

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. IPR2024-01011
: U.S. PATENT NO. 8,968,924 B2
7 MOLECULAR REBAR DESIGN, :
LLC, :
8 :
Patent Owner. :
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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 21, 2025 at 10:51 a.m.,
15 before Jennifer K. Starner, RPR, a Notary Public within and
16 for the State of Ohio.

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

2 It is stipulated by and between counsel for the
3 respective parties that the deposition of YU ZHU, PhD, an
4 expert witness herein, called as upon Cross-Examination by
5 the Patent Owner may be taken at this time and place
6 pursuant to the Federal Rules of Civil procedure and Notice
7 as to the time and place of taking said deposition; that the
8 deposition was recorded in stenotypy by the court reporter,
9 Jennifer K. Starner, RPR, and transcribed out of the
10 presence of the witness; and that said deposition is to be
11 submitted to the witness for his examination and signature,
12 and that signature may be affixed out of the presence of the
13 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 Hi, Dr. Zhu.

7 A Hi.

8 Q Let me go back. I'm not going back
9 through the introduction with you because we just went
10 through that regarding breaks and all that stuff. In this
11 deposition you're here to offer testimony on U.S. Patent
12 8,682,924, correct?

13 A Yes, that's correct.

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

16 A Yes, that's okay.

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

19 A Yes.

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

22 A Yes.

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

25 A I'm on the claim page.

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

3 A Yes, I saw discrete carbon nanotubes.

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

7 A Yes. Correct.

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

11 A Yes.

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

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

25 Q So that understanding of discrete carbon

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

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

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

10 A I saw uniformly dispersible oxidized
11 carbon nanotubes, yes.

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

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

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

1 way.

2 A Uh-huh.

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

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

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

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

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

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

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

6 A Yes, I open that reference.

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

9 A Yes.

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

16 Did I read it correctly?

17 A Yes. That's correct.

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

20 MR. IN: Objection to form.

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

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

11 Q Okay. The cathode comprises active
12 material, correct?

13 A Yes.

14 Q And it will comprise a binder typically?

15 A Yes.

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

18 A Yes, a lot of times.

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

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

1 A Yes. That is one common approach.

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

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

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

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

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

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

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

1 A Paragraph 5?

2 Q Yes, sir.

3 A Yes, sir.

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

11 Did I read that correctly?

12 A Yes, that's correct.

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

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

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

1 A Yes.

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

12 Did I read that right?

13 A Yes.

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

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

1 electrode will be improved.

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

7 MR. IN: Objection. Form.

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

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

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

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

5 Did I read that correctly?

6 A Yes.

7 Q And so what is this referring to?

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

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

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

14 A Yeah.

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

16 A 13. Yes, I'm here.

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

19 A 10.

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

22 A Summary?

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

1 title --

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

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

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

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

11 A Yes. Correct.

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

23 Do you see that?

24 A Yes, I saw those words.

25 Q So Cheng -- again, Cheng is trying to

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

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

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

8 A Yes. 13 provided some details about his
9 process.

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

13 A Yeah. The Paragraph 13 is first step.

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

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

1 carbon nanotube as well as acetylene black.

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

15 So -- so it has prepared a mixture of
16 this first with certain percentage. He said 0.5 to
17 8 percent of those carbon nanotube and acetylene together
18 and -- as compared with the dispersion -- as compared
19 with -- as compared with the dispersion medium. And there
20 will be some ratios between the solvent and the solvent
21 materials. And in this process, it was prepared by using a
22 dispersion polymer as well, which is used to help the
23 nanotube to be de-bundled, to be dispersed and to be roughed
24 by those polymers and dispersed as individual carbon
25 nanotube in this medium.

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

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

16 A Yes.

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

19 A Yes.

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

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

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

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

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

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

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

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

25 Q Now, you mentioned that in Step 1 of

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

3 A Yes.

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

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

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

10 A Yes.

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

14 A Yes. That's true.

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

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

21 A Uh-huh.

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

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

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

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

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

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

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

13 A Yes, I saw this paragraph.

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

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

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

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

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

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

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

1 act as the active material, right?

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

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

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

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

14 A Yeah. Eventually become conducting
15 agent, yes.

16 Q Okay. What is pyrolytic carbon?

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

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

25 Do you see that?

1 A Yes, I saw that.

2 Q What does that mean in layman's terms?

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

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

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

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

7 A I didn't see the carbon thermal
8 reduction.

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

12 A 39. Paragraph 39?

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

15 And you see he says --

16 A I saw that, yes.

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

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

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

25 A Yes.

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

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

7 Q Okay. And --

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

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

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

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

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

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

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

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

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

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

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

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

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

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

1 in this solution.

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

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

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

1 bomaning is quite common in this case.

2 Q So the bomanine is to help with the
3 dispersion?

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

17 Q Okay. And then we go down to
18 Paragraph 19. This is where -- Paragraph 19 of Cheng, this
19 is where Cheng is describing the third step of his process.
20 And it says, "In situ solid phase reaction: After the mixed
21 precursor powder is dried in step (2), calcining the same at
22 600°C to 850°C in an inert protective atmosphere for 4 to 48
23 hours, pulverizing the burned material and then sieving the
24 same through a sieve of 150 to 400 meshes, thereby obtaining
25 the carbon nanotube lithium iron phosphate composite cathode

1 material."

