as well as acetylene black.

And you needed to have a dispersion medium, which is help to dissolve a number of things. Here it will not dissolve the carbon nanotube. It's not a solid. It cannot dissolve acetylene black. So they will just use a dispersion agent, so -- which means they are uniformly dispersed in this medium. And so it can have several different type of the medium. So sometimes it can be used in water. Sometimes you can use organic solvent. And the choosing of using water and organic solvent may be determined by what kind of a binder you will be using. The binder polymer you really need to be dissolved in such kind of solvent, which is a dispersion medium -- dispersion agent, which is mentioned here.

So -- so it has prepared a mixture of this first with certain percentage. He said 0.5 to 8 percent of those carbon nanotube and acetylene together and -- as compared with the dispersion -- as compared with -- as compared with the dispersion medium. And there will be some ratios between the solvent and the solvent materials. And in this process, it was prepared by using a dispersion polymer as well, which is used to help the nanotube to be de-bundled, to be dispersed and to be roughed by those polymers and dispersed as individual carbon nanotube in this medium.

And the polymer is polyvinylpyrrolidone or polyvinyl alcohol, PVP and PVA. They both are solid in water in this case. And typically those polymer are forming a roughing of the surface of the carbon nanotube. Therefore, they have the functions to actually de-bundle all those nanotube polymers -- or the nanotube bundles when they are in a solid status. And so those will help those nanotubes to be separated from each other due to the rough of the polymer, PVP and PVA, on the surface of the nanotube. So it's kind of, like -- you can consider it similar as a functionalization, yeah, process. So this is basically what they describe in this paragraph. So dispersed carbon solid by assisting PVP and PVA.

Q Okay. And the carbon nanotubes are being used as a conducting agent, correct?

A Yes.

Q And the acetylene black, is that also being used as a conducting agent?

A Yes.

Q Do you know why -- or what is your understanding as to why Cheng is using both carbon nanotubes and acetylene black?

A This is actually a general procedure or general protocol for all those carbon nanotubes as a common filler-based battery electrode composite preparation. So

carbon nanotube is relatively large in terms of the length, right. So it's good to forming percolation network as mentioned by Cheng.

And the other thing is that you have to have good point of contact. And the point of contact was made by the carbon nanotube -- some part of the carbon nanotube with some of those active materials or particles. And active materials/particles on the surface may not be very conductive, you know, in all cases. So they want to have some of the smaller particles like a carbon black, acetylene black. In this case, you only have size very small from, like, a few nanometers to a few tenths of a nanometer. When you have those things, it basically can cover on the surface of big -- relatively big, active materials, particles in some cases. And, therefore, they can build up a better electrical connection with -- with nanotube. So if you don't use nanotube, this can also work. So without carbon nanotube, you can also have a bulk of carbon black. Basically you need a little more to build out this network. And it's less efficient as compared with the use of those carbon nanotube and carbon black, yeah. Acetylene black in this case, yeah. So there's a slightly different function on the conducting fillers.

Q And then is -- is PVP a resin? Is it considered a resin?

A PVP and PVA in this case -- actually a polymer is used to disperse carbon nanotube. This is not exactly the binder materials which we talk about in lithium ion batteries.

Q Understood. So give me one second. Is it possible for carbon nanotubes and acetylene black to agglomerate?

A Well, there is always possibility that those carbon materials will agglomerate. That is why you always want to have a dispersion medium. You want to have sonication, which is actually separating them from each other physically. And, also, you want to have some polymer like PVP and PVA in this case, which can help rough the surface of the binder. So even you stop sonication, which means the basic separation/agitation force was stopped, those materials can still maintain separated status. And that functioning is pretty much similar as you oxidize the carbon nanotube. So once you oxidize carbon nanotube, you can also maintain this separated status after you use physical force to agitate in the solution and separate them from the solid into the liquid medium. And in -- if nanotube was oxidized, generally you don't need to add additional PVP and PVA in this case to help them to maintain the separated status.

Q Now, you mentioned that in Step 1 of

Cheng, which is in Paragraph 13, he's using the PVP or PVA as a dispersing agent, correct?

A Yes.

Q He's not using it as a binder, correct?

A No. This is not in a binder for the polymer.

Q So I want to flip back. Taking back over -- so remember part of this IPR petition there's the Ohata and Kavan reference, correct?

A Yes.

Q In Ohata, he's using the resin of his masterbatch both as a dispersion agent and as a binder, correct?

A Yes. That's true.

Q Okay. I just wanted to clarify because that's just the difference that popped in my head and I want to know if I had it straight.

So if we go down to Step 2 of -- well, actually going back real quick to Step 1 for just a second, it talks about ultrasonically dispersing?

A Uh-huh.

Q And that's where it's talking about ultrasonically dispersing the carbon nanotubes, acetylene black in dispersing agent together. Is it common to ultrasonically disperse conductive agents?

A Yes. It is common, yeah. Most of the preparation involve ultrasonication to disperse solid in liquid medium.

Q And is ultrasonic dispersible -- is that -- what is that again in your own words? I know you told me in a prior depo, but what is the conversion?

A Well, ultrasonication is basically using a physical agitation force, right. So you have some with basically agitating materials including a solid and a liquid. So all than those agitation raw materials started to disperse, right. So one phase was entering the other phase. And the problem with ultrasonication is once you stop to give this agitation force, they started to precipitate and aggregate again, right. So this is a problem that people needed to solve. That's why you needed to add PVP and PVA. So even after agitation sonication is stopped, the material still can be a separated status.

And the same thing for the carbon nanotube, oxidized carbon nanotube. When you have oxidized carbon nanotube as a solid powder, when you have -- then dissolve it in water and you also needed to have some sonication or similar physical agitation process to have something to dissolve, right. Just like you have a solid to be dissolved in water. You have to use your spoon to stir it a little bit to help them to dissolve. And once they

dissolve -- because in case of the oxidized carbon nanotube, they're hydrophilic. So they were state as in status without reaggregate and form precipitated. And in case of non-functionalized carbon nanotube, you needed to add something, which prevented them further aggregate after the -- after this agitation is stopped. Therefore, the reason he is adding PVP and PVA is to help the dispersed status even after sonication agitation is finished.

Q Got it. Can I get you to go to Paragraph 14 of Cheng. And Paragraph 14 is the beginning of what I'm going to call the second step or Step 2 of Cheng's process. Do you see that paragraph?

A Yes, I saw this paragraph.

Q And can you explain what Cheng is doing in Step 2?

A Yeah. So Step 2 is also quite common. So after you have dispersed conductive fillers, you want to add your active materials, right. So in Step 2 basically they just add active materials. And these active materials is related to lithium iron phosphate, right. It could be the lithium iron phosphate material itself. Could be the precursors of lithium iron phosphate as well.

And they also add -- in this case I also noticed they add some organic carbon source, right. So the organic carbon source is also quite commonly used because

you can have a better dispersion of the organic carbon sources in the dispersion medium because they are generally soluble in the dispersion medium at the very beginning. And then you can -- pyrolytic forming those carbons if you raise the temperature and those organic carbon can eventually incorporate into the network and they help the conductive network to rebuild in a better way. So some people add organic carbon. In this case, some people do not add organic carbon. And this is just as an option -- steps to optimize the procedure, but this is actually quite common, yeah. All these things are quite common: Adding the lithium iron phosphate materials, adding the organic carbon source and later on forming organic carbon source from some carbons, which has similar function as the premixed carbon nanotube and acetylene black, and eventually forming good conductive network to improve the performance of the electrode, yeah.

Q And is the purpose of the lithium source to help create the lithium iron phosphate?

A Yes. The lithium source is used to create lithium iron phosphate. It could be the lithium iron phosphate itself. It could be some precursors of the lithium iron phosphate.

Q And then the lithium -- the purpose of the lithium iron phosphate in the composite of Cheng is to

act as the active material, right?

A Yes. The lithium iron phosphate is the active materials.

Q And then you talked about the carbon source. Is the purpose of the carbon source to essentially act as a binder for the cathode?

A Not really. This is -- the organic carbon source is acting as a carbon at the end of the day. So it will be converted into some kind of carbon and provide a similar function as carbon nanotube and acetylene black.

Q Okay. So they're using the -- they're using -- basically the carbon is acting as a conducting agent?

A Yeah. Eventually become conducting agent, yes.

Q Okay. What is pyrolytic carbon?

A Pyrolytic carbon, which means organic carbon was decomposed and, therefore, it was carbon conducting fillers.

Q And it says, "The pyrolytic carbon formed by the organic carbon source in a subsequent heat treatment process being capable of acting synergistically with the carbon nanotubes in performance to improve performance of the electrode material."

Do you see that?

A Yes, I saw that.

Q What does that mean in layman's terms?

A That means it's an optional approach, right. So that's why I say some people use it, some people don't use it. So you always want a conductive network to give you as better as possible, right. So this will improve the active materials utilization. It will improve the variability of the battery. And in this case, you want to use carbon source to be really distributed uniformly as conducting fillers in your composite electrode materials. Your previous -- you disperse the nanotube as a pre-dispersion. You disperse the acetylene black as a pre-dispersion. All those things are focusing on the same purpose: How well the carbon fillers can be distributed better in the final active materials composite.

And the same thing here is adding some organic carbon source. This will be -- organic carbon source can be dissolved in the dispersion medium typically. So once they convert it in the pyrolytic carbon, you can consider those carbon -- pyrolytic carbon can be very well dispersed in the active materials because active material was also, if it's precursor, dissolved in this dispersion medium. So they are basically formed in, like, a one-part synthesis and they can be intermittently integrated together and forming a better conductive network, yeah. So this is a

way, a general way, a very commonly used way to actually build up a good conductive pathway inside of active materials composite.

Q And it mentions the heating process -- or heat treatment process. Is that -- is that what Cheng refers to as carbon thermal reduction?

A I didn't see the carbon thermal reduction.

Q Well, let me -- let me -- maybe -- if you go to Paragraph 39 of Cheng, you'll see that he uses that phrase.

A 39. Paragraph 39?

Q Yes, sir. The last -- well, it's only one sentence, so...

And you see he says --

A I saw that, yes.

Q It says, "In situ solid phrase reaction." In parenthesis, "Carbon thermal reduction." Is that the heating -- is that the heat treatment process he's describing in the summary that we just talked about?

A Yeah. This is the heat treatment for converting carbon -- organic carbon source into carbon.

Q And an example of an organic carbon source provided in Cheng is sucrose, for example, correct?

A Yes.

Q Okay. So in order to have this -- in order to create this carbon, you have to perform that heating -- heat treatment process, correct?

A Yes. In order to convert an organic carbon source into carbon, you have to conduct the heat treatment.

Q Okay. And --

A As I said, this is an optional approach. People can take it and people can just discard it. You already have carbon nanotube. You already have acetylene black. So this is an option. Some people will choose it to just getting better dispersion of the carbon nanotubes.

Q And I just want to be clear, that in Cheng he always teaches this step of converting the carbon source into carbon, correct?

A In Cheng's example, yes, whom we just discussed in Paragraph 13. And this -- or 14, Paragraph 14. This is the process he used to add organic carbon source in forming pyrolytic carbon.

Q But in -- but you're saying that you don't have to perform that step when you're making a cathode. That's just the way that Cheng chose to do it?

A Yeah. From the POSITA's general understanding, you need carbon fillers in the cathode materials to form a composite. So as I also mentioned, the

carbon fillers can be a combination of different carbon fillers. For example, in Cheng's case he used initial carbon black as well as acetylene black, right. So those are the two different carbon fillers serving as the same function in the composite to provide conductivity for the composite.

And the organic carbon source is additional carbon after it was converted to the pyrolytic carbon. It also provide conductive filler for serving for the same purpose as carbon nanotube and acetylene black, to provide good electrical conductivity. And all of those three are serving as the same function in terms of what is the use of those materials in the composite electrode, cathode or anode.

Q And then we go down to Paragraph 15 -- or I'm sorry. We go up. We're back up to Paragraph 15. And so Cheng in this paragraph he describes using a lithium source, an iron source and a phosphate salt. And that is to create the lithium iron phosphate, right?

A Yes. That is used to create lithium iron phosphate.

Q And at the same time, he's -- at the same time, he's mixing a lithium source, an iron source and a phosphate salt, he's also adding an organic carbon source in the mixture from Step 1, correct?

A Yes, that's correct, in his procedure.

Q Why is -- why is Cheng performing that process of mixing the lithium iron source -- I'm sorry -- the lithium source, the iron source and the phosphate salt while simultaneously adding the organic carbon source and the mixture from Step 1?

A Yeah. The reason is that they're all soluble in water. So in this case -- so dispersion medium or other dispersion medium and solid. And then you can get a more uniformed dispersion of the iron source, lithium source and phosphorous source. After these three sources react together, they form lithium iron phosphate and you have organic carbon. And after the organic carbon was converted into pyrolytic carbon, it will be very close to all those formed lithium iron phosphate particles as well.

And also in this mixture, you also have carbon nanotube, you also have acetylene black, which means all those active materials of lithium iron phosphate, once it was formed, it will be very close to this existing acetylene black and carbon nanotube. They will be attached on the surface of the carbon nanotube, for example, and form very smooth protein coverage in this case. So this is typically what they call NC2 reaction, right. So the NC2 reaction, it means I have a very good contact between all those ingredients because my active materials was dissolved

in this solution.

And then as they're forming the final product, which, therefore, it will be attached on the solid particles that was distributed in those solution medium, those solid particles of carbon nanotube in this case and some acetylene black and could be some carbon formed by the organic carbon source.

Q Okay. And then at the end of that -- of that Paragraph 15 it says, "Adding a mixing and milling medium to perform mixing and ball-milling." Why is Cheng performing that -- that process as part of Step 2?

A The ball-milling was typically used to disperse those solid and liquid medium. And in this case, it has insoluble part, which is carbon nanotube and acetylene black; and you have some soluble part, which is lithium salt, iron salt and phosphorus salt, and those things can be dissolved in the solvent. And organic carbon sources could be also dissolved in the solvent. And if you add too much, it may also exist as some of the slurry status. In this case, you have several different type of the solid and you have something dissolved in the solvent and you want to mix them very -- very well to have the solid and the liquid as a good contact. And that typically can be done by some milling procedure. So you can use bomanine (phonetic). You can use also other mixing procedure, but

bomaning is quite common in this case.

Q So the bomanine is to help with the dispersion?

A The bomanine itself is -- may help the mixing of the different ingredients rather than the helping of the nanotube to be dispersed in this medium because nanotube has been pre-dispersed. So there's two procedures. The nanotube was pre-dispersed by using PVP and PVA in this case. So they were not aggregated in solid mixture in this case. And then you have other solid particles and you have other solutions that you mix together with -- with the dispersed nanotube solution. And this bomanine procedure is used to help the other ingredient like the different lithium iron phosphorous source materials and the organic carbon based materials to be better mixed with pre-dispersed carbon nanotube and acetylene black.

Q Okay. And then we go down to Paragraph 19. This is where -- Paragraph 19 of Cheng, this is where Cheng is describing the third step of his process. And it says, "In situ solid phase reaction: After the mixed precursor powder is dried in step (2), calcining the same at 600°C to 850°C in an inert protective atmosphere for 4 to 48 hours, pulverizing the burned material and then sieving the same through a sieve of 150 to 400 meshes, thereby obtaining the carbon nanotube lithium iron phosphate composite cathode

material."

Did I read that correctly?

A Yes.

Q And so this -- this is the -- we talked about the heat treatment processes earlier. This -- and which you would agree with me that he also refers to that as a thermal carbon -- carbon thermal reduction, correct?

A Yes. Yeah. Because -- yes.

Q This Step 3 is describing what Cheng calls a carbon thermal reduction or a heat treatment process, correct?

A Yes. In this patent, it was given the name like this, yeah. So basically the procedure is forming lithium iron phosphate, right. Before you were forming lithium iron phosphate, you had this solid mixture, right, because you already evaporate all the solid and everything was mixed well. And in this case, the lithium salt, the phosphorus salt and iron salt are still in the salt status. They are not lithium iron phosphate.

Q I'm sorry. Can you say that again? You said what status? Soft?

A Salt. It's a -- it's a lithium precursor. You can call it a lithium precursor. Lithium carbonate, lithium hydroxide. Those are lithium sources, right. So the lithium precursor, iron precursor and

phosphorus precursors, they were just mixed in this phase, at this stage. They have not formed an active material, which is a lithium iron phosphate, which is all of it crystal, right. So they have not formed this case. And from the precursor to the formation of the lithium iron phosphate, there are a number of ways you can do that. So in this case -- in this specific patent, they used -- one way is to heat materials to a the temperature of 600 to 850 degrees heat. But there are actually several techniques to -- to achieve this purpose. And it has already been well discussed by the time while Cheng was working on that. And you can use this precursor in relatively low temperature, but you can put a little bit of pressure if you needed to, to be under a little bit of pressurized conditions and using slightly lower temperature. And you can still basically have the reaction between all these three precursors, lithium precursor, iron precursor and phosphorus precursor, in forming the lithium iron phosphate.

So those are all well documented procedures. So what I mention here specifically with a used -- we use Cheng's patent. It's not saying that Cheng's patent disclosed all the procedures. It's just one of the examples that you need to use precursor materials in situ to react together in the existence of carbon nanotube to forming a good contact between the carbon nanotube and the

final formed lithium iron phosphate.

However, there are many other approaches. The detailed experimental procedure may be slightly different, but they follow exactly the same purpose. You have to have some dispersed carbon nanotubes. And the carbon nanotube -- because the dispersion medium oftentimes use water, it will be better to use some oxidized carbon nanotube in this case. And you needed to mix with precursor in order to form very uniform mixture. The precursor will be converted into lithium iron phosphate. And this conversion can be called out on the different experimental conditions, and all those experimental conditions has already been disclosed, yeah.

This is one experimental condition mentioned in Cheng's patent, which is to raise the temperature to about 600 to 850 degrees, and in this condition lithium iron phosphate will be formed.

Q Right. And in the specific process that Cheng discloses, he has to perform Step 3, correct, to form the lithium iron phosphate?

A Yes. This is approach he take. He could also take a different approach to form lithium iron phosphate, but the approach is close in this paragraph. He's using a higher temperature.

Q Understood. And that higher

temperature, does that also help you convert the carbon source into carbon?

A Yeah. That is the reason likely he will choose this relatively high temperature because he has some organic source. He also wanted organic source to be converted into carbon. But as I said, the organic source is an optional step and the carbon fillers in this composite already have two as a -- as a type, right, carbon nanotube and acetylene black. And organic carbon source is the third type of the carbon filler he integrated into this final cathode material. Therefore, he would like to use it to increase the conductivity. Because of that, it is likely the reason he increased the temperature.

Q And when you oxidize carbon nanotubes, you add functional groups to them, correct?

A Yes. When you oxidize the carbon nanotube, you oxidize the surfacer carbon atoms and the end tube carbon atoms of the nanotube and then you add functional group.

Q Then -- I'm sorry. I didn't mean to cut you off. When you --

MR. ZINDA: Well, let's -- how about -- I think now is probably a good time for a break actually because I'm going to switch topics. So how about a ten-minute break? Does that work?

MR. IN: Yes.

MR. ZINDA: Thank you.

(Whereupon, a brief recess was taken.)

Q Dr. Zhu, when we last -- right before we took the break, you had mentioned Step 3 of Cheng. You said that that step is optional, correct?

A Yes. Step 3 of Cheng is one step that is forming from the precursor to the lithium iron phosphate and, yeah, there are many ways to do that. That's one of them.

Q But in the specific process that we discussed about Cheng, the three-step process, he has to perform Step 3 to form the lithium iron phosphate, correct?

A Well, that's what I said. This is optional for him and the POSITA should know a number of different ways to form the lithium iron phosphate. And those are all well documented ways to produce lithium iron phosphate. When you prepare lithium iron phosphate, you always need a precursor: Lithium, iron and phosphorus. And how do you prepare them, actually what experimental condition. Like, what is the temperature you would like to use. What is the pressure you would like to use. And this is basically an option of the -- of the researchers, whether there are existing protocols, existing batteries by that time already and -- to forming the lithium iron phosphate.

And this is just one of the approach taken by Cheng in his example to do that. And he can certainly don't use that high temperature, use a lower temperature. He can still form lithium iron phosphate under the right condition.

Q Okay. And then in Cheng if you -- if you were to use oxidized carbon nanotubes in the three-step process that we talked through in Cheng, you would expect that the functional groups would be removed by those high temperatures, correct?

A Well, not exactly the case. So this is an in situ reaction. So what is in situ reaction? It actually means there are some reactions that happen between your lithium iron phosphate precursor and other things existing in the -- in the -- in the solution. And the in situ means that one of those binder of the lithium iron phosphate to be formed together with other things. And, otherwise, they would like to synthesize lithium iron phosphate by itself without adding any other things. By adding other things, the intention here is to form an interaction, forming bonds between the lithium iron phosphate with others. And oxidized carbon nanotubes, the oxygen functional group can be removed if the carbon nanotube was heated without adding anything else. So if you heat oxidized carbon nanotube in vacuum and keep the temperature higher or some other environment, like nitrogen

or atom, and then those oxygen functional group will be removed. That is the condition that oxidized carbon nanotube to be sitting by itself, not mixing with any other else. And if you mix carbon nanotube with other things, it is not a guarantee that oxygen functional group will be removed. Instead you can have reaction with other -- with other -- other materials added together, particularly in the case of this, these added materials is actually very reactive. It's lithium precursor, phosphorus precursor and iron precursor. That is not even involved lithium iron phosphate particles. And there's a high likelihood to actually bonding those things together. That is why they call this in situ reaction. So, otherwise, they just call it a reaction. Not necessary to put words like in situ.

Q What temperature would you expect functional groups of oxidized carbon nanotubes to be removed in and by themselves without anything checked?

A Well, in a vacuum, those functional group will start to be removed at a temperature of around 260 degrees, depending on what kind of functional group. So even if you heat it at very high temperature, some functional group will still handle the material. And you can have some XPS data to see those oxidized carbon nanotube after heating. And other times you will detect some of the oxygen signals even after the high temperature treatment,

which is an indication that not all group will be removed, yeah. Some group will be very difficult to be removed.

Q Would you expect some oxidized groups to be removed at 600 degrees?

A I would expect some oxidized group will be removed at 600 degrees. However, I also expect at 660 degrees heat that those removed are not necessary to just leave a hole open there. Instead they can actually react with the lithium precursor and actually attach with the lithium iron phosphate and those places. And oxygen atoms in this case, not necessary to be removed. Instead they can actually form bonding with other materials, particularly with lithium iron phosphate is actually kind of the oxide of materials.

So you have a lot of oxygen group -- oxygen atoms over there. And those oxygen atoms can be shared by the oxidized functional groups of the oxygen atom and oxidized carbon nanotube. Therefore, they can actually form a bond in this process.

Q Okay. So are -- just one second. Sorry. We -- when we talk about the temperature that could potentially remove functional groups from oxidized carbon nanotubes -- or let me state it this way: Heat exposure that could potentially remove functional groups from oxidized carbon nanotubes, one of the considerations is

temperature, correct? So the higher the temperature, the more likely it is that you can remove functional groups, correct?

A Yeah. In the condition, if nothing else exist. Yeah. In the condition that only nanotube, oxidized nanotube is heated without existence of other ingredient surrounding it.

Q And then, secondly, the amount of time that you heat the nanotubes could affect the amount of oxidation that's removed; is that fair?

A Yes. In principal, the time will have impact on this, yeah. Also, under the same conditions that there's only oxidized carbon nanotube, nothing else exist around it.

Q And you mentioned before that Cheng uses the temperature of 600 to 850 degrees Celsius, correct?

A Yes.

Q And you mentioned before that it's -- that you could use -- in your opinion, you could use a lower temperature?

A Yes. This is a wide temperature range people can actually choose to forming lithium iron phosphate.

Q So is it your opinion that you would use a lower temperature if you were using oxidized carbon

nanotubes or would you do the same thing that Cheng did?

A I could use either way. I don't think it's necessary to have any specific difference in this case. You just needed to choose a way to forming lithium iron phosphate. And end of the day, you consider the cost of the raw materials and distribution of the carbon fillers and whether you would like to add any other ingredients in the lithium iron phosphate. And there are many considerations like that.

So sometimes you -- you can consider using higher temperature. Sometimes you can consider using lower temperature, yeah. So it's a wide range of selection depending on the exactly raw materials reaction conditions and the result you would like to achieve.

Q Are you aware of any specific example of anybody using -- anybody calcining oxidized carbon nanotubes at 600 degrees or higher?

A Yeah. We actually provided one examples, which is those examples in this case. It's oxidized carbon nanotubes. And it was, I think -- what is exactly the number? Let me go through the list of exhibits. We will provide an example. Go to my exhibit list. That is exhibit -- Exhibit 1032.

Q Okay. Let me pull that up.

A Yeah.

Q Where does this -- Exhibit LGES 1032, where does it disclose the temperatures that it's heating at?

A It's not in the -- in the manuscript. It's in the support information. Yeah. It says the temperature is 600 something to forming -- yeah, to -- in the sample. In the paper it says it will be heated and it's oxidized the nanotube. It has already been discussed and it's acid treated oxidized nanotube. So this is exactly the examples you were asking for. You were asking if there's any evidence that oxidized the nanotube mixed with lithium iron phosphate precursors and use relatively high temperature to form it.

Q Can you tell me where the temperature is disclosed? You said it's not in this document; it's in another document?

A This is a scientific paper, right. The support information from this scientific paper, which is actually available online. So if you go to this paper's web page, the support information is free of charge to download. So you don't need to buy access to access this one. The experimental detail was mentioned in the support information.

I think the exact mention of -- let me see. So if you look at Page 1 of this Document 1032, and if

you look at the first page and you look at the bottom of the first page on the left column, the last sentence, "Electronic support information available: Details of the experimental procedures, XRD patents, impedance spectra." See blah, blah, blah. That's -- that's the support information of where you will find the experimental procedure.

Q Okay. Thank you. So I want to turn to Gan, which is LGES 1021. And when I say --

MR. ZINDA: For the reporter it's G-A-N.

Q So Dr. Zhu, when I say Gan, you understand I'm referring to LGES 1021, correct?

A Yes, I understand. I'm on the page.

Q You're there. Okay. Can you go to Paragraph 2 for me?

A Paragraph 2. Yes, I'm on Paragraph 2.

Q Can you tell me what is PEDOT exactly, P-E-D-O-T?

A Yeah. PEDOT is -- the name is actually right above this is. It's a poly (3,4-ethylenedioxythiophene). Right. So this is a conjugated polymer which has thiophene as a conjugated unit. And the thiophene has a side chain which has two oxygen bridge. And it was conducted on the top two carbons of five-member thiophene. So thiophene has -- thiophene is a

five-membrane structure, aromatic structure. It has four carbon atoms and one sulfer atoms in forming a five-member ring. And on the opposite side of the thiophene there are two carbons on that, two positions. There is a bond which are two oxygen connected together to bridge this two carbons in addition to the carbon, carbon bond. And this one was called 3,4-ethylenedioxythiophene. And it was polymerized on the 2,5 position of this molecular, which is -- which are the two carbon matters that is not connected with oxygen atoms. And they can be polymerized, which means they're forming a connected bond across those two positions and forming a medial structure. And this medial structure is a polymer, which is called poly (3,4-ethylenedioxythiophene). And the 3,4 are the position where the ethylenedioxy group was -- was positioned. And 2, 5 are the position where the polymerization happens.

Q So is PEDOT a conductive polymer?

A Yeah, it's a conducting polymer.

Q And that's -- PVDF would be an example of a non-conductive polymer, right?

A Yeah. In this sense, a PVDF is not a conducting polymer. However, the conducting polymer and the connectivity is a skill much lower than anything we call conductive, like a carbon, like a metal. So there are conductivity differences. It's orders of magnitude.

Q And one of the purposes of Gan to -- when he talks about making a composite of carbon nanotubes in conductive polymer material, he is talking about trying to basically create a polymer that has carbon nanotubes in it so that it's more conductive?

A Yes. Generally, the conductivity of the carbon nanotube is better that any kind of conductive polymer. So adding conductive polymer into the -- or adding the carbon nanotubes into the conducting polymer to prepare the polymer composite is to improve the electro conductivity -- electrical conductivity of the composite. So they have similar meanings, like, you add carbon nanotube into something like other non-conducting polymer like PVDF or other things. Or you can compare it with adding conducting fillers of carbon nanotube into a less conductive cathode material because cathode material is not completely non-conductive. It has a little bit of conductivity, but the conductivity is not as good as carbon nanotube. Therefore, there are some similar comparison cases in this -- in this sense. You have more conductive fillers, which is the nanotube, and you are putting this in to a less conductive medium, which can be a conducting polymer, can be a non-conductive PVDF, can be less conductive cathode materials.

Q Okay. And then if you go down to

Paragraph 18 of Gan.

A Yes.

Q So here he's -- starting at Paragraph 18, he's describing the functionalization of carbon nanotubes, correct?

A Yes.

Q And then in the final sentence of Paragraph 18 he says, "The functionalization of the CNTs achieves at least one or more of the following objectives."

So I'd like to talk through these with you. So Paragraph 19 he states, "1. Improves the solubility and dispersibility of the CNTs in water and conductive polymer materials into which the CNTs are to be mixed in accordance with the embodiments described herein."

Do you agree with that statement?

A Yes, I agree.

Q In Paragraph 20 he says, "Reduces" -- excuse me. Paragraph 20 Gan states, "2. Reduces contact resistance between CNTs incorporated into the conductive polymer by drawing the CNTs closer together."

Do you agree with that statement?

A Yes, I agree, but there are some subtle differences. When he say draw all the CNTs close to each other, in this sense he means there are point of contacts between the conductive -- between the CNT together. It does

not mean the conductive -- or the carbon nanotube are rebundled and forming a bundled structure because the carbon nanotube was functionalized in the pi pi stacking, which leads to the bundled carbon nanotube was disrupted.

Q Okay. So if I understand you correctly, in Paragraph 20 when he refers to functionalization of carbon nanotube when used in a conductive polymer material drawing the CNTs closer together, you're saying that just means it causes the CNTs to touch but not intertwine?

A Exactly. That's what it is in the contact resistance.

Q When CNTs are drawn closer together as described in Paragraph 20, is there any sort of Van Der Waals forces that are holding them together?

A It can be a market for interaction because the nanotube has already been functionalized in this case, right. So you have oxygen functional group on the surface of carbon nanotube. So not only Van Der Waals force exist in this case. There are also ionic bonding force exist in this case. And it could have also hydrogen conductive force in this case. So there are -- those are much more complicated situation in terms of the force that -- between those conduct -- functional groups of the carbon nanotubes.

Q Okay. And then 21, Paragraph 21 of Gan,

"3. Provides a conductive bridge between CNTs to reduce the electrical contact resistance therebetween."

So first question, do you agree with that statement?

A Yes. This is actually referred to the conduct -- conductivity of the -- of the composite material as a whole, right. So this is basically bring two carbon nanotube or more carbon nanotube more closer as a point of contact in this way, right. So you can build up electrical conducting network in a continuous medium and, therefore, the conductivity will be enhanced in this case. The contact resistance -- when they mention the contact resistance, they're talking about, okay, one nanotube contact another nanotube with kind of a point of contact without actually aggregating. When they aggregate, that means the two nanotubes parallelly impacts, which also have good contact between those two nanotube. It does not contribute to the network in the medium which is not preferred. So you have aggregate in this case. And Paragraph 21 actually is saying this reduced contact resistance is provided by building this bridges between those CNT, which is a result of functionalized CNT because the functional group on the CNT has stronger interaction as compared with non-functionalized CNT. So they can easily build up this contact point without having it aggregated into bundles which lose the conducting

network function.

Q So essentially Paragraph 20 and 21 are both about improving the -- improving the conductivity by having the nanotubes, I guess, contact one another to form a better network?

A Right. If you have nanotube -- it's quite fairly to understand. If your two nanotube -- if there's two nanotube that does not have any contact, then there's no electrical connection between them, right. So the electrode has to move from one to the other. They must have some place to contact. So the point of contact provided such kind of bridge. But you also do not want two nanotubes just bundle together. And then you only have contact with those two nanotube, which is you'll need a lot more nanotube to actually build the network, which is not preferred in this composite for lithium ion battery.

Q And if we can go down to Paragraph 41 of Gan. Do you see where it says, "Figure 5 is a scanning electron microscope image"?

A Figure 5. So I just want to doublecheck with you the paragraph you just mentioned.

Q Paragraph 41.

A 41. Okay. Across to the picture. 41.

Q Yeah. But it says, "Figure 5."

A Correct.

Q "Figure 5 is a scanning electron microscope image of the MWNT-PEDOT:PSS/PMMA composite after the acetone treatment."

And then it says, "Figure 5 illustrates the presence of random interconnected network of MWNTs and PEDOT:PSS." That's referring to multi walled nanotubes, correct?

A Yes.

Q So this is describing how there's an interconnected network of multi walled nanotubes. And then it goes on to say, "The arrows in Figure 5 identify locations where the PEDOT:PSS effectively wraps around and binds with MWNTs to form a percolated network."

Do you see that?

A Yes, I see those words.

Q So Figure 5 -- is one of Gan's goals to achieve a percolated conductive network?

A Yes. One of the goals is to achieve this percolated network. And this is actually the same goal as any of the polymer -- any of the lithium ion battery cathode materials preparation. You would like to achieve this connected network, which is called a percolation network. And this network can provide electrical conductivity. The carbon nanotube was connected with this network with minimum amount of weight ratio. Then it is

preferred to forming a composite in the lithium ion battery electrode.

Q And then it says, "A percolated" -- this is going back to Paragraph 41 again. It says, "A percolated network refers to the network of CNTs and conductive polymers in forming a continuous conductive path extending through the composite."

And so that continuous conductive path is the path of interconnected carbon nanotubes and conductive polymer material?

A Yes. All of the conducting species like conductive nanotube and a conductive polymer all, of course, have some conductivity as well.

Q And it says, "The presence of such continuous conductive path through the composite is believed to be a reason why the electrical conductivity and the conductive polymer material increases when CNTs are present."

Did I read that right?

A Yes.

Q And so basically Gan is saying this is a good thing that we have this percolated network?

A Right. If you have a percolated network for the conductivity, right, this is a good thing for -- for intense conductivity of the composite as a whole. So this

is basically actually quite a general understanding of the POSITA in working with lithium ion battery electrode. He knows that the battery electrode was actually formed by some conductive fillers with less conductive active materials. And those conducting fillers needed to provide a percolated conductive pathway in order to enhance the electrical conductivity of the electrode materials composite as a whole. And that's basically every -- every researcher working on the lithium ion battery is looking for. So that's why it's quite understandable for them to looking for how other assistance, which not having active materials of the electrode, but have less conductive medium as compared with carbon nanotube and how the carbon nanotube was better distributed in those systems to forming a populated network. And those knowledge and those reference will certainly provide insight for the POSITAs to -- to build up those composite with a connected conducting pathway, yeah, with nanotube.

Q Dr. Zhu, I really appreciate it.

MR. ZINDA: I have no further questions. I'll pass the witness.

MR. IN: Actually, yeah. No further questions from the petitioner either. Thank you.

MR. ZINDA: All right. 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 24th 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, Ph.D., 03/21/2025

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

_____ _____

Yu Zhu, Ph.D. Date

Sworn to and Subscribed before me

_____, Notary Public.

This_____day of _____, 20____.

My Commission Expires:

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