

1 UNITED STATES PATENT AND TRADEMARK OFFICE
2 BEFORE THE PATENT TRIAL AND APPEAL BOARD

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4 MICRON TECHNOLOGY, INC.

5 Petitioner

6 v.

7 PRESIDENT & FELLOWS OF HARVARD COLLEGE

8 Patent Owner
9 -----

10 Case Nos. IPR2017-00662 (US 6,969,539)
11 IPR2017-00663 (US 8,334,016)
12 IPR2017-00664 (US 8,334,016)
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14
15 DEPOSITION OF SANJAY BANERJEE, Ph.D.
16
17
18

19 DATE: Friday, October 13, 2017

20 TIME: 9:00 a.m.

21 LOCATION: WEIL, GOTSHAL & MANGES LLP
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23 Redwood Shores, California 94065

24 REPORTED BY: LYNNE M. LEDANOIS, C.S.R. 6811

25 JOB NO: 131316

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Page 6 1 INDEX OF EXHIBITS 2 Deposition Description Page 3 Exhibit 12 U.S. Patent No. 6,537,613 B1, 4 Senzaki, Hochberg, Anthony, 5 Norman; 101 6 Exhibit 13 Document headed, Japanese 7 Journal of Applied Physics, 8 September 1998, Vol. 37, 9 No. 9A; 122 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25	Page 7 1 Redwood Shores, California 2 Friday, October 12, 2017 3 9:00 a.m. 4 5 (Exhibits 1 through 5 marked.) 6 SANJAY BENERJEE, Ph.D., 7 having been duly sworn, testified as follows: 8 EXAMINATION 9 BY MR. LEN: 10 Q Good morning, sir. 11 A Good morning. 12 MR. LANG: So Jason Lang on behalf of 13 Micron. We're doing this on one transcript? 14 MR. LEN: Yes. 15 BY MR. LEN: 16 Q On behalf of plaintiff -- on behalf of 17 the patent owner, this is Gregory Len from 18 Pepper Hamilton. With me is Greg Mesmer. 19 Good morning again, sir. 20 A Good morning. 21 Q If you could please state your name 22 for the record. 23 A Sanjay Kumar Banerjee. 24 Q Sir, have you ever been deposed 25 before?
Page 8 1 A Yes, I have. 2 Q How many times? 3 A Probably around a dozen times. 4 Q So I'm sure because you've been 5 deposed before, you're familiar with the rules 6 and procedures of how today is going to work. 7 But we'll just review them quickly to remind you 8 of a couple of things. 9 First, obviously, this is a question 10 and answer process. So I'll ask you the 11 questions and in your answer, please not only 12 give your attorney, Mr. Lang, time to object, 13 but also try to speak slowly and clearly for our 14 court reporter who's going to do a great job. 15 And please give verbal answers because nodding 16 your head is not going to show up on the 17 transcript. 18 Also, it's important that we try to 19 speak clearly so we don't talk over each other 20 so it's, again, easier for the court reporter 21 today. 22 Obviously, it may be a long day, but 23 it's not a marathon. We want to be sure if you 24 need a break, you can, so please let me know. 25 And again, it's important to be clear.	Page 9 1 So from time to time, I may ask you a 2 question that Mr. Lang may object to. Unless he 3 instructs you not to answer, you can go ahead 4 and answer. 5 Do you understand? 6 A Yes. 7 Q Dr. Banerjee, you're not on any 8 medication today, are you? 9 A No. 10 Q There's nothing that would prevent you 11 from testifying truthfully and accurately today; 12 is that right? 13 A I take blood pressure medication, but 14 it does not -- 15 Q Does not affect you? 16 A No. 17 Q Great. Sir, what is your current job 18 title? 19 A The Cockrell chair professor of 20 electrical answer computer of engineering at the 21 University of Texas. I also am the director of 22 the Microelectronics Research Center there. 23 Q And how long have you had that 24 position? 25 A I've been at the University of Texas

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Page 10 1 since 1987 when I joined as an assistant 2 professor. Then I became the director I believe 3 in 1999 and then I also became the Cockrell 4 chair around that time. 5 Q What are your responsibilities, job 6 responsibilities in your current position only? 7 A Well, as a professor, I director 8 research done by my graduate students and it's a 9 multifaceted job involving writing research 10 grants, get funding, and then directing the 11 research of my graduate students, help write and 12 edit the research papers and things like that. 13 In addition, as director of the 14 microelectronics center, we have a clean room 15 where my colleagues and I fabricate 16 microelectronic devices things like transistors, 17 capacitors. So in that role, I manage the clean 18 room, the equipment, I manage the engineers who 19 run the equipment and maintain the equipment and 20 things like that. 21 So I wear two hats. 22 Q And you also teach students, I would 23 assume? 24 A Yes. 25 Q Did you have any jobs prior to being	Page 11 1 an assistant professor in 1987 at University of 2 Texas? 3 A Yes. 4 Q What was that? 5 A I got my Ph.D. from the University of 6 Illinois in 1983. I started working at Texas 7 Instruments in Dallas in their corporate 8 research labs. 9 Q And what was your responsibility while 10 you were working for Texas Instruments at 11 Dallas? 12 A As part of the team that worked on 13 dynamic random access memories, DRAMs, where we 14 worked on trench capacitor sales for DRAMs. 15 We actually made the world's first 16 4 megabit DRAM at that time. 17 Q You mentioned trench capacitor. Are 18 you familiar with the term "stacked capacitor"? 19 A Yes. 20 Q What is the difference between a 21 trench capacitor and a stack capacitor? 22 A So in a DRAM, you store charge in a 23 capacitor, through what is called an access 24 transistor. And unfortunately, the charge tends 25 to leak away from the capacitor. That's why a
Page 12 1 DRAM is dynamic in the sense that you have to 2 periodically refresh the information in the 3 cell. 4 To make sure that the information does 5 not get destroyed, you need a certain minute 6 amount of storage capacitance and therefore, 7 storage charge. And the problem has been as 8 chips have been scaled according to Moore's law, 9 the area that it can devote to a memory cell has 10 shrunk and therefore, people want to maintain 11 enough cell capacitance. 12 And the two ways people have done that 13 is to basically use the a third dimension on the 14 chip. You either go down and dig a hole or 15 trench so that you have a larger surface area on 16 the trench walls to do work for the capacitor or 17 you can stack up multiple electrodes, so you go 18 up the vertical dimension. 19 MR. LANG: Greg, I think we should 20 read the IPR proceedings on the record that 21 we're here about today. 22 MR. LEN: Absolutely. 23 MR. LANG: Since there is some pending 24 ones, I don't want there to be any 25 confusion.	Page 13 1 MR. LEN: Absolutely. I appreciate 2 that. If you don't mind, I'm just going to 3 finish with -- 4 MR. LANG: Sure. 5 MR. LEN: -- with Dr. Banerjee's -- 6 right after this, I'll let you finish the 7 train of thought on Dr. Banerjee's 8 employment and educational occasional 9 history. 10 BY MR. LEN: 11 Q So, Dr. Banerjee, you mentioned that 12 prior to starting at University of Texas, you 13 worked at Texas Instruments. Did you have any 14 positions prior to Texas Instruments? 15 A When I was doing my Ph.D, I was 16 appointed as a graduate research assistant. And 17 then after I got my Ph.D. for a couple of 18 months, before I joined TI, I worked as a 19 visiting assistant professor at the University 20 of Illinois. 21 But that was just a -- I think I did 22 that for two or three months I think. It was a 23 temporary position. 24 Q Doctor, your Ph.D. is in what? 25 A It's electrical and computer

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Page 14 1 engineering. 2 MR. LEN: So as part of reciting for 3 the record, first we're going to will mark 4 the petitions that are at issue today. 5 MR. LANG: Okay. Great. 6 MR. LEN: I'll read them into the 7 record. 8 Doctor, the court reporter has 9 premarked the petitions and your 10 declarations that we're going to speak about 11 today. I'm handing you what's been 12 premarked as Banerjee Exhibit 1, which is a 13 petition for inter partes review of U.S. 14 Patent Number 6,969,539. 15 Doctor, I'll definitely give you time 16 to look through all of those. But just so 17 we can continue on this process, I'm going 18 to mark them all at once. The court 19 reporter has premarked as Banerjee Exhibit 2 20 a document that on its face states: 21 Declaration of Sanjay Banerjee, Ph.D. in 22 support of petition for inter partes review 23 of U.S. Patent Number 6,969,539. The lower 24 right-hand corner it's marked as Micron 25 Exhibit 1003, Page 1.	Page 15 1 Doctor, I'm going to hand to you 2 what's been marked as Banerjee Exhibit 3 Number 3, which is a petition for 4 inter partes review of U.S. Patent Number 5 8,334,016. 6 And I'm handing what's been premarked 7 as Banerjee Exhibit Number 4. It's 8 declaration of Sanjay Banerjee, Ph.D., in 9 support of petition for inter partes review 10 of U.S. Patent Number 8,334,016. This 11 document in the lower right-hand corner is 12 also marked as Micron Exhibit 1003, Page 1. 13 Now, Doctor, what I'm going to be 14 handing you is marked as Banerjee Exhibit 15 Number 5, the petition for inter partes 16 review of U.S. Patent Number 8,334,016. 17 (Exhibit 6 was marked.) 18 MR. LEN: Finally, what's been marked 19 as Banerjee Exhibit Number 6 is the 20 declaration of Sanjay Banerjee in support of 21 petition for inter partes review of U.S. 22 Patent Number 8,334,016. Again, in the 23 lower right-hand corner it's marked as 24 Micron Exhibit 1003, Page 1. 25
Page 16 1 BY MR. LEN: 2 Q Doctor, I'll give you a minute to look 3 through those if you want. Maybe you have had a 4 chance. Do you recognize these documents? 5 A Yes, I do. 6 Q What are they? 7 A They are the IPRs and my declarations 8 related to the '539 patent and the '016 patent. 9 MR. LEN: My co-counsel noted to me 10 that it did not include the official IPR 11 numbers. So we can put those on the record. 12 IPR 2017-00662 is the IPR for the 6,969,539 13 patent, which is Banerjee Exhibit 1. 14 And IPR 2017-00663 is the IPR for 15 Patent 8,334,016. And that's Banerjee 16 Exhibit Number 3. 17 And then finally, IPR 2017-00664 is 18 the IPR for Patent 8,334,016, which is 19 marked as Banerjee Exhibit Number 5. 20 BY MR. LEN: 21 Q Even to be more specific, Doctor, if I 22 can have you direct your attention to Exhibit 23 Number 1, which is the petition for the '539 24 patent. 25 Do you see on the first page in the --	Page 17 1 I guess in the outline or the table of contents 2 it discusses claims at issue; is that correct? 3 Strike that. 4 You understand that Claims 24, 26 and 5 29 of the '539 patent are at issue; correct? 6 A Yes. 7 Q And similarly, if we go to Exhibit 8 Number 3, or the 663 IPR for the '016 patent, if 9 you look at the claims at issue, you understand 10 that Claims 1 through 3, 5 through 7, 9 and 10 11 are at issue in this IPR; true? 12 A Yes. 13 Q And finally, if we turn to Exhibit 14 Number 5, which is the 664 IPR, you understand 15 that Claims 1, 2, 7, 8 and 10 are at issue in 16 this IPR; correct? 17 A Yes. 18 Q Thank you, Doctor. So I guess just to 19 back up. 20 Doctor, what, if anything, did you do 21 to prepare for today? 22 A Today? 23 Q Yes. 24 A Well, when I got up, I quickly 25 reviewed my declarations, the '016 patent, the

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Page 18 1 '539 patent this morning. 2 Q And did you do anything to prepare 3 before today? 4 A Yes. 5 Q What did you do? 6 A I met with counsel two days. 7 Q Did you meet with anyone else besides 8 your attorneys? 9 A No. 10 Q Did you have any discussions with 11 anyone at Micron in preparation for today? 12 A No. 13 Q Did you have any discussions with 14 anyone besides your attorneys in preparation for 15 today? 16 A No. 17 Q In your preparations prior to today, 18 prior to this morning, did you review any 19 documents? 20 A Yes. 21 Q What documents did you review prior to 22 today? 23 MR. LANG: I'll instruct the witness 24 to only disclose that if the -- for 25 documents that refreshed your recollection.	Page 19 1 If any documents refreshed your 2 recollection, you can identify those. 3 Otherwise, it's privileged and on that 4 basis, I instruct you not to answer. 5 BY MR. LEN: 6 Q I don't want to know what you talked 7 about with your attorneys, just if you can 8 remember if any documents that you reviewed that 9 refreshed your recollection prior to today. 10 A I'm not sure what you mean by 11 refreshed my recollection. In what sense? I am 12 a little bit confused. 13 Q Anything that helped your memory as to 14 your testimony of what's in your declarations 15 that we're here to speak about today. 16 A Okay. So once again, I looked at the 17 IPRs themselves, I looked at my declarations, I 18 looked at the Patents '016, '539. I looked at 19 the Buchanan patent, the Senzaki patent, the Min 20 document, the Shin document. And then those are 21 the main ones. 22 Q So, Doctor, if I can direct your 23 attention to what should be marked as Exhibit 24 Number 2, which is your 662 '539 patent 25 declaration.
Page 20 1 A Okay. 2 Q More specifically, if I can direct 3 your attention to -- let's see here. Direct 4 your attention to Paragraph 79 on Page 38. Once 5 you're ready, Doctor. 6 A Yes. 7 Q You agree with me that the claims of 8 the -- strike that. 9 You agree with me that Claims 24, 26 10 and 29 of the '539 patent are clearly reciting 11 ALD process; is that correct? 12 MR. LANG: Objection, form. 13 THE WITNESS: May I have a copy of the 14 '539 patent, please? 15 MR. LEN: Doctor, I'm handing the 16 court reporter what will be marked as 17 Banerjee Exhibit Number 7, a copy of 18 U.S. Patent 6,969,539. The lower right-hand 19 corner it's marked as Micron Exhibit 1001. 20 (Exhibit 7 was marked.) 21 BY MR. LEN: 22 Q So just to circle back, your statement 23 in your declaration that these claims, Claim 24, 24 26 and 29 of the '539 patent, are clearly 25 reciting ALD. You agree with that; correct?	Page 21 1 A Yes. 2 Q Okay. If I can now turn your 3 attention to Exhibit Number 4 for the '016 4 patent. If I can direct your attention to 5 Paragraph 79 in that declaration as well. 6 A Yes, I see that. 7 Q You would agree with me that the 8 process recited in Claims 1 through 3 and 5 9 through 10 of the '016 patent is clearly 10 reciting ALD; correct? 11 A May I have a copy of the '016 patent, 12 please. 13 MR. LEN: Doctor, I'm going to hand to 14 the court reporter to be marked as Banerjee 15 Exhibit Number 8 is a copy of U.S. Patent 16 8,334,016. In the lower right-hand corner 17 it's also marked as Micron Exhibit 1001. 18 (Exhibit 8 was marked.) 19 BY MR. LEN: 20 Q After reviewing the '016 patent, 21 Doctor, do you agree with me that the Claims 1 22 through 3 -- the process recited in Claims 1 23 through 3 and 5 through 10 of the '016 patent 24 are clearly reciting ALD? 25 A Yes.

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Page 22 1 Q Doctor, Are you familiar with chemical 2 vapor deposition? 3 A Yes. 4 Q Are you comfortable with the 5 abbreviation CVD? 6 A Yes. 7 Q What is your general description of 8 CVD? 9 A I've been working on CVD for probably 10 over 30 years as part of my research. You 11 introduce multiple reactants into a reaction 12 chamber in which you place a substrate on which 13 you're trying to grow a film. 14 And as the term CVD implies, these 15 reactants or precursors that are introduced into 16 the reaction chamber undergo some sort of a 17 chemical reaction, perhaps partly in the gas 18 phase but also on the surface of the substrate. 19 The specific details depend on what kind of CV 20 reaction you're talking about. 21 Q In your answer about CVD, you 22 mentioned the chemical reaction that partly 23 could occur in the gas phase. 24 What do you mean when you say gas 25 phase reactions?	Page 23 1 A So typically these precursors or 2 reactants are flowed into the chamber and it's 3 easy to transport those reactants if they are in 4 a gas or vapor phase. 5 Now, typically you provide some sort 6 of energy to induce chemical reactions between 7 the molecules of the reactants that are 8 introduced into the chamber. For the sake of 9 simplicity, let's assume there's just two 10 reactants that are reacting. 11 So you introduce them into the CVD 12 chamber and by providing thermal energy or in 13 some cases plasma excitation if you're doing 14 plasma CVD, you induce some reactions between 15 the molecules of the two reactants in the gas 16 phase. That, by the way, is known as 17 homogeneous reaction. 18 But generally speaking, you don't want 19 the reaction -- for a well designed CVD process, 20 you don't want the reaction to go all the way to 21 completion in the gas phase. You want the 22 surface of the substrate to play a role also, 23 which then leads to the deposition of film on 24 the surface of the substrate. 25 Q Doctor, in your previous answer you
Page 24 1 mentioned that when you're introducing the 2 components into the chamber, you provide thermal 3 energy. 4 By thermal energy it could mean 5 heating the chamber; is that correct? 6 A Typically, yes. 7 Q And does CVD require introduction of 8 multiple components at the same time? 9 A Not necessarily. 10 Q So a single component could result in 11 the CVD reaction? 12 A In some cases, yes. 13 Q Doctor, do you agree that the -- do 14 you agree that the -- strike that. 15 You mentioned deposition on a film of 16 a surface as a result of a CVD reaction; 17 correct? 18 A Yes. 19 Q Are you comfortable characterizing 20 that deposition of a film as growth of the film? 21 A People use that term sometimes 22 interchangeably. 23 Q And do you agree that CVD growth of a 24 film is continuous as long as there is an 25 available supply of reactants into the chamber?	Page 25 1 MR. LANG: Objection, form. 2 THE WITNESS: It depends on what you 3 mean by "continuous." So in some cases, you 4 can have what's called an incubation period 5 or a nucleation period where initially there 6 is negligible growth and then the growth 7 starts. 8 But typically, as long as the 9 reactants are available in the chamber, the 10 growth will continue. So it's continuous in 11 that sense. 12 BY MR. LEN: 13 Q So, Doctor, changing gears, are you 14 familiar with atomic layer deposition? 15 A Yes. 16 Q And are you familiar with the 17 abbreviation ALD? 18 A Yes. 19 Q Okay. So it's okay if we use that 20 abbreviation today? 21 A Sure. 22 Q Okay. I guess to start, could you 23 give me your explanation of what ALD is? 24 A So an ALD, typically you have to have 25 two reactants which are introduced alternatively

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Page 26 1 into the reaction chamber. You flow in reactant 2 Number 1 and induce some sort of a chemical 3 reaction on the surface of the substrate. 4 And then you purge the reaction 5 chamber to remove the excess reactants and then 6 you flow reactant Number 2, have some suitable 7 reaction on the surface of the substrate. Then 8 you purge excess reactant two and you repeat the 9 cycle till you have the proper thickness of the 10 film deposited. 11 Q Isn't it true that ALD requires the 12 ability to adjust the deposition condition such 13 that the process can be made to be self 14 limiting? 15 MR. LANG: Objection to form and 16 relevance. 17 THE WITNESS: It depends on what you 18 mean by self limiting. 19 BY MR. LEN: 20 Q Well, let's turn to your declaration 21 for the 662 IPR, which is the '539 or Exhibit 1. 22 I'm sorry, Exhibit 2, I apologize. Exhibit 1 is 23 the IPR petition. 24 If I can direct your attention to 25 Paragraph 44 on Page 19 of your declaration.	Page 27 1 A Yes, I see that. 2 Q I think it's the third sentence down 3 in the middle of the paragraph, middle of the 4 page, starts with -- the sentence starts with: 5 By adjusting the deposition conditions. 6 Do you see that? 7 A Yes. 8 Q And it continues: Which is a routine 9 optimization process done in ALD. The 10 sequential surface reaction -- I apologize. 11 The sequential surface processes can 12 be made to be, quote, self controlling, end 13 quote, or, quote, self limiting, end quote, 14 meaning that the film growth does not continue 15 as a function of time or the availability of 16 precursor gas. 17 Do you see that? 18 A Yes. 19 Q So do you agree with the statement 20 that ALD requires the ability to adjust the 21 deposition conditions such that the process can 22 be made to be self limiting? 23 MR. LANG: Objection to form and 24 relevance. 25 THE WITNESS: ALD can be made self
Page 28 1 limiting, but it does not necessarily have 2 to be. 3 BY MR. LEN: 4 Q And you see right below that sentence 5 there's -- it continues on with a paren that 6 says: Describing self controlled processes in 7 the, quote, ALE window. 8 Do you see that? 9 A Yes. 10 Q Sorry. First, in your understanding, 11 is ALE and ALD used interchangeably? 12 A Yes. 13 Q Okay. So if I'm referring to an ALD 14 window, even though it says ALE window, you 15 understand they are the same? 16 A Yes. 17 Q So are you familiar with a concept of 18 an ALD window? 19 A Yes. 20 Q What is an ALD window? 21 A So when you optimize the ALD process, 22 one of the knobs you can adjust is the 23 temperature of the substrate. And the other one 24 is the precursor dose on the surface of the 25 substrate, the dose being the number of	Page 29 1 molecules impinging on the surface per unit 2 area. 3 So by ALE or ALD window, you're 4 talking about choosing substrate temperatures 5 and a dose where the growth may be self 6 limiting. 7 BY MR. LEN: 8 Q Within that window; correct? 9 A Within that window. 10 Q And within that window, the rate of 11 growth won't be dependent on the temperature; is 12 that correct? 13 MR. LANG: Objection to form. 14 THE WITNESS: The increase of the 15 thickness -- there would be no change of the 16 thickness because of -- in that growth cycle 17 as a function of temperature. 18 BY MR. LEN: 19 Q Within the window? 20 A Within the temperature window, yes. 21 Q So I think following up on what we 22 were just discussing, Doctor, if I can direct 23 your attention to Paragraph 46 of your 24 declaration. 25 A Okay.

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Page 30 1 Q So we were just discussing the ALD 2 window and the ability for a process to be self 3 limiting. Do you agree that's a key difference 4 between ALD and CVD? 5 MR. LANG: Objection to form. 6 THE WITNESS: Yes, that is one key 7 difference between ALD and CVD. 8 BY MR. LEN: 9 Q What are the other key differences 10 between ALD and CVD? 11 A Well, ALD in many cases gives you 12 better coverage over -- better step coverage 13 when you have topography on the surface, for 14 instance. 15 Q And why does ALD give better step 16 coverage? 17 A It can give better step coverage 18 because the ALD process is controlled by surface 19 reactions to a greater degree than many CVD 20 processes. CVD can also give you good step 21 coverage. It depends on the growth parameters 22 of CVD. 23 Q Are there any other differences 24 between self limiting and good step coverage 25 between CVD and ALD?	Page 31 1 A It all depends on the context. But in 2 many cases ALD processes can be run at lower 3 substrate temperatures than CVD. 4 Q Any other differences that you can 5 think of? 6 A Not off the top of my head. 7 Q Okay. So, Doctor, we were talking 8 about gas phase reactions and I think you 9 mentioned homogeneous reaction, nucleation 10 reactions. 11 Let me turn your attention to the 12 place in your declaration that you mention that, 13 Paragraph 59 on Page 27. 14 A Yes, I see that. 15 Q You talked about generally gas phase 16 reactions are not desirable I think before. 17 Is there -- strike that. 18 I guess generally is there a risk of 19 gas phase reactions in ALD? 20 A No. What we are talking about here is 21 various gas phase nucleation. There is a 22 difference. 23 So in CVD, you can have gas phase 24 reactions. But you don't want it to go all the 25 way to completion leading to the formation of
Page 32 1 the final product in the gas phase. That's 2 called gas phase homogeneous nucleation. So you 3 don't want a snowfall of these particles on the 4 film. 5 Q To create like a powder on the film? 6 A Exactly. 7 Q That wouldn't be considered a good 8 deposition film? 9 A Right. 10 Q Thinking about an ideal ALD process, I 11 think you have a good image here in your 12 declaration if we start around Paragraph 45. 13 And just before we do that, so the -- 14 isn't it true that the risk of gas phase 15 nucleation is reduced in ALD because the 16 reactants are introduced alternately? Is that 17 true? 18 A That's correct. 19 Q And you mentioned purging, that helps 20 it as well? 21 A Right. 22 Q So back to your example here in 23 Paragraph 45 on Page 20 of your declaration, 24 which is Exhibit Number 2, can you walk me 25 through the images here that you display in	Page 33 1 Paragraph 45? 2 A Sure. Here we're looking at ALD of 3 zinc sulfide and the two reactants in this case 4 are zinc chloride and hydrogen sulfide. 5 So the first step is you introduce 6 reactant Number 1, which is zinc chloride. And 7 as shown in the first figure labeled 1, it 8 chemisorbs or maybe physisorbs on the surface. 9 And it forms a monolayer or a fraction of a 10 monolayer. 11 And then you remove the excess zinc 12 chloride, you purge the chamber of the excess, 13 then you flow in reactant Number 2, which is 14 hydrogen sulfide, which reacts with the zinc 15 chloride, leading to the formation of zinc 16 sulfide, and HCL, which are actually two 17 molecules of HCL. You have to balance the 18 reaction. 19 You purge that out, leading to the 20 formation of a monolayer or a fraction of a 21 monolayer of zinc sulfide shown in step 4. 22 And then you repeat the process. So 23 you go back to step 1, you introduce zinc 24 chloride again and so on and so forth. 25 Q You mentioned I think in -- first in

Page 34 1 layer step 1, you mentioned chemisorb and 2 physisorb; is that correct? 3 A Yes. 4 Q What is the difference between 5 chemisorb and physisorb? 6 A So in chemisorption you're talking 7 about forming some sort of a chemical bond in 8 this case between the zinc chloride molecules 9 and on the surface. 10 Now, the very first step would be the 11 surface of the substrate that you're depositing 12 on, but once the reaction starts, the surface 13 would be zinc sulfide. 14 So in this case you're talking about 15 chemisorption, chemical bond formation between 16 zinc chloride molecules and zinc sulfide as a 17 reaction to seeds. On the other hand, when you 18 talk about physisorption, you are talking about 19 weaker bonding, things like Van Der Waals 20 interactions perhaps. 21 So you have this physical 22 physisorption between zinc dichloride and the 23 zinc sulfide in this case. Once again, the 24 details depend on what type of film and what 25 kind of chemistry you're looking at.	Page 35 1 Q When you get down to step 4, do you 2 agree that ideally as represented in this 3 simplified diagrams here that after a cycle, a 4 monolayer of growth is expected or monolayer of 5 deposition is expected? 6 MR. LANG: Objection to form. 7 THE WITNESS: Ideally you get a 8 monolayer, but in many cases you don't due 9 to what are called steric hindrances. 10 BY MR. LEN: 11 Q And I was going to direct you to that. 12 I think it's Paragraph 47 of your declaration. 13 A Yes, I see that. 14 Q So as you mentioned, steric 15 hinderance, you would agree that due to the 16 steric hindrance, you may get less than a 17 monolayer of growth during ALD; correct? 18 A That's correct. 19 Q Is there ever any cases where you 20 would get more than a monolayer of growth during 21 ALD? 22 A You could. That depends on the 23 details of the molecules that are being 24 absorbed. 25 Q For example, what type of details
Page 36 1 would it depend on? 2 A It will depend on the constitution of 3 the molecule and the ligands or the chemical 4 groups that are attached to the molecule. 5 Q You mentioned ligands that are 6 attached to the molecule. In your 7 understanding, what is a ligand? 8 A A ligand is a group of atoms that are 9 attached to another atom or group of atoms. 10 Q I am a mechanical engineer. Would it 11 be fair to call it like a building block of the 12 molecule? 13 A I like that terminology and I very 14 often think of organic chemistry as Lego 15 building blocks. So I think it's a good 16 analogy. 17 Q All right. So earlier, Doctor, we 18 were talking about the ALD window. Isn't it 19 true that in some cases precursors can be 20 alternately introduced into a reaction chamber, 21 but due to the process conditions, the process 22 would run as a CVD process instead of an ALD 23 process? 24 MR. LANG: Objection to form. 25 THE WITNESS: Could you repeat the	Page 37 1 question, please. 2 MR. LEN: I'll rephrase. 3 BY MR. LEN: 4 Q Doctor, we talked about the ALD 5 window. What happens in a process if you're 6 outside of the ALD window? 7 A Well, if you're outside of the window, 8 for instance, if you have higher substrate 9 temperatures, for example, you could certainly 10 have CVD processes taking over. 11 Q Okay. And what happens if you're 12 below the lower limit of the temperature in the 13 ALD window? 14 A Once again, you could have things like 15 perhaps condensation of the molecules. 16 Q Anything else? 17 A You can also get less growth than you 18 would get during when you're in the ALD window 19 because for chemical reactions, you often have 20 to overcome what's known as an activation 21 barrier. 22 So if you're below the ALD window in 23 terms of temperature, the molecules cannot have 24 enough thermal energy to go over the barrier and 25 that would preclude those chemical reactions on

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Page 38 1 the surface from happening. 2 Q So we just mentioned if we're in the 3 condition of being higher than the ALD 4 temperature window, that you could have the 5 condition of a CVD process taking over; is that 6 correct? 7 MR. LANG: Objection to form. 8 THE WITNESS: It depends on the 9 specifics. So if you're running an ALD 10 process, as I mentioned before, you 11 typically don't introduce all of the 12 reactants simultaneously. 13 BY MR. LEN: 14 Q Right. 15 A So then, if I'm running -- trying to 16 run an ALD process but I have exceeded the 17 temperature of the ALD window, that may lead to 18 the decomposition decision of that particular 19 reactant, but in general that will not lead to 20 the deposition of a film with the right chemical 21 composition or stoichiometry. 22 Q And you mentioned decomposition with 23 reactant. Are you familiar with the term 24 "thermal decomposition"? 25 A Yes.	Page 39 1 Q Is that what you're referring to in 2 your last answer? 3 A Yes. 4 Q And you mentioned that the 5 decomposition of the film will not lead to the 6 deposition of a film with the right chemical 7 composition. What did you mean by that? 8 A So hypothetically, if we go back to 9 the example shown in Paragraph 45 of my 10 declaration, and I'm flowing in the zinc 11 dichloride, but I'm operating at a temperature 12 higher than the ALD window, this is a 13 hypothetical -- I'm not sure exactly what the 14 chemical reactions would be in this case -- what 15 could happen is the zinc dichloride molecules 16 might decompose, leading to the deposition of a 17 film of zinc, which has a different composition 18 than the zinc sulfide in this case. 19 Q Following along that of the film with 20 a different chemical composition, is it 21 desirable to avoid thermal decomposition? 22 A It depends on what you mean by that. 23 It depends on the context. 24 Q Understood. Let me rephrase. 25 If your goal is to produce a
Page 40 1 particular film with a particular chemical 2 composition, it would follow that it's desirable 3 to avoid thermal decomposition which would -- as 4 you stated, would result in a different 5 composition; is that correct? 6 MR. LANG: Objection, form. 7 THE WITNESS: Are we talking about an 8 ALD process or CVD process? 9 BY MR. LEN: 10 Q We can start with an ALD process. 11 A If it's an ALD process that you're 12 after, you would not want such a high 13 temperature that you have a lot of thermal 14 decomposition that goes on. But in many 15 practical cases, a little bit of thermal 16 decomposition may be tolerable. 17 Q Understood. In going back to our 18 hypothetical discussing the ALD -- strike that. 19 So following up on our last 20 statements, are you familiar with the term 21 "thermal stability"? 22 A Yes. 23 Q And in the context of ALD precursors, 24 what is your understanding of thermal stability? 25 A So the precursors are stored in a	Page 41 1 chamber separate from the reaction chamber. In 2 some sort of a cylinder perhaps. You don't want 3 those precursor molecules to fall apart when 4 they are being stored in the storage chamber, 5 for example. That would be an example of how 6 thermal stability plays a role. 7 Q Does thermal stability also play a 8 role during deposition process? 9 A Yes. 10 Q Just thermal stability play a role in 11 whether or not thermal decomposition occurs? 12 A Yes. 13 Q What role does it play in whether or 14 not thermal decomposition occurs? 15 A So in general, as a molecule is more 16 and more thermally stable, it will be harder and 17 harder to thermally decompose it. 18 Q In your opinion, how is the thermal 19 stability of a molecule often reported? 20 A Well, in my lab we talk about it in 21 terms of, for example, the shelf life of the 22 molecule. You must notice, of course, that they 23 store the precursors in the storage chamber, 24 typically those would be at a lower temperature 25 than the reaction temperature.

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Page 42 1 Q Okay. And do you ever talk about 2 thermal stability in terms of melting points of 3 that molecule? 4 A I mean, if it's a solid precursor that 5 you're talking about, you talk about melting 6 point in that context. 7 Q Does boiling point of a molecule play 8 into the thermal stability? 9 A So in many cases the precursors are 10 liquids, say at ambient temperature, in that 11 case the boiling point plays a role, of course. 12 Q And so just to sum it up to come back, 13 you would agree that for hypothetical ideal ALD 14 process, it would be desirable for the precursor 15 to exhibit sufficient thermal stability to avoid 16 thermal decomposition during an ALD process; is 17 that correct? 18 MR. LANG: Objection to form. 19 THE WITNESS: You would want the 20 precursor molecule to have enough thermal 21 stability such that it does not degrade 22 under ambient temperature conditions, for 23 example, so that you have enough shelf life. 24 BY MR. LEN: 25 Q What about having enough thermal	Page 43 1 stability to not degrade under the ALD process 2 conditions and by -- let me rephrase. By 3 degrade, I mean enter into thermal 4 decomposition. 5 A Yes. I mean, you would want the 6 molecule to be sufficiently stable such that 7 there is not a whole lot of thermal 8 decomposition within that ALD window. 9 Q And typically during an ALD process, 10 the substrate would be at the same temperature 11 within the ALD window; is that correct? 12 A And the substrate temperature is what 13 you're talking about the ALD window? 14 Q Just to clarify. 15 A Yes. 16 Q All right. If we can direct your 17 attention to Paragraph 57 of Exhibit Number 2. 18 Are you ready? 19 A Yes. 20 Q So in this Paragraph 57, you identify 21 a number of different qualities that 22 characterize a desirable precursor for ALD; is 23 that correct? 24 A Yes. 25 Q If you see the third sentence in this
Page 44 1 paragraph you state: These include reactivity 2 towards surface ligands, thermal stability 3 against decomposition at ambient temperatures in 4 volatility within adequate the window between 5 vaporization temperature and decomposition 6 temperature. 7 Do you see that? 8 A Yes. 9 Q Let's walk through each one of these. 10 So the first desirable quality you 11 list is reactivity towards surface ligands. 12 Now, we mentioned surface ligands earlier as 13 these building blocks. 14 What exactly do you mean when you say 15 reactivity towards surface ligands? 16 A So in the example that we talked about 17 a few minutes earlier, talking about deposition 18 of zinc sulfide thin films, so at the end of the 19 cycle, suppose the top layer consists of sulfur 20 atoms. In this case when you then flow in zinc 21 chloride, you would be talking about the 22 reactivity of the zinc chloride molecules with 23 the surface sulfur atoms on the surface. 24 Q And every activity, then, is 25 particular to the chemistries of the molecules;	Page 45 1 is that correct? 2 A That's correct. 3 Q So for a person to design an ALD 4 process, it's important that they understand the 5 reactivities of the particular molecules; is 6 that correct? 7 MR. LANG: Objection, form. 8 THE WITNESS: Yes, you would have to 9 know what the chemistries are. 10 BY MR. LEN: 11 Q And then not only what the chemistries 12 are, but whether or not they're reactive with 13 each other; is that correct? 14 A That's part of the chemistry. 15 Q Okay. So to follow up with that, how 16 do you know if the precursors will be reactive 17 towards the surface ligands? 18 A Well, there is a lot of information 19 that you can glean, for example, from chemical 20 handbooks. For instance, there is a 21 CRC Handbook of Physics and Chemistry that I 22 have had for 30 years, which lists, for 23 instance, chemical bond strengths between 24 different atoms. 25 So you could look at that as an

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Page 46 1 initial guide in terms of, you know, which 2 reactions are likely to happen as a starting 3 point. 4 Q And so if the CRC Handbook is a good 5 place as a starting point, are there any other 6 ways that you know whether the precursors will 7 be reactive with the surface ligands? 8 A There are many other sources of 9 information, of course. I often look at Google 10 or Wikipedia. There is an enormous amount of 11 chemical information that's readily available 12 these days. 13 Q And an example of information that 14 would be available on Google or Wikipedia, that 15 would be someone actually tested the reactivity 16 of the two chemicals together, is that what 17 would have happened? 18 A In many cases, yes. 19 Q So if the first part is that the 20 chemicals would be reactive, then by nature, as 21 part of the reaction, there will be something 22 left over after the reaction. 23 How would you know what part of the 24 ligand or which ligand would be left on the 25 surface following the reaction?	Page 47 1 MR DEFENSE: Objection to form. 2 THE WITNESS: So typically, when you 3 look at this bond strength between the 4 different molecules, the weaker bonds would 5 tend to break apart more easily than 6 stronger chemical bonds. 7 So that would be the first thing they 8 would want to look at. 9 BY MR. LEN: 10 Q Is there anything else you would want 11 to look at to try to determine which ligands 12 would be left on the surface? 13 A That would depend on the details of 14 the chemistry that you're looking at. 15 So you used the analogy of building 16 blocks earlier on. So you want to look at the 17 structure of the molecule, for example, to see 18 when you absorb these molecules on the surface, 19 you know, what sort of bonds are likely to form. 20 And then what chemical groups or ligands might 21 cleave off. 22 MR. LANG: When we get to stopping 23 point. 24 MR. LEN: Absolutely. Let's just do 25 one more question.
Page 48 1 BY MR. LEN: 2 Q Okay. So just following up, we talked 3 last just about the structure of the molecule, 4 but prior to that we talked about the bond 5 strength and that the weak bonds might be broken 6 first. 7 How would one of skill in the art know 8 whether the strong bonds are also broken? 9 A I mean, it would depend on the 10 relative bond strength. So if the stronger 11 bonds were only slightly stronger than the 12 weaker bonds, then there will probably be a 13 competition where both sets of bonds break to a 14 certain degree. 15 How much breakage there is of the 16 bonds would obviously also depend on the 17 temperature. 18 Q Right. 19 A In fact, most of these chemical 20 reactions have a -- many of these chemical 21 reactions have an exponential dependence on 22 temperature that's known as the Arrhenius 23 dependence where these bond strengths relate to 24 what is known as the activation energy of the 25 process.	Page 49 1 Q Would the ratio of the breakage of the 2 weak bonds to the strong bonds depend on 3 anything else beyond the temperature dependence? 4 A The temperature would be one of the 5 main parameters. There may be other things 6 depending on the specifics of the reaction that 7 you're looking at. 8 Q Is the breakage of the weak bonds and 9 the strong bonds, is that easily predictable? 10 MR. LANG: Objection, form. 11 THE WITNESS: As I told you, there are 12 many chemical handbooks where you can look 13 up chemical bond strengths. And a lot of 14 these have been measured experimentally. 15 But it uses powerful theoretical 16 techniques also that might reduce it also 17 where you can calculate these bonds using 18 quantum chemistry, the standard software 19 that people use to calculate these. 20 BY MR. LEN: 21 Q And to your knowledge, did that 22 standard software exist in the time frame of 23 2000 to 2001? 24 A Yes, I believe so, yes. These are 25 techniques known as density functional theory

Page 50 1 that my group uses and many chemists use -- and 2 many other groups use as one example. 3 Q And that theory is supported often 4 with actual testing; is that true? 5 A You always would like to correlate 6 thermal activity with external data, yes. 7 Q In fact, the theories have greatly 8 improved since the time frame of 2001 until now; 9 is that true? 10 MR. LANG: Objection, form. 11 THE WITNESS: It depends on exactly 12 what you are talking about. 13 BY MR. LEN: 14 Q They fit the actual data better now? 15 MR. LANG: Objection to form. 16 THE WITNESS: In a broad sense, yes. 17 But it all depends on the specifics. 18 MR. LEN: So I think now is a good 19 time to go off the record and take a break. 20 (Recess taken.) 21 THE COURT: 22 MR. LEN: We're back on the record. 23 Welcome back, Doctor. 24 THE WITNESS: Thank you. 25	Page 51 1 BY MR. LEN: 2 Q Right before we left, we were talking 3 about your Paragraph 57 in your declaration for 4 the '539 patent which is in support of the 662 5 IPR petition. And specifically Paragraph 57 6 mentions some desirable qualities for precursors 7 for ALD. 8 We were discussing the reactivity 9 towards surface ligands before we left, but now 10 I would like to pick back up on the second 11 quality in that list in Paragraph 57, which is 12 thermal stability against decomposition at 13 ambient temperatures. 14 Can you tell me a little bit about 15 what you mean by that? 16 A Sure. So you store the precursors in 17 a cylinder, perhaps, and that's generally going 18 to be kept at room temperature in most cases. 19 So that's what I meant by ambient temperatures. 20 But in some cases, if a precursor is 21 very unstable, people might cool the storage 22 chamber down to make sure it does not thermally 23 decompose while it's being stored. 24 Q So is it fair to say that thermal 25 stability is desirable in ALD precursors?
Page 52 1 A I mean, in terms of the shelf life of 2 the precursor, yes. You don't want it to fall 3 apart while it's being stored. 4 Q Similarly, you don't want it to 5 thermally decompose in an ALD process; correct? 6 MR. LANG: Objection to form. 7 THE WITNESS: It depends on the 8 specifics, but in general, yes. 9 BY MR. LEN: 10 Q And if we move on to your next 11 characteristic is volatility with an adequate 12 window between vaporization temperature and 13 decomposition temperature. 14 Can you tell me a little bit about 15 that? 16 A Sure. So you have to transport vapors 17 of the precursor from the storage chamber into 18 the reaction chamber where the substrate is. 19 So what that means is you have to have 20 enough vapor pressure so that the vapors can be 21 transported at perhaps the ambient temperature 22 or maybe at a somewhat higher temperature. But 23 the temperature at which you have enough vapor 24 pressure to transport vapors of the reactant 25 should not at the same time cause those	Page 53 1 precursor molecules to fall apart. That's what 2 I mean by the temperature window. 3 Q Doctor, can an ALD process be run with 4 a precursor that does not possess these 5 qualities as noted here in Paragraph 57? 6 MR. LANG: Objection to form. 7 THE WITNESS: These are desirable 8 attributes for ALD. I mean, you would have 9 to show me a specific example to comment on 10 that further. 11 BY MR. LEN: 12 Q But if we just -- let's just focus on 13 your last desirable quality. If the precursor 14 does not have adequate volatility within the 15 window between vaporization and decomposition, 16 can you run ALD in that instance? 17 MR. LANG: Objection to form. 18 THE WITNESS: Once again, it would 19 depend on the specifics, but in general, I 20 agree with the statement that you do need 21 suitable temperature window between the 22 vaporization temperature and the 23 decomposition temperature of the molecules. 24 BY MR. LEN: 25 Q If the precursor does not have

Page 54 1 adequate reactivity towards the surface ligands, 2 is it possible to run an ALD process? 3 MR. LANG: Objection to form. 4 THE WITNESS: I mean, in general you 5 would want it to be chemically reactive so 6 that you have chemisorption. But in some 7 cases I believe you could alternatively have 8 physisorption that I mentioned earlier on 9 due to weaker Van Der Waals interactions 10 between the molecules. 11 BY MR. LEN: 12 Q Are the weaker Van Der Waals 13 interactions due to -- for the physisorption 14 more prone to desorbing off the surface? 15 A In general that's true because those 16 bonds are weaker. 17 Q And that would affect the thickness of 18 the deposited layer; true? 19 A Yes, typically you won't get as much 20 coverage on the surface. 21 Q Would that affect the step coverage 22 too? 23 A Offhand I cannot think of a reason why 24 it would. But you could give me specific 25 examples.	Page 55 1 Q Just to clarify your previous answer, 2 we indicated that desorption could affect the 3 deposited layer. And your answer was yes, 4 typically you can't get as much coverage on the 5 surface or you can get as much coverage on the 6 surface? 7 A What I meant was if you have weak 8 physisorption, the physisorbed molecules might 9 be more prone to reabsorption from the surface 10 also. 11 Q Right. 12 A So you would not get as much coverage 13 on the surface if some of the molecules 14 desorbed. 15 Q And then finally, just to close it 16 off, isn't it true that without thermal 17 stability, that you're not able to run an ALD 18 process; is that true? 19 A I mean, you want the molecules to be 20 sufficiently thermally stable such that as it's 21 being stored, it does not degrade the 22 composition in the storage chamber. 23 Q And also similarly, you would want to 24 have enough thermal stability such that it would 25 not unnecessarily thermal decompose during the
Page 56 1 ALD process; is that true? 2 MR. LANG: Objection to form. 3 THE WITNESS: You want enough thermal 4 stability where you don't get a lot of 5 thermal decomposition within the ALD window. 6 BY MR. LEN: 7 Q We've been discussing kind of desired 8 or qualities that we would want for an ALD 9 process. It also follows that there is a 10 certain minimum required or needed for the ALD 11 process to successfully operate; is that true? 12 A I'm not sure what you mean by minimum. 13 Q That's fine. Rephrase. 14 Your last answer we were talking about 15 you want enough thermal stability where you 16 don't get a lot of thermal decomposition within 17 the window. I was just trying to clarify, you 18 were describing it as a desire or want that 19 there is -- you would need a certain minimum 20 thermal stability in order to have a successful 21 ALD process; true? 22 MR. LANG: Objection, form. 23 THE WITNESS: Minimum defined as in, 24 you know, how much of a shelf life you would 25 want. Exactly what that number is, you	Page 57 1 know, it would depend on the manufacturer, 2 for example, and many other parameters. 3 BY MR. LEN: 4 Q Are there any other qualities that are 5 desirable for ALD precursors beyond the ones 6 that are listed here in Paragraph 57? 7 A I mean, you would not want precursors 8 which might introduce contaminants which could 9 degrade the film that you're depositing. 10 So in the example that I cited where 11 you use chlorine based precursors, in some 12 circumstances, residual chlorine in the film 13 might end up causing corrosion, for instance. 14 So that would not be a desirable thing. 15 Q Are there any other desirable 16 characteristics? 17 A Desirable characteristics in terms of 18 what again? 19 Q For ALD precursors as we were 20 discussing in the context of Paragraph 57. 21 A Sure. I mean, ideally you want to 22 avoid precursors which may be highly toxic, for 23 instance, is one instance, if possible. 24 Q Just to clarify, when you say highly 25 toxic, would you include highly radioactive

Page 58 1 precursors? Would you want to avoid that as 2 well? 3 A Yes. 4 Q Doctor, if I can have you turn to 5 Page 45 in your declaration of the '539 patent. 6 MR. LEN: While you do that, I'm going 7 to hand the court reporter what will be 8 marked as Exhibit 9. Banerjee Exhibit 9 is 9 U.S. Patent Number 6,984,591 and it's marked 10 on the lower right-hand corner as Micron 11 Exhibit 1005. 12 (Exhibit 9 was marked.) 13 THE WITNESS: Yes. 14 BY MR. LEN: 15 Q Do you recognize Exhibit Number 9, 16 Doctor? 17 A Yes. 18 Q What is it? 19 A It's a patent by Buchanan. 20 Q Is that the same patent by Buchanan 21 that's referenced on Page 45 of your 22 declaration? 23 A Yes. 24 Q If we turn to the first page of 25 Buchanan patent Exhibit Number 9, do you agree	Page 59 1 with me that Buchanan generally is directed to 2 the use of precursor source mixture useful for 3 CVD or ALD of a film? 4 A Yes. 5 Q Doctor, you studied the Buchanan 6 patent in connection with your analysis as 7 represented in your declaration; true? 8 A Yes. 9 Q And as part of that study, you read 10 through the Buchanan patent; is that true? 11 A Yes. 12 Q Doctor, do you know, how many 13 precursor source mixtures does Buchanan 14 disclose? 15 A I don't know the exact number, but 16 quite a few. 17 Q And without speculating, when you say 18 quite a few, does that mean more than 100? 19 A If we look at the various permutations 20 and combinations, probably. 21 Q And does -- looking at the various 22 permutations and combinations, is that more than 23 1,000? 24 MR. LANG: Objection to form. 25 THE WITNESS: I don't know. I have
Page 60 1 not done a count. 2 BY MR. LEN: 3 Q Okay. If I can direct your attention, 4 Doctor, are you familiar -- well, first, are you 5 comfortable when we talk about that and the 6 column and line numbers, column being the number 7 at the top of the column? 8 A Yes. 9 Q To navigate here. We can direct our 10 attention to, let's see, Column 4 towards the 11 top of that column. 12 Do you see where it states that: This 13 invention comprises at least one precursor 14 composed of an element collected from the group 15 consisting of. 16 Do you see that? 17 A Which line? 18 Q Sorry. Line starting 2 and line 3 on 19 Column 4. 20 A Yes, I see that. 21 Q Okay. Then you see right after it 22 says, "composed of an element selected from the 23 group consisting of," it lists a number of 24 elements. 25 Do you see that?	Page 61 1 A Yes. 2 Q Okay. Without having to count them up 3 at the moment, I'll represent for you that it's 4 50 elements there in that list. 5 Does that sound about right? 6 A Sounds too many, but I'll take your 7 word for it. 8 Q Okay. It continues on, after Line 7 9 it states: To which is bound at least one 10 ligand selected from the group consisting of. 11 Do you see that? 12 A Yes. 13 Q And that ligand, that's the same 14 ligand we have been talking about earlier in 15 terms of building blocks; correct? 16 A Yes. 17 Q Do you know how many ligands are in 18 that group? 19 A I have not counted. 20 MR. LEN: I'll represent for the 21 record it's 20. 22 THE WITNESS: Okay. 23 BY MR. LEN: 24 Q And then following on after 25 approximately Line 12 after that list, you see

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HARVARD Ex. 2121 p. 16
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Page 62 1 it states: Which is dissolved, emulsified or 2 suspended in an inert liquid selected from the 3 group consisting of. 4 Do you see that? 5 A Yes. 6 Q And then it goes on to list the inert 7 liquids; is that true? 8 A Yes. 9 Q Then finally, approximately Line 18, 10 the last sentence of that paragraph it states: 11 The precursor source mixture may be a solution, 12 emulsion or suspension and may consist of a 13 mixture of solid, liquid and gas phases which 14 are distributed throughout the mixture. 15 Do you see that? 16 A Yes. 17 Q So just breaking this down, we've 18 looked at the elements first and then we looked 19 at the ligands. If we just take the first 20 ligand, what is a hydride ligand? 21 A It's a hydrogen containing group. 22 Q What is an alkyl ligand? 23 A This would be like methyl or ethyl 24 groups. 25 Q And I might pronounce this wrong, but	Page 63 1 alkene? 2 A Alkyne. 3 Q Alkyne is the third number in that 4 list. What is that? 5 A These are all hydrocarbons. 6 Q And so we just looked at these 7 three -- first three ligands in this group. Are 8 there different types of hydride ligands? 9 A Yes. 10 Q Would it be fair to say that there's 11 multiple permutations of hydride ligands 12 possible? 13 A There's several, yes. 14 Q How many, do you know? 15 A It depends on what it's attached to, 16 but it could have monohydrides or dihydrides. 17 Q Okay. You mentioned monohydrides and 18 dihydrides. Would there be multiple different 19 types of monohydrides? 20 A You would have to show me some of the 21 molecules that you are talking about. Mono 22 means one hydrogen, di means two, so on and so 23 forth. 24 Q Just in terms of the ligands, are 25 there multiple different types of monohydride
Page 64 1 ligands? 2 A Offhand I couldn't tell you. You have 3 to show me specific molecules. 4 Q Just to follow up, are there multiple 5 different types of dihydride ligands? 6 A Once again, I could not tell you. 7 Dihydride, like I said, is two hydrogens stuck 8 together. You would have to show me a specific 9 formula. 10 Q So you mentioned formula. So let's 11 turn to the next page in Buchanan, which is 12 Column 5. If you look midway down Column 5 13 around Line 45, do you see a generalized formula 14 for the precursor there? 15 A Yes. 16 Q Can you explain to me what that is? 17 A It shows M is one of the elements from 18 the list starting Line 46 or so, I guess. And 19 then R1 and R2, they say it could be the same or 20 different ligands from the group consisting of 21 alkyls, for example. 22 And then A is an optional coordinate, 23 it could be bound or associated ligands from the 24 phosphine group, phosphides. A means -- A 25 referring to nitrogen and so on and so forth.	Page 65 1 Q And Buchanan is using this generalized 2 formula to describe its list of precursors; is 3 that true? 4 A Yes. 5 Q It's your opinion that each of these 6 precursors describe this generalized formula as 7 suitable for both CVD and ALD; true? 8 A Yes, in general. 9 Q And when you say in general, what do 10 you mean by that? 11 A I mean when you talk about CVD or ALD 12 processes, you cannot divorce the molecule from 13 the deposition conditions. So you would have to 14 choose appropriate substrate temperature, for 15 instance. 16 Q And that appropriate substrate 17 temperature you just mentioned, that would 18 relate to the ALD window we talked about 19 earlier; true? 20 A Yes, in the context of ALD, yes. 21 Q And so if you're outside of the ALD 22 window, it would not be appropriate for ALD; is 23 that true? 24 MR. LANG: Objection to form. 25 THE WITNESS: It would depend on the

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Page 66 1 specifics. 2 I mean, ideally you would want to 3 operate within the ALD window, but depending 4 on the circumstance, you might be able to 5 deviate from that window a little bit. It 6 all depends on the context in the 7 application. 8 BY MR. LEN: 9 Q But you still agree, as you stated 10 earlier, you still have to choose an appropriate 11 substrate temperature; is that correct? 12 A Yes. What I said was when I talk 13 about CVD or ALD processes, you have to choose 14 the precursor in concert with the deposition 15 conditions such as substrate temperature. 16 Q You cannot divorce those two? 17 A You generally cannot, no. 18 Q Okay. And so if you don't know the 19 process conditions, is it possible to say that a 20 precursor can work for both CVD and ALD? 21 MR. LANG: Objection to form. 22 THE WITNESS: ALD is a subset of CVD, 23 so in many cases, precursors that are 24 suitable for CVD are also suitable for ALD. 25 But once again, the devil -- the	Page 67 1 details, you have to look at specifics. But 2 a lot of CVD precursors can be suitable for 3 ALD. 4 BY MR. LEN: 5 Q But not all; is that correct? 6 A Yes, there can be some where CVD 7 precursors may not work for ALD, that's correct. 8 Q Without knowing the process 9 conditions, you would not be able to know if the 10 CVD precursor would work for ALD; isn't that 11 true? 12 MR. LANG: Objection to form. 13 THE WITNESS: I mean, as I told you 14 before, you have to look at the precursor 15 molecules in concert with the process 16 conditions -- 17 BY MR. LEN: 18 Q Right. 19 A -- to determine if it's suitable for 20 CVD or ALD. 21 Q But it's your opinion that each of the 22 precursors disclosed by Buchanan with its 23 generalized formula is suitable for ALD; is that 24 correct? 25 A In general, the precursors with this
Page 68 1 generic formula are suitable for CVD or ALD. 2 Q And as we discussed before, in general 3 means that there are contexts which some are not 4 suitable for ALD and CVD; is that correct? 5 A I mean, there could be some specific 6 molecules which may not be suitable for one or 7 the other. 8 Q I think I know the answer to this 9 based on our discussion. How would you know if 10 one is not suitable for one or the other? 11 MR. LANG: Objection to form. 12 THE WITNESS: Well, one knows in 13 general what the desirable attributes for 14 ALD are, as we discussed some time back, 15 right. 16 And you could look at some of these 17 handbooks or sources such as Google or 18 Wikipedia or I believe the university has 19 access to something called the Web of 20 Science. That's one example where you can 21 look at technical literature. 22 So there is a lot of information out 23 there about, for instance, these chemical 24 bond strengths that we talked about earlier, 25 right? And you could use these as an	Page 69 1 initial guide to try to figure out which 2 precursors might be suitable for certain 3 processes. 4 BY MR. LEN: 5 Q But that information you just 6 mentioned, those handbooks and Wikipedia and 7 Google, that's -- none of that is disclosed in 8 Buchanan; is that correct? 9 MR. LANG: Objection to form. 10 THE WITNESS: These are things that a 11 person of ordinary skill in my opinion would 12 be familiar with. 13 BY MR. LEN: 14 Q And so a person of ordinary skill 15 would know that in general, not all of the 16 precursors disclosed in Buchanan work for both 17 CVD and ALD; is that true? 18 MR. LANG: Objection to form. 19 THE WITNESS: It all depends on the 20 specifics and the context, of course. 21 BY MR. LEN: 22 Q I apologize. 23 A So there could be a few outliers in 24 the list of these precursor molecules discussed 25 in Buchanan that may not work for one or the

Page 70 1 other. 2 Q And that depends on the process 3 conditions, as we discussed earlier; correct? 4 MR. LANG: Objection, form. 5 THE WITNESS: I mean, when you design 6 a CVD or ALD process, as I mentioned before, 7 you have the molecules, the precursor 8 molecules working in concert with the 9 process foundations, yes. 10 BY MR. LEN: 11 Q So starting with -- if we can look at 12 a subset of some of the precursors discussed in 13 Buchanan, I would like to direct your attention 14 I think to the bottom of Column 5 in Buchanan. 15 There's -- the very last full sentence 16 starting on Line 66, do you see that? 17 It states: The preferred precursors 18 of the present invention are compounds which are 19 readily vaporized. 20 Do you see that? 21 A Yes. 22 Q Do you know, just off the top of your 23 head, if Buchanan gives any further description 24 of what is required to give preferred precursor? 25 A This is certainly one of the	Page 71 1 attributes. I don't recall if Buchanan 2 explicitly talks about some of the other 3 desirable attributes. If you point me to a 4 section, I can certainly look at it. 5 Q That's okay. If we look at the list 6 of Buchanan preferred precursors, if you look at 7 Column 6, do you agree that Column 6 is a list 8 of preferred precursors according to Buchanan? 9 A Yes. 10 Q And in fact, if we continue on through 11 Buchanan, starting in Column 8, Buchanan lists 12 several different categories of preferred 13 precursors, is that correct, one of which is 14 shown in Column 8? 15 A Yes. 16 Q And a preferred precursor category is 17 hydride containing compounds in Column A; is 18 that correct? 19 A Yes. 20 Q And in fact, if we go through -- 21 return to Column 9, there's preferred precursor 22 mixtures for alkyl-containing compounds; is that 23 correct? 24 A Yes. 25 Q Similarly, Column 11, preferred
Page 72 1 mixtures for alkenyl-containing compounds; 2 correct? 3 A Yes. 4 Q Column 12 is preferred source mixtures 5 for carbonyl-containing compounds; true? 6 A Yes. 7 Q Column 13 is preferred mixtures for 8 alkoxy-containing compounds; is that true? 9 A Yes. 10 Q Column 14 lists preferred mixtures for 11 amino-containing compounds; true? 12 A Yes. 13 Q Column 15 lists preferred mixtures for 14 phosphido-containing compounds; is that true? 15 A Yes. 16 Q Column 16 is precursor source mixtures 17 for nitrate-containing compounds; true? 18 A Yes. 19 Q Column 17 lists precursor source 20 mixtures for preferred silyl-containing 21 compounds; is that true? 22 A Yes. 23 Q So all told, if we count those up, 24 that's ten categories of preferred precursors; 25 correct?	Page 73 1 A I haven't done the count, but I'll 2 take your word for it. 3 Q Within those categories of preferred 4 precursors, isn't it true that Buchanan 5 identifies some highly preferred precursors? 6 A Yes. 7 Q In your review of Buchanan, did 8 Buchanan ever state why those precursors are 9 highly preferred? 10 If I can direct your attention to 11 Column 9 for the hydrides, line approximately 12 33, there's highly preferred mixtures, I 13 apologize, for alkyls. 14 A Yes, I see that. 15 Q But there is no description of why 16 these precursors are highly preferred, is there? 17 A Well, a person of ordinary skill would 18 know what some of the attractive attributes of 19 ALD precursors are, for instance, as we 20 discussed earlier. 21 And then as I mentioned, if we look at 22 the list of highly preferred precursors that 23 Buchanan talks about, it would be quite 24 straightforward in my opinion to, you know, look 25 up in standard handbooks or some of the other

Page 74 1 sources that I mentioned, for instance, what 2 some of these chemical bond strengths are. 3 That would give a person of ordinary 4 skill a very good start in terms of choosing a 5 precursor for a particular ALD process, for 6 instance. 7 Q As you mentioned before, a person of 8 ordinary skill would know that you cannot 9 divorce the ALD precursor molecule for the 10 process conditions it's going to be run at; is 11 that true? 12 A True. I mean, to design an ALD 13 process, you have to choose a precursor and the 14 ALD deposition conditions, yes. 15 Q And similarly, a person of ordinary 16 skill would know in general not all CVD 17 precursors work for ALD; is that true? 18 MR. LANG: Objection form. 19 THE WITNESS: Not all CVD precursors 20 may work for ALD, but because ALD is a 21 subset of CVD, looking at CVD precursors is 22 an excellent starting point in my opinion 23 for searching for ALD precursors. 24 BY MR. LEN: 25 Q Doctor, if we can turn your attention	Page 75 1 back to Buchanan. 2 And you were looking at your 3 declaration before, but if we can turn back to 4 Buchanan to Column 12. If I can direct your 5 attention to the top of Column 12, I think 6 that's one of the subsets of preferred 7 precursors we mentioned earlier, which is 8 precursor source mixtures for 9 carbonyl-containing compounds around Line 6. 10 Do you see that? 11 A Yes. 12 Q Are you familiar with metal carbonyl 13 compounds? 14 A I haven't worked with those. I'm 15 worked with the amides myself. 16 Q Are you familiar with the use of 17 medical carbonyl compounds in ALD? 18 A In my own research I haven't used 19 those. 20 Q So off the top of your head, are you 21 familiar with any examples of metal carbonyls 22 being used in ALD? 23 A There's many ALD processes in the 24 literature. Off the top of my head, I couldn't 25 at this point.
Page 76 1 Q If I can direct your attention now, 2 Doctor, to Column 21 of the Buchanan patent. At 3 the top, Line 4, Column 21 is Example 4. 4 Do you see that? 5 A Yes. 6 Q The example is entitled "Deposition of 7 a Metal Silicide Film in an Atomic Layer 8 Deposition Reactor Utilizing a Precursor Source 9 Mixture." 10 Do you see that? 11 A Yes. 12 MR. LANG: Real quick, Greg, I'm 13 trying to figure something out. I don't see 14 you as counsel of record on these. 15 MR. LEN: Do you want to go off the 16 record? 17 MR. LANG: Yes. 18 MR. LEN: Going off the record. 19 (Recess taken.) 20 BY MR. LEN: 21 Q Go back on the record. Welcome back, 22 Doctor. 23 A Thank you. 24 Q Right before we went off the record, I 25 think we were directing your attention to the	Page 77 1 Buchanan patent, the top at Column 21, 2 Example 4. 3 Do you see that? 4 A Yes. 5 Q At the bottom of the first paragraph, 6 the last sentence says -- around Line 15, it 7 says: In this example, silane is used as the 8 silyating agent and hydrogen as the reactant. 9 Do you see that? 10 A Yes. 11 Q And following below that, the first 12 sentence of the next paragraph states: The 13 cobalt-containing precursor source mixture is 14 comprised of 50 grams of CO subscript 2, paren, 15 CO, closed paren, subscript 8 and a liter of 16 pentane. 17 Do you see that? 18 A Yes. 19 Q Is that -- the chemical formula that I 20 just recited, CO₂, paren, CO, closed paren, 8, 21 do you know what that stands for? 22 A I believe it's one of the carbonyls. 23 Q It's cobalt carbonyl; is that true? 24 A Yes. 25 Q If we can look back to where we were

20 (Pages 74 to 77)

Page 78 1 at Column 12, I think there is -- I think we 2 were looking at the list of precursor source 3 mixtures for carbonyl-containing compounds? 4 A Yes. 5 Q If we look down Line 56 or 57, you see 6 the highly preferred precursor source mixtures 7 comprise? 8 A Okay. 9 Q And the third one in that list of 10 carbonyl-containing precursors is the CO₂, 11 paren, CO, closed paren, 8. Is that cobalt 12 carbonyl? 13 A Yes. 14 Q So that's a preferred precursor 15 according to Buchanan; correct? 16 A It's a highly preferred precursor. 17 Q Highly preferred precursor. Do you 18 know, is that highly preferred for CVD or ALD? 19 A In general in Buchanan they talk about 20 highly preferred for both CVD and ALD with the 21 caveat that you choose appropriate deposition 22 conditions. 23 Q So in general, if you don't choose 24 appropriate deposition conditions, it wouldn't 25 be appropriate for ALD; is that correct?	Page 79 1 MR. LANG: Objection to form. 2 THE WITNESS: You can always choose 3 the wrong deposition conditions and the 4 process would not work. 5 BY MR. LEN: 6 Q So if you would direct your attention 7 back to Column 21 of Buchanan. Approximately 8 Line 22, first sentence of that paragraph 9 states: The precursor source mixtures are 10 vaporized at 40 degrees to 260 degrees C, 11 preferably 40 degrees through 180 C. 12 Do you see that? 13 A Yes. 14 Q And it follows on: The substrate 15 temperature is about 100 degrees through 1200 16 degrees C and preferably 200 degrees to 17 800 degrees C. 18 Do you see that? 19 A Yes. 20 Q Do you know what the thermal 21 decomposition of thermal carbonyl is? 22 A Not off the top of my head. 23 Q As you mentioned before, you would 24 look at some of these handbooks typically; 25 correct?
Page 80 1 A Yes. 2 MR. LEN: Doctor, I'll hand to the 3 court reporter what will be marked by the 4 court reporter as Banerjee Exhibit 5 Number 10, a document that is a photocopy of 6 a textbook. The title is Organic Synthesis 7 Via Metal Carbonyls, Volume 1, Irving Wender 8 and Piero Pino as editors. 9 (Exhibits 10 and 11 were marked.) 10 MR. LEN: While you're looking at 11 that, I'm handing to the court reporter a 12 photocopy of a textbook with the title on 13 its first page The Chemistry of Metal CVD by 14 T. Kodas and M. Hampden-Smith. 15 This textbook has a copyright date of 16 1994. 17 MR. LANG: I'll object to Exhibits 9 18 and 10 on foundation and completeness and 19 relevance for now. 20 MR. LEN: I think you meant 10 and 11. 21 MR. LANG: Thank you. 10 and 11. 22 BY MR. LEN: 23 Q So, Doctor, if I can direct your 24 attention Exhibit 10, which was Organic 25 Synthesis Via Metal Carbonyls. If I can direct	Page 81 1 your attention to photocopied Page 39, Table 1. 2 A Excuse me. Have I reviewed this 3 document or cited it in my declaration? I don't 4 recall it. 5 Q You don't know? 6 A I don't recall. 7 Q You mentioned you would go to chemical 8 handbooks, is that correct, to find out the 9 thermal decomposition temperature of cobalt 10 carbonyl? 11 A In general, yes. And there's many 12 handbooks, of course. 13 Q So I would like to direct your 14 attention to Table 1 on Page 39 of this 15 photocopy. This states: Selected physical data 16 of medical carbonyls. 17 Do you see that? 18 A Yes. 19 Q If you look midway down the table, do 20 you see the entry that's CO₂, paren, CO, closed 21 paren, 8? 22 A Yes. 23 Q Is that the cobalt carbonyl we were 24 discussing earlier? 25 A Yes.

21 (Pages 78 to 81)

Page 82 1 Q And you see the second column states 2 color, it's orange. 3 Do you see that? 4 A Yes. 5 Q The third column is labeled MP, paren, 6 degree C, closed paren. 7 Do you see that? 8 A Yes. 9 Q What does that stand for? 10 A I assume that's the melting point, but 11 I'm not sure. Can I review the document? 12 Q If I can direct your attention, 13 though, back to the cobalt carbonyl line in that 14 column. Do you see where it states 51 to 52 15 DEC? Do you see that? 16 A Yes. 17 Q In your understanding, does that mean 18 that the decomposition temperature is 51 to 19 52 degrees C? 20 A I don't recall this document, so I 21 have to review cobalt carbonyl. Could you point 22 me to the document where it describes -- where 23 where it defines DEC? 24 Q Is it your understanding that DEC 25 could mean decompose?	Page 83 1 MR. LANG: I'll object again to this 2 line of testimony. I guess it's a form 3 objection, but it's based on the 4 completeness of the document. 5 BY MR. LEN: 6 Q Doctor, in your opinion, would a 7 person of ordinary skill in the art be able to 8 read Table 1? 9 A If he or she had the complete 10 handbook, yes. 11 Q And you, in fact, have complete 12 handbooks in your office; is that true? 13 A I have the CRC Handbook, for instance. 14 Q Let's try Exhibit 11, which is a 15 little bit thicker of an exhibit. If I can 16 direct your attention to what's labeled in the 17 upper left-hand corner as Page 378 of this 18 exhibit. 19 Do you see where it says Metal 20 Carbonyls there? 21 A Yes. 22 Q Below that there's Table 8-8, 23 properties of metal carbonyls and carbonyl 24 halides. Do you see that? 25 A Yes.
Page 84 1 Q At the bottom of the Table 8-8 on 2 Page 378, do you see there is an entry for CO₂, 3 open paren, CO, closed paren, 8? Do you see 4 that? 5 A Yes. 6 Q Is that the metal carbonyl we have 7 been talking about? 8 A Yes. 9 Q Do you see in the second column over 10 there's listed MP degree C? Do you see that? 11 A Yes. 12 Q And then the third column to the right 13 there's BP degree C. Do you see that? 14 A Yes. 15 Q Your understanding is MP represents 16 melting point? 17 A I believe so, but I really -- yeah, I 18 believe so, but ... 19 Q I can direct your attention to 20 Page 372 of that document. There is a table on 21 Page 372 for metal alkyls. Do you see that? 22 A Yes. 23 Q In the paragraph above the table, the 24 second to last sentence states: In general, 25 most alkyls have low melting and boiling points	Page 85 1 and high vapor pressures. 2 Do you see that? 3 A Yes. 4 Q And right below that sentence about 5 melting points and boiling points, do you see 6 the table contains the column for MP degree C 7 and BP degree C? 8 A Yes. 9 Q With that understanding, does MP mean 10 melting point? 11 A Yes. 12 Q And BP means boiling point? 13 A Yes. 14 Q So we can direct your attention back 15 to Page 378, Table 8-8, properties of metal 16 carbonyls and carbonyl halides. 17 Direct your attention down to the 18 cobalt carbonyl example, you see under the MP 19 column it's listed as 51 degrees C. Do you see 20 that? 21 A Yes. 22 Q And then under the BP column it's 23 listed as 52 degrees C? 24 A Yes. 25 Q And again, under the color inform

22 (Pages 82 to 85)

Page 86 1 column, you see it's orange/crystal? 2 A Yes. 3 Q So then, Doctor, if we turn your 4 attention back to Buchanan, back to Column 21, 5 Line 24, you see where it states the substrate 6 temperature is about 100 degrees C, 1200 7 degrees C and preferably 200 degrees C to 800 8 degrees C? 9 A Yes. 10 Q Both minimums in those temperature 11 ranges are above 52 degrees C; is that correct? 12 A Yes. 13 Q And in your understanding, does that 14 mean that that's above the boiling point of 15 cobalt carbonyl? 16 A Yes. 17 Q And based on the notations in the 18 textbooks, is it your understanding that that's 19 above the thermal deposition of cobalt carbonyl? 20 A Yes. 21 Q In fact, the CRC Handbook that you 22 mentioned earlier uses DEC as an abbreviation 23 for decomposition; isn't that true? 24 A I think so, yes. 25 Q Doctor, if we can switch gears a	Page 87 1 little bit and go back to your declaration 2 which, for your reference, is Exhibit Number 2, 3 declaration for the '539 patent in support of 4 the 662 IPR. 5 I want to direct your attention to 6 Paragraph 137. I'll give you a chance to review 7 that. It's a big paragraph. 8 A Yes. 9 Q I want to talk a little bit about a 10 person of ordinary skill testing precursors that 11 might be listed in Buchanan. 12 If we direct your attention within 13 Paragraph 137 on Page 69 of your declaration, 14 midway down that page there's sentence that 15 starts: Indeed, my experience. 16 A Yes. 17 Q Do you see that? 18 It goes on to state: In my 19 experience, using one of these precursors to 20 deposit a film in an ALD reactor, along with 21 testing to determine the properties of the 22 deposited film, would generally take no more 23 than one day in a lab equipped with proper ALD 24 equipment. 25 Do you see that?
Page 88 1 A Yes. 2 Q So I would like to elaborate a little 3 bit. What is your experience in testing 4 precursors? 5 A In my lab, I have three ALD reactors. 6 And the end application in my case is typically 7 microelectronic devices such as capacitors or 8 transistors. 9 So when we test precursors for the 10 suitability for ALD, for the initial screening 11 if you will, you can run quick experiments where 12 you choose temperature -- several temperatures 13 in sort of the typical ALD window. 14 And then you dose reactants for maybe, 15 you know, half a second cycles and then maybe 16 one-second cycles and then five-second cycles 17 and you do the cycles maybe, you know, ten, 20 18 times, so that hopefully you can build up enough 19 film thickness that can be measured. 20 After you do those depositions, we 21 measure them using a tool known as an 22 ellipsometer, for example, which enables you to 23 measure full thicknesses. So then you can 24 correlate the deposited full thickness with the 25 dosing durations and you can find out that the	Page 89 1 thickness scales linearly with the dosing 2 durations for the precursors, that's probably a 3 CVD type process with a full thickness, grows 4 more or less linearly with the growth time. 5 On the other hand, if it's an ALD 6 process, above certain dose duration, you would 7 find that the thickness did not increase or it 8 increased marginally. So that would be a quick 9 first test to determine if I'm in the -- sort of 10 the ALD window that we had talked about. 11 Q You mentioned that you do that test to 12 test the suitability of the precursor frailty. 13 A Right. 14 Q Why do you have to test it for 15 suitability? 16 A There's enough -- there is a lot of 17 information in this handbook for the other 18 sources that we mentioned. We should give a 19 person of ordinary skill strong hints as to 20 which precursors might be suitable for ALD 21 because of the desired attributes that we had 22 talked about earlier. 23 But of course, you know, chemistry is 24 a science, and at the end of the day, you do 25 want to do experiments to make sure that what a

23 (Pages 86 to 89)

Page 90 1 strong suggestions based on thermal dynamics are 2 borne out in the lab. 3 Q And that's because the data does not 4 always perfectly correlate to the theory; is 5 that correct? 6 A It depends on what you mean by 7 "perfectly." I mean, that depends on the 8 context. But the information that would be 9 available to a person of ordinary skill would be 10 an excellent starting point to choose, you know, 11 deposition conditions which could be in this ALD 12 window, for instance. 13 But then, of course, you do want to do 14 experiments to confirm that. 15 Q In writing your declaration for this 16 process for the -- in support of the IPRs, did 17 you test any precursors? 18 A Not in the context of writing this. 19 But I've been working on ALD since I think 1991. 20 We've done a lot of research on ALD of silicon, 21 germanium and subsequently high-K gate 22 dielectrics such as hafnium oxide, zirconium 23 oxide. In that context I have worked with some 24 of these dialkylamide precursors. 25 Q Are you familiar with the term to	Page 91 1 synthesize a precursor? 2 A Yes. 3 Q What does it mean to synthesize a 4 precursor? 5 A So chemists talk about synthesis by 6 reacting different reagents or molecules so that 7 we end up with a byproduct which is your desired 8 molecule. 9 Q Have you ever synthesized a desired 10 molecule? 11 A The microelectronics is a highly 12 interdisciplinary field, as I'm sure you know. 13 So as an electrical engineer working on 14 microelectronics process technology for 30 plus 15 years, I've worked very closely with my 16 colleagues in chemistry, for instance, and very 17 often directed them, of course, the synthesis of 18 molecules that would be useful to us. 19 My students and I have worked with 20 colleagues in chemistry and, in fact, we 21 submitted a patent disclosure on the synthesis 22 of a beryllium precursor molecule. 23 Unfortunately, the patent got 24 abandoned and ultimately wasn't issued. 25 So in fields such as microelectronics,
Page 92 1 you really don't work in silos of electrical 2 engineers who don't talk to chemists or 3 chemists who don't talk to the physicists. It's 4 a very interdisciplinary space. 5 Q Just to circle back to your discussion 6 about testing the precursors for suitability for 7 ALD, just to be clear, not all precursors have 8 the same ALD window; is that true? 9 A That's true. 10 Q It's part of the reason you need to 11 test for it; is that correct? 12 A That's correct. 13 Q Now, going back to our discussion of 14 synthesizing precursors, in a hypothetical if 15 you're going to perform a test to test a 16 precursor out of Buchanan for its suitability 17 for ALD, where would you get the precursor? 18 A Many of these precursors have been 19 known for a long time. So, for instance, this 20 dialkylamide precursors, which are the subject 21 of '016 and '539, I believe they have been known 22 at least since the 1960s. I recall reviewing a 23 document by Bradley, for instance, perhaps even 24 before that, I don't know. 25 So in our case when we want to test	Page 93 1 new precursors, we often buy them from 2 third-party vendors, in our case companies such 3 as Sigma-Aldrich, for example. 4 Q And Sigma-Aldrich would be a 5 commercial chemical supplier; is that fair to 6 say? 7 A Yes. 8 Q And do commercial chemical suppliers 9 have standard catalogs or offerings of chemicals 10 that they offer? 11 A Yes. 12 Q And if a precursor that you wanted to 13 test was not in the commercial supplier's 14 standard catalog, how would you go about 15 obtaining it? 16 A So in our case, if it's an exotic 17 precursor, often what we do is walk over to our 18 chemistry department and work with them and have 19 them synthesize the precursors, which as I 20 mentioned a few minutes back I did with my 21 colleague in chemistry who, you know, 22 synthesizes beryllium precursors. 23 We were interested in developing a 24 process for building an oxide gate dielectric 25 growth. So that would be one example.

Page 94 1 And often what happens is after you 2 find that a precursor is useful and you publish 3 some papers on that, the commercial vendors will 4 then -- 5 Q Sell it? 6 A -- put them on the catalog. 7 Q When you work with your chemist 8 colleagues, how long does it take them to 9 synthesize a chemical? 10 A That would depend on what particular 11 molecule you're talking about, I guess. 12 Q So some can take longer to synthesize 13 than others? 14 A It depends on what you mean by longer. 15 Presumably, yes, I'm sure some reactions are 16 more complicated than others. 17 Q I understand. Do you know in your 18 experience if any synthesis of chemicals have 19 taken longer than a day? 20 A Offhand, I could not tell you. 21 Q Let's go back to the Buchanan exhibit, 22 Doctor, which should be marked as Banerjee 23 Exhibit Number 9, talk about a couple more 24 examples of precursors. 25 If I can direct your attention to	Page 95 1 Column 6, which I believe we established is a 2 list of preferred precursors. 3 Most of the way down the page in 4 Column 6, Line 59, I direct your attention to 5 the first full precursor in Line 59 or the 6 second from the left, which is IR, open paren, 7 PF, subnote 3, closed paren, sub 4. 8 Do you see that? 9 A Yes. 10 Q Do you know what precursor that is? 11 A IR I think is iridium, if I remember 12 right. So the subscript for -- I don't know 13 exactly, but, I mean, you can look at the 14 formula and kind of guess. 15 So it would be tetra -- it's a 16 compound of phosphorous and fluorine, so I 17 presume phosphofluoride or something, but I 18 don't know exactly. 19 Q The iridium compound, is that 20 radioactive? 21 A I couldn't tell you offhand. 22 Q Do you know any of the characteristics 23 or qualities of this precursor? 24 A This particular one, no, not offhand. 25 Q Where would you go to find that
Page 96 1 information out? 2 A Once again, the various handbooks that 3 I mentioned or in terms of whether it's 4 radioactive or not, a very useful source of 5 information is known as the MSDS sheet, material 6 safety data sheet, and that would have 7 information about whether it was radioactive or 8 not, for instance. 9 Q In this list in Column 6, Buchanan 10 doesn't list why this is included in the list of 11 highly preferred precursors; isn't that true? 12 A From the description in Buchanan plus 13 the knowledge of a person of ordinary skill that 14 show the desired attributes for ALD precursors, 15 you know, presumably these have those attributes 16 in terms of suitable volatility, reactivity to 17 the surface, et cetera, et cetera. 18 Q And a person of ordinary skill would 19 have to test the suitability, as you mentioned 20 before; is that correct? 21 MR. LANG: Objection, form. 22 THE WITNESS: The first thing one 23 would do is one would look at these 24 handbooks that I mentioned and look at 25 things like vapor pressure, for instance,	Page 97 1 and that would be the first thing that you 2 would want to do to, you know, narrow down 3 the list if necessary, right. 4 And then depending on the context, you 5 would do for the testing along the lines 6 that I mentioned before. 7 BY MR. LEN: 8 Q I guess we mentioned before in your 9 declaration there's various desirable qualities, 10 including reactivity with a surface, and you 11 mentioned thermal stability in addition to being 12 volatile and some of the other desired 13 characteristics. 14 If you look back to Column 5, the last 15 line on Column 5, Buchanan only lists precursors 16 that are readily vaporized; isn't that true? 17 A In this particular spot, yes. 18 Q And you don't know of anywhere else 19 where he lists desirable qualities to be 20 qualified as a preferred precursor in Buchanan? 21 A In this one, I don't recall, but once 22 again, when I read Buchanan in the context of a 23 person of ordinary skill, he or she, I believe, 24 would be aware of the other desired attributes. 25 Q Let's look at the top of Column 6 as

25 (Pages 94 to 97)

Page 98 1 one last example of a precursor. I think it's 2 Line 17. Midway over from the left it's listed 3 as bisbenzene cobalt. Do you see that? 4 A Yes. 5 Q And I apologize, it's bisbenzene-CO, 6 which is an abbreviation for cobalt; correct? 7 A Yes. 8 Q This is in the list of preferred 9 precursors in Column 6; is that correct? 10 A Yes. 11 Q What, if anything, can you tell me 12 about this precursor, bisbenzene cobalt? 13 A I wasn't aware of the specifics of 14 this, but I did read your expert's declaration 15 and I read that it was not easy to synthesize in 16 a pure form, for instance. But I was not aware 17 of that prior to Dr. Gladfelter's declaration. 18 Q There is no indication here in 19 Buchanan of why it's highly preferred beyond 20 that it's readily vaporized; is that true? 21 A What is highly preferred I think would 22 also depend on the context. So there may be 23 certain applications where you need certain 24 properties of purity levels, for example, while 25 there could be other applications where the	Page 99 1 demands may be a little bit more flexible. So 2 it all depends on the context. 3 Q Going back to -- you read 4 Dr. Gladfelter's declaration that bisbenzene 5 cobalt is hard to synthesize. Do you agree with 6 that? 7 A I have not worked with this particular 8 compound, so I'm taking Dr. Gladfelter's word 9 for it. 10 Q I guess just to clarify, since you 11 have not worked with this particular compound, 12 bisbenzene cobalt, are you aware of any ALD 13 processes that use bisbenzene cobalt? 14 A Not off the top of my head, no. 15 MR. LEN: Now is probably a good time 16 to take a break for lunch? 17 MR. LANG: Yes. That's fine. If you 18 want to eat now. Do you want to eat or go 19 one more session? 20 (Recess taken.) 21 BY MR. LEN: 22 Q Welcome back, Doctor. 23 A Thank you. 24 MR. LEN: Just one administrative 25 point before we get going, I spoke with
Page 100 1 counsel and we agree that this transcript 2 today can be used for the purposes of all 3 three petitions that we mentioned earlier, 4 specifically IPR 2017-00662, IPR 2017-00663, 5 and IPR 2017-00664. 6 MR. LANG: Right. I agree, just 7 because I don't have anything that 8 corresponds to the Exhibits 1 through 6. 9 MR. LEN: That's correct. 10 BY MR. LEN: 11 Q Thank you, Doctor. Welcome back. 12 To that point, counsel's point, if I 13 can have you turn your attention to Exhibit 6, 14 which should be your declaration in support of 15 the 664 petition for the '016 patent. 16 Do you have that? 17 A I have it. 18 Q If I can direct your attention to the 19 first page of the table of contents. Do you see 20 that? 21 A Yes. 22 Q You agree with me that the first 23 grounds is Claims 1 through 2, 7 and 10 with 24 regards to Senzaki in view of Min? 25 A Yes.	Page 101 1 Q And ground 2 on the second page of the 2 table of contents is Claim 8 is rendered obvious 3 by Senzaki in view of Min and Shin. Do you see 4 that? 5 A Yes. 6 Q Let's see if I can now direct your 7 attention to Page 47 of your declaration. 8 There's a heading there that's labeled 9 Heading A is U.S. Patent Number 6,537,613, 10 paren, Senzaki. Do you see that? 11 A Yes. 12 MR. LEN: I'm going to hand to the 13 court reporter what will be marked as 14 Banerjee Exhibit 12. It is a copy of 15 U.S. Patent 6,537,613 by Senzaki. In the 16 lower right-hand corner labeled Micron 17 Exhibit 1005. 18 (Exhibit 12 was marked.) 19 BY MR. LEN: 20 Q Do you recognize this document? 21 A Yes. 22 Q What is it? 23 A It's the Senzaki patent. 24 Q And it's, in fact, the same Senzaki 25 patent that you reference on Page 47 of your

Page 102 1 declaration? 2 A Yes. 3 Q If we look at the first page of 4 Senzaki, you agree with me as stated in the 5 first sentence of the abstract that Senzaki is 6 directed to a process for deposition of a 7 multiple metal and metalloid compound layer with 8 a compositional gradient of the metal and 9 metalloid in the layer on a substrate of an 10 electronic material. 11 Do you see that? 12 A Yes. 13 Q Do you agree with that? 14 A Yes. 15 Q If I can direct your attention back to 16 Page 47 of your declaration, specifically 17 Paragraph 97. 18 Midway down on the page, do you see 19 where you state: Senzaki addresses the 20 purported failure of the prior art to provide a 21 desirable method for controllably producing a 22 mixed metal/methyl oxide, oxynitride, or nitride 23 film with a compositional gradient over the 24 depth of the deposited layer. 25 Do you see that?	Page 103 1 A Yes. 2 Q So do you agree that it was a goal of 3 Senzaki to produce films with mixed metal, 4 metalloid, oxide, oxynitride or nitride films 5 with a compositional gradient over the depth of 6 the deposited layer? 7 A Yes. 8 Q And that goal informs one of skill in 9 the art when reading Senzaki; is that true? 10 MR. LANG: Objection, form. 11 THE WITNESS: Could you repeat, 12 please. 13 BY MR. LEN: 14 Q I'll rephrase. 15 The stated goal of a reference informs 16 one of skill in the art when they are reading 17 that reference; isn't that true? 18 MR. LANG: Objection to form. 19 THE WITNESS: In -- Senzaki is trying 20 to address this need. 21 BY MR. LEN: 22 Q So if I can direct your attention to 23 Column 3 of Senzaki, specifically starting 24 around Line 40. 25 Specifically I guess it would be
Page 104 1 Line 43 through 45 states: The results show 2 that the metal silicate thin films with a 3 metal/metalloid compositional gradient are 4 deposited by controllably varying the deposition 5 temperatures. 6 Do you see that? 7 A Yes. 8 Q What is that referring to, 9 controllably varying deposition temperatures? 10 A So this relates to the formation of 11 the gate dielectric or insulator such as in a 12 MOSFET. And typically you want a high silicon 13 content close to the silicon substrate interface 14 from a device point of view. And reduce the 15 silicon content and increase in this case the 16 zirconium content as you move further away from 17 the interface. 18 And the way they are achieving that is 19 changing the temperature as they deposit the 20 gate dielectric layer upon layer upon layer. 21 Q Do you agree, Doctor, that a person of 22 ordinary skill in the art would understand that 23 varying the deposition temperatures of the 24 precursor mixtures results in varying deposition 25 rates as described in Senzaki?	Page 105 1 A Senzaki talks both about the CVD 2 growth method and the ALD growth method, among 3 other techniques. So if one were to use these 4 precursors in the ALD growth mechanism, you 5 would get this digital control over the layer 6 thicknesses where the thickness depends on the 7 number of growth cycles, as opposed to a linear 8 increase of the film thickness with time as you 9 see in the case of CVD. 10 Q And would the ALD growth mechanism 11 satisfy the goal of Senzaki to vary the 12 compositional gradients? 13 A You can certainly achieve that, yes. 14 Q So you can achieve -- so I guess can 15 you give me an example of how the ALD growth 16 mechanism would achieve the goal of varying the 17 compositional gradients? 18 A Sure. So what you do is in this case, 19 because I'm interested in forming an alloy of 20 silicon and zirconium, and I'm interested in 21 tweaking the ratio as you move away from the 22 interface, what I do is, assuming I'm using the 23 ALD growth mechanism, in the initial stages of 24 the dielectric formation, I'd flow more of the 25 silicon containing precursor, in this case, SIN

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Page 106 1 methyl groups, SINME2, parentheses, 4, and less 2 of the zirconium ethylamide, ZRNE2, parentheses, 3 4. And you'll do that using the ALD more, as I 4 mentioned, where you get additional control over 5 the layer thickness. 6 But then as you build up the layers 7 towards the latter part of the process, A, you 8 change the temperature and you'd change the 9 ratio of the zirconium containing flux versus 10 the silicon containing flux. You have more of 11 the zirconium-containing precursor flowing to 12 the reactor and less of the silicon-containing 13 precursor. But you certainly achieve that in 14 the ALD growth mode. 15 Q There is no examples of ALD in the 16 Senzaki patent, is there? 17 A Certainly in Column 4 it talks about 18 growth using CVD as well as atomic layer 19 deposition in Line 8, I guess. 20 Q May I direct your attention to 21 Columns 5 and 6, there's subheadings Example 1, 22 Example 2, Example 3, and Example 4. Do you see 23 that? 24 A Yes. 25 Q All of those Examples 1 through 4 are	Page 107 1 CVD; is that true? 2 A The heading states CVD, but the way I 3 read it is in the context of the specifications 4 in Column 4, I would read these examples as you 5 could achieve this film growth either in CVD or 6 via ALD. That's the way I read them. 7 Q And the process conditions could 8 potentially change for ALD; isn't that correct? 9 A Sure. I mean, you tweak the 10 deposition temperature, for example, and things 11 like that. 12 Q Isn't it true that all of the examples 13 use a mixture precursor? 14 MR. LANG: Objection, form. 15 THE WITNESS: Again, in these examples 16 they have mixtures of precursors. 17 BY MR. LEN: 18 Q And so in your hypothetical ALD 19 example before, the mixtures must vary their 20 ratio during the deposition process; is that 21 correct? 22 A If, as in Senzaki, they are interested 23 in changing the relative mol fractions of, say, 24 zirconium versus silicon, you would have to 25 adjust the relative flow rates of the
Page 108 1 zirconium-containing precursor versus the 2 silicon-containing precursor. 3 Q In examples in Senzaki, Senzaki 4 teaches varying the compositional -- strike 5 that. 6 Senzaki teaches varying the 7 composition by varying the deposition 8 temperature; isn't that correct? 9 A That's correct. 10 Q And as a result of varying the 11 deposition temperature, in examples in Senzaki, 12 the deposition rates change; is that also 13 correct? 14 A The deposition rates in the ALD mode 15 would be digital control, but in this particular 16 Example 1, they are changing the silicon to 17 zirconium alloy composition by changing the 18 deposition temperature because depending on the 19 temperature, the relative incorporation of 20 silicon atoms versus zirconium atoms is being 21 changed in this particular context. 22 Q And in the context of the precursors 23 for Senzaki, the solventless mixtures of 24 precursors, those are premixed prior to 25 deposition; is that true?	Page 109 1 A In Example 1 as shown over here, it is 2 premixed. And they are changing the relative 3 mol fractions by adjusting the temperature, but 4 you could also accomplish different compositions 5 by having a separate source of the 6 zirconium-containing precursor and the 7 silicon-containing precursor and could adjust 8 those flow rates also in ALD. 9 That's not what is described in 10 Example 1, but as a person of ordinary skill, 11 they could do that also. 12 Q So it would no longer be premixed; is 13 that true? 14 A Yes. 15 Q So if we go back to the first page of 16 Senzaki in the abstract, Senzaki discloses a 17 process and it lists several steps in the 18 process. If you look about at the fourth line 19 down in the abstract of Senzaki, do you see 20 where it starts with A? 21 A Yes. 22 Q It says -- A is: Providing two or 23 more metal ligand and metalloid ligand complex 24 precursors, wherein the ligands are preferably 25 the same.

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Page 110 1 A Yes. 2 Q B, delivering the precursors to the 3 deposition zone where the substrate is located; 4 C, contacting the substrate under deposition 5 conditions with a precursor; D, varying the 6 temperature of deposition from a first 7 temperature to a second distinct temperature 8 which is at least 40 degrees C from said first 9 temperature during the contact; and E, 10 depositing a multiple metal and metalloid 11 compound layer on the substrate from the 12 precursors resulting in a compositional gradient 13 of the metal and metalloid in the layer as a 14 result of step D. 15 Do you see that? 16 A Yes. 17 Q That's a very specific five-step 18 process; is that correct? 19 A Yes. 20 Q And that does not mention the 21 varying -- varying the precursors independently 22 that you just talked about earlier; right? 23 A In this case it does not, but one 24 could do that quite easily in my opinion. 25 Q So if we go back to Example 1, it's	Page 111 1 your opinion that this precursor in Example 1 on 2 Column 5 of Senzaki can be used in ALD? 3 A That's correct. You could choose the 4 deposition temperature, for instance, in the ALD 5 window. 6 Q And so you mentioned the ALD window. 7 If there's two precursors in the mixture of 8 Senzaki, which ALD window do you choose? 9 A You choose a common window where both 10 the silicon-containing precursor and the 11 zirconium-containing precursor would fall within 12 the window. And what they are doing -- what you 13 do there is you choose the appropriate 14 temperatures where the relative incorporation 15 rates of the zirconium atoms versus the silicon 16 atoms could be changed. 17 And this, once again, goes back to the 18 relative bond strength in this case between the 19 zirconium and oxygen and silicon and oxygen. 20 Q Do you know if the ALD windows overlap 21 for those two precursors? 22 A Not offhand, no. 23 Q So if I can direct your attention back 24 to Column 3 of Senzaki at the top. 25 Lines 3 through 7, we start from the
Page 112 1 top: In the present invention, a new metal and 2 metalloid deposition resulting in a 3 compositional gradient is disclosed that can be 4 used for precursor dispersing delivery methods, 5 including DLI in CVD applications. Preferably 6 the precursors are a solventless mixture. 7 Do you see that? 8 A Yes. 9 Q Are you familiar with the term DLI? 10 A Yes. 11 Q What is that? 12 A Direct liquid injection. 13 Q And just to further explain that, what 14 does -- what is direct liquid injection in the 15 context of CVD? 16 A So the precursors in this case are 17 kept in a -- some sort of a chamber in a liquid 18 state and they are injecting presumably vapors 19 of that into the growth chamber where the, in 20 this case, CVD reactions are occurring. 21 Q When you say they are injecting 22 presumably vapors, what do you mean by that? 23 A So that is described in Column 1 24 around lines I guess 30 on. 25 So common precursor delivery methods	Page 113 1 used in CVD processing include vapor draw, 2 bubbling with a carrier of gas where you have 3 the liquid and then you bubble an inert gas such 4 as argon perhaps -- argon or nitrogen typically. 5 Mist droplet, they spray aerosols, and DLI. 6 And they say that DLI is preferred for 7 the consistent delivery of multi-components 8 because it delivers the same ratio of the 9 constituents in the reactor as in the source 10 container. DLI has the added advantage of 11 storing precursor at room temperature and 12 heating only the amount required for delivery, 13 therefore improving precursor shelf life. 14 So you keep the main part of the 15 reactants at the ambient temperature, you don't 16 heat that up. And thereby you minimize the 17 thermal decomposition and thereby improve the 18 shelf life of the reactor. 19 Q The thermal stability that we talked 20 about earlier? 21 A Yes. 22 Q I think you just mentioned in that 23 passage that you read that DLI is actually 24 preferred because it allows for a consistent 25 delivery of the components because it delivers

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Page 114 1 the same ratio of the constituents; isn't that 2 true? 3 A Yes. 4 Q Isn't that -- that's opposite of the 5 proposed ALD method that we talked about earlier 6 of varying ratio of the constituents; is that 7 correct? 8 MR. LANG: Objection to form. 9 THE WITNESS: So I was describing a 10 way of achieving this compositional 11 variation that a person of ordinary skill 12 would be able to achieve based on his or her 13 knowledge. 14 But in this particular example, they 15 have premixed ratio, so they are not varying 16 the ratio of the constituents in this case, 17 they are achieving the different mol 18 fractions by adjusting the temperature where 19 at different temperatures, you have 20 differences of the incorporation rate of the 21 silicon-containing species versus the 22 zirconium-containing species. 23 I'm trying to illustrate there are 24 many ways of skinning a cat. 25	Page 115 1 BY MR. LEN: 2 Q But the preferred goal of Senzaki is 3 to do the specific way of direct liquid 4 injection with CVD to vary the temperatures; is 5 that correct? 6 MR. LANG: Objection to form. 7 THE WITNESS: In my opinion, the 8 overarching goal is to achieve a gate 9 insulator, gate dielectric where you can 10 control the relative ratios of 11 silicon-containing species versus in this 12 case the transition metal-containing 13 species. And that's governed by device 14 requirements. 15 And the way they've achieved that as 16 described in Senzaki is by adjusting the 17 deposition temperature. 18 BY MR. LEN: 19 Q As we went through in the specific 20 steps in the abstract? 21 A Yes. 22 Q Okay. So let's direct our attention 23 to Column 4 of Senzaki at the top. I think you 24 mentioned this a little bit earlier. 25 Midway down the first full paragraph
Page 116 1 right about Lines 8 through 10, states -- 2 A Which column again? 3 Q Column 4, Line 8 states: Or by atomic 4 layer deposition. 5 Do you see that? 6 A Yes. 7 Q And then it continues on: In atomic 8 layer deposition, approximately a single layer 9 of precursor molecules are adsorbed on to a 10 surface. 11 Do you see that? 12 A Yes. 13 Q And adsorbed, is that different from 14 chemisorbed that we talked about earlier? 15 A It could be chemisorbed or 16 physisorbed. 17 Q If we go back up to the previous 18 sentence, it starts out in that paragraph saying 19 that: In addition to thermal low pressure CVD, 20 the above precursors could be used for 21 atmospheric pressure CVD, subatmospheric 22 pressure CVD, plasma, photo, radical, or laser 23 enhanced CVD deposition, and jet vapor 24 deposition well recognized deposition 25 techniques, or by atomic layer deposition.	Page 117 1 Is that correct? 2 A Yes. 3 Q Senzaki does not specify which 4 precursors are suitable for ALD process, does 5 it? 6 A As I mentioned before, ALD is a subset 7 of CVD and when it comes to ALD, one would 8 naturally look to the precursors that are used 9 for CVD as sort of an initial set of possible 10 precursors. 11 And then, of course, there could be 12 cases where some of them that are used for CVD 13 may or may not be applicable for ALD. But in a 14 large number of cases, ALD -- CVD precursors can 15 also be used for -- CVD precursors could also be 16 used for ALD with suitable choice of the 17 deposition parameters. 18 Q And so one of the ways to determine if 19 the precursor would be suitable for ALD, as we 20 discussed earlier, would be to test its 21 suitability; is that correct? 22 MR. LANG: Objection to form. 23 THE WITNESS: As I told you, what one 24 would do is look at information that is 25 readily available in handbooks or on the

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Page 118 1 Internet to guide your choice and use 2 thermal dynamics as the initial guide. 3 But of course, at the end of the day, 4 you would have to do some experimentation. 5 BY MR. LEN: 6 Q And you have not done any 7 experimentation in connection with your 8 declaration, have you? 9 A No. 10 Q And have you done any experimentation 11 with any of the precursor to make sure it's 12 listed in Senzaki? 13 A As part of my research, not in the 14 context of this declaration, I have worked with 15 the zirconium precursors, hafnium precursors. I 16 can recall offhand if I've worked with the 17 specific silicon-containing precursor. But we 18 have made devices where we try to adjust the 19 composition of these dielectrics to improve 20 transistor properties. 21 Just as an aside, the goal over here 22 is you want a silicon rich interfacial layer to 23 improve what is known as the carrier mobility in 24 the channel of the MOSFET when it traverses from 25 the source to the drain. So that's the goal of	Page 119 1 having a silicon rich interface layer, but then 2 you increase the zirconium content as you move 3 further up in order to improve and increase the 4 dielectric constant of the gate dielectric so 5 that you have better transistor performance. 6 Q And so thank you. 7 Just to clarify then, going back to 8 Example 1 on Column 5 of the Senzaki patent, the 9 solventless mixture of the zirconium precursor 10 and the silicon precursor, you're unsure if 11 you've ever worked with that specific precursor; 12 is that correct? 13 MR. LANG: Objection, form. 14 THE WITNESS: I'm pretty sure I've 15 worked with the zirconium precursor to grow 16 zirconium oxide. I don't believe I've 17 worked with this particular mixture. I 18 don't think I've worked with particular 19 mixture to grow this alloy of zirconium and 20 silicon. That we haven't done. But I've 21 worked with -- I'm pretty sure I worked with 22 this particular zirconium precursor or maybe 23 the methyl derivative of that. 24 BY MR. LEN: 25 Q Keeping your attention to the specific
Page 120 1 mixtures listed here in Senzaki as a whole as 2 opposed to the components of the mixture, do you 3 know if any of the mixtures in Senzaki can be 4 used for an ALD process? 5 A Not offhand. So what you want to do 6 as a person of ordinary skill is see what the 7 ALD window is for the zirconium-containing 8 precursor and the silicon-containing precursor 9 and see if there is a common window. And that's 10 where one would operate if we wanted to work 11 with this alloy. That's what we want to do. 12 Now, if one found that there was no 13 common temperature window, it would be -- what a 14 person of ordinary skill would then do would 15 choose sort of analogs of these precursors, 16 okay? So instead of the ethyl groups, use the 17 methyl groups in some cases such that you have a 18 common temperature window where you can do ALD 19 as one example. 20 So the way I read Senzaki is it talks 21 about CVD as well as these other techniques, 22 including atomic layer deposition. And the 23 goal, the overarching goal is to grow a gate 24 dielectric where the composition changes to 25 satisfy the device requirements. And it can	Page 121 1 achieve that in multiple ways, as I was trying 2 to describe before. 3 Q And in fact, the preferred way as 4 described in Senzaki is through direct liquid 5 injection in a CVD process; is that correct? 6 A That's one exemplary way that's 7 described. 8 MR. LEN: Let's go off the record just 9 quickly so I can consolidate my notes. 10 MR. LANG: There is a rule you can't 11 skip back in your outline once you are on 12 the last page. 13 (Recess taken.) 14 BY MR. LEN: 15 Q Welcome back, sir. 16 A Thank you. 17 Q If I can direct your attention back to 18 your declaration, which is marked as Banerjee 19 Exhibit 6. It might be in front of you already. 20 A Yes. 21 Q And if I can direct your attention to 22 Page 50 of the declaration. Do you see that 23 there is subheading B entitled Jae-Sik Min, 24 et al., Atomic Layer Deposition of TiN Films by 25 Alternate Supply of

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Page 122 1 Tetrakis(ethylmethylamino)-Titanium and Ammonia. 2 Do you see that? 3 A Yes. 4 MR. LEN: Handing the court reporter 5 what will be marked as Banerjee Exhibit 13, 6 a document that in the lower right-hand 7 corner is marked as Micron Exhibit 1006. 8 And the title on its face is Japanese 9 Journal of Applied Physics, Part 1, Regular 10 Papers, Short Notes and Review Papers, 11 September 1998, Volume 37, Number 9A. 12 (Exhibit 13 was marked.) 13 BY MR. LEN: 14 Q Doctor, do you recognize Exhibit 15 Number 13? 16 A Yes. 17 Q What is it? 18 A It's a paper by Min, et al., on ALD of 19 ti nitride films using this precursor. Let me 20 just leave it like that. It's a complicated 21 name. 22 Q In fact, is it the same Min paper 23 that's referenced on Page 50 of your 24 declaration? 25 A Yes.	Page 123 1 Q If I can direct your attention to 2 Page 7 of the exhibit as noted in the lower 3 right-hand corner after Micron Exhibit 4 Number 1006. 5 If you see in the first line of the 6 abstract under the title -- see where it states 7 that Atomic Layer Deposition (ALD) of amorphous 8 TiN films on SiO2 between 170 degrees C and 9 210 degrees C has been investigated by alternate 10 supply of reactant sources, Ti[N(C2H5 CH3)4 11 [tetrakis(ethylmethylamino) titanium:TMAT] and 12 NH3. 13 Do you see that? 14 A Yes. 15 Q So is it fair to say that Min is 16 directed to atomic layer deposition of titanium 17 nitride films between 170 and 210 C utilizing 18 TMAT and ammonia? 19 MR. LANG: Objection to the form. 20 THE WITNESS: It does talk about ALD 21 deposition ti nitride using TMAT and 22 ammonia. 23 BY MR. LEN: 24 Q Titanium nitride, that's a nitride 25 film; correct?
Page 124 1 A Yes. 2 Q And how is a nitride film different 3 from an oxide film? 4 A Nitride films involve reactions with 5 nitrogen versus oxide films involve reactions to 6 oxygen. In many cases, for microelectronics 7 applications, they belong to the same similar 8 category. They are ceramic materials, they are 9 insulators, which is solid with a so-called 10 energy band gap. 11 So although nitrides are not the same 12 as oxide, a person of ordinary skill would look 13 to both of those as belonging to the same -- 14 belonging to the same class of materials. 15 Q Do you know, Doctor, are nitrides 16 conductors? 17 A It depends. So silicon nitride, for 18 example, is an insulator with a lower band gap 19 than silicon dioxide. And these strengths can 20 be understood -- broad trends can be understood 21 based on the periodic table. 22 Q And based -- sorry, are you finished? 23 A What was the question again? 24 Q I'll rephrase it. 25 Based on your understanding of the	Page 125 1 periodic table, is titanium nitride a conductor? 2 A So crystalline titanium nitride is 3 actually an insulator with a band gap of around 4 three to four electron volts. I think I 5 mentioned that in my declaration. 6 However, when you put down those 7 films, they are often not in a single crystal 8 form. So as used in microelectronics, very 9 often these are used as -- ti nitride can be 10 used as a conductor, although the conductor of 11 ti nitride is not going to be as high as that of 12 a metal such as titanium. 13 That's why these are sometimes used as 14 barrier layers or local interconnects and things 15 like that, but you cannot use them as long 16 distance interconnects such as copper. 17 Q Doctor, isn't it true the Min does not 18 disclose the use of precursors source mixtures? 19 A I guess it's talking about using TMAT 20 in this particular case. Are you asking what if 21 TMAT is mixed with another reactant or -- 22 Q The last reference we just spoke 23 about, Senzaki disclosed precursor source 24 mixtures; correct? 25 A Right.

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Page 126 1 Q Isn't it true the Min does not 2 reference precursor source mixtures? 3 A Right. In this case, it's STMAT 4 that's being used for one half of the cycle. 5 Q TMAT alone reacts differently in a 6 deposition reaction than it would if it was 7 mixed with something else; is that correct? 8 A I'm not sure I understand your 9 question. 10 Q Do precursor mixtures react 11 differently than single precursors in a 12 deposition reaction? 13 MR. LANG: Objection to form. 14 THE WITNESS: What mixture are you 15 referring to in this context? 16 BY MR. LEN: 17 Q Generally if you mix something that's 18 not inert with a precursor, will that affect the 19 deposition reaction? 20 MR. LANG: Objection to the form. 21 THE WITNESS: That would depend on the 22 specifics of what mixture you're talking 23 about. But in a broad sense, I suppose 24 that's true. 25 BY MR. LEN:	Page 127 1 Q Let's go back to your declaration, 2 Paragraph 106 of your declaration. You mention 3 that -- 4 MR. LANG: Exhibit 6? 5 MR. LEN: I apologize, yes. Your 6 declaration, which is Exhibit 6. 7 BY MR. LEN: 8 Q Paragraph 106 on Page 54. The second 9 sentence in Paragraph 106 states: By carrying 10 out this routine optimization process, Min 11 achieved a temperature range in which film 12 thickness per cycle was independent of substrate 13 temperature, between 170 degrees C and 14 210 degrees C. 15 Do you see that? 16 A Yes. 17 Q Is this discussing the ALD window that 18 we talked about earlier today? 19 A Yes. 20 Q And then in fact, if we look at -- go 21 back to look at Min, which is Exhibit 13, 22 turning turn to Page 8 of Min in the lower 23 right-hand corner, if you look at Figure 3 in 24 the upper right-hand corner of Min -- do you see 25 Figure 3 there?
Page 128 1 A Yes. 2 Q In fact, Figure 3 shows an ALD window 3 in which the deposition rate is independent of 4 deposition temperature; isn't that true? 5 A The deposition rate defined as film 6 thickness per cycle is independent of 7 temperature between, I guess, 170 and 210, yes. 8 Q And you agree that it's independent? 9 A Yes. 10 Q Based on your earlier discussions 11 today, you agree if you're outside of the ALD 12 window for Min, the process would change to a 13 CVD process; correct? 14 MR. LANG: Objection to form. 15 THE WITNESS: If you're higher than 16 this temperature window? 17 BY MR. LEN: 18 Q Yes. 19 A You get decomposition of the TMAT as 20 shown over here. But if that's all that you 21 flow in without ammonia, you do not get CVD of 22 ti nitride. You get a film of titanium 23 presumably. 24 Q The film of titanium would be due to a 25 CVD process; correct?	Page 129 1 MR. LANG: Objection to form. 2 Greg, you agree that form covers asked 3 and answered? 4 MR. LEN: Yes. 5 THE WITNESS: So above 210 degrees, if 6 the TMAT decomposed, it would be a 7 decomposition. 8 BY MR. LEN: 9 Q In fact, if we look back at your 10 Paragraph 106 of Exhibit 6, states -- the third 11 sentence down states: In contrast, Min noted 12 that above 230 degrees C, ALD was not taking 13 place but, rather, CVD was taking place because 14 film thickness per cycle above 230 degrees C 15 gradually increased as a function of 16 temperature. 17 Do you see that? 18 A Yes. 19 Q So you agree that above the 20 temperature window, CVD can take place? 21 A Yes. 22 Q You mentioned that the titanium 23 nitride might not be deposited above a certain 24 temperature. 25 A I stated that if you just flow in the

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Page 130 1 TMAT without the ammonia, if you commingle the 2 two, then you could get ti nit. 3 Q Would you agree that impurities can 4 impact the dielectric properties of a film? 5 A It depends on what kinds of impurities 6 you're talking about. Some could, some may not. 7 Q And would you agree that impurities 8 could also be referenced to as contamination of 9 the film? 10 A Some people do. 11 Q Okay. And in that context when people 12 are referring to contamination of the film, you 13 would want to avoid that to maintain the 14 dielectric properties of them; is that correct? 15 A Yes. The contaminants have a 16 deleterious effect on the properties. You would 17 want to avoid. 18 Q In fact, carbon can be a contaminant 19 with deleterious effect; is that true? 20 A It can have bad effects on dielectrics 21 in some cases, yes. 22 Q Also can nitrogen have bad effects on 23 dielectrics? 24 A In some cases, yes, but in some cases 25 nitrogen can also have beneficial effects, it	Page 131 1 turns out. 2 MR. LEN: Okay. Jason, I think we're 3 at the end of our questions for now. We'll 4 pass the witness to you. 5 MR. LANG: Yes, I have a couple of 6 questions. 7 EXAMINATION 8 BY MR. LANG: 9 Q Good afternoon, Dr. Banerjee. 10 A Good afternoon. 11 Q Are you familiar with this -- kind of 12 the comical scene where some wizard from 13 500 years ago is just throwing everything in a 14 black pot and a magic potion comes out? 15 A Yes. 16 Q Sometimes referred to as alchemy? 17 A Yes. 18 Q In the late '90s, is that what people 19 were doing with picking precursors? 20 MR. LEN: Object to form. 21 THE WITNESS: Not at all, no. 22 BY MR. LANG: 23 Q And what were some of the initial 24 steps folks took when they were looking at 25 precursors to use?
Page 132 1 A As I mentioned during my earlier 2 testimony, this -- there is an enormous body of 3 knowledge in terms of the thermodynamic 4 properties of these chemicals as far as other 5 things. So you would want to look to that, for 6 instance. 7 Q Dr. Banerjee, did that type of 8 information exist in the late 1990s? 9 A Yes