2 Did I read that correctly?

3 A Yes.

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

8 A Yes. Yeah. Because -- yes.

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

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

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

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

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

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

1 final formed lithium iron phosphate.

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

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

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

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

25 Q Understood. And that higher

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

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

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

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

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

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

1 MR. IN: Yes.

2 MR. ZINDA: Thank you.

3 (Whereupon, a brief recess was taken.)

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

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

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

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

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

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

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

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

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

18 **A Well, in a vacuum, those functional**
19 group will start to be removed at a temperature of around
20 260 degrees, depending on what kind of functional group. So
21 even if you heat it at very high temperature, some
22 functional group will still handle the material. And you
23 can have some XPS data to see those oxidized carbon nanotube
24 after heating. And other times you will detect some of the
25 oxygen signals even after the high temperature treatment,

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

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

5 A I would expect some oxidized group will
6 be removed at 600 degrees. However, I also expect at
7 660 degrees heat that those removed are not necessary to
8 just leave a hole open there. Instead they can actually
9 react with the lithium precursor and actually attach with
10 the lithium iron phosphate and those places. And oxygen
11 atoms in this case, not necessary to be removed. Instead
12 they can actually form bonding with other materials,
13 particularly with lithium iron phosphate is actually kind of
14 the oxide of materials.

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

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

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

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

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

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

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

17 A Yes.

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

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

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

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

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

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

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

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

24 Q Okay. Let me pull that up.

25 A Yeah.

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

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

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

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

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

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

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

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

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

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

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

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

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

19 A Yeah. PEDOT is -- the name is actually
20 right above this is. It's a poly
21 (3,4-ethylenedioxythiophene). Right. So this is a
22 conjugated polymer which has thiophene as a conjugated unit.
23 And the thiophene has a side chain which has two oxygen
24 bridge. And it was conducted on the top two carbons of
25 five-member thiophene. So thiophene has -- thiophene is a

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

17 Q **So is PEDOT a conductive polymer?**

18 A Yeah, it's a conducting polymer.

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

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

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

6 A Yes. Generally, the conductivity of the
7 carbon nanotube is better than any kind of conductive
8 polymer. So adding conductive polymer into the -- or adding
9 the carbon nanotubes into the conducting polymer to prepare
10 the polymer composite is to improve the electro
11 conductivity -- electrical conductivity of the composite.
12 So they have similar meanings, like, you add carbon nanotube
13 into something like other non-conducting polymer like PVDF
14 or other things. Or you can compare it with adding
15 conducting fillers of carbon nanotube into a less conductive
16 cathode material because cathode material is not completely
17 non-conductive. It has a little bit of conductivity, but
18 the conductivity is not as good as carbon nanotube.
19 Therefore, there are some similar comparison cases in
20 this -- in this sense. You have more conductive fillers,
21 which is the nanotube, and you are putting this in to a less
22 conductive medium, which can be a conducting polymer, can be
23 a non-conductive PVDF, can be less conductive cathode
24 materials.

25 Q Okay. And then if you go down to

1 Paragraph 18 of Gan.

2 A Yes.

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

6 A Yes.

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

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

15 Do you agree with that statement?

16 A Yes, I agree.

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

21 Do you agree with that statement?

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

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

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

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

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

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

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

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

3 So first question, do you agree with
4 that statement?

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

1 network function.

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

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

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

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

22 Q Paragraph 41.

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

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

25 A Correct.

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

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

8 A Yes.

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

14 Do you see that?

15 A Yes, I see those words.

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

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

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

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

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

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

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

19 Did I read that right?

20 A Yes.

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

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

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

19 Q Dr. Zhu, I really appreciate it.

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

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

24 MR. ZINDA: All right. Thank you.

25

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

2

3 STATE OF OHIO :
4 COUNTY OF HAMILTON : SS:
5 :

6

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

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

13

14

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16

17

YU ZHU, PhD

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19

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

21

22

23

24

25

1 C E R T I F I C A T E

2 STATE OF OHIO :
3 COUNTY OF HAMILTON : SS:
4 :

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

20 IN WITNESS WHEREOF, I have hereunto set my hand
21 and official seal of office at Cincinnati, Ohio, this
22 24th day of March, 2025.

23 Jennifer K. Starner

24 My commission expires: Jennifer K. Starner, RPR
25 March 7, 2029 Notary Public

1 CHANGES AND SIGNATURE

2 WITNESS NAME: Yu Zhu, Ph.D., 03/21/2025

3 PAGE LINE CHANGE REASON

4 _____

5 _____

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15 _____

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

19 _____

20 _____

21 Yu Zhu, Ph.D. Date

22 Sworn to and Subscribed before me

23 _____, Notary Public.

24 This _____ day of _____, 20____.

25 My Commission Expires:

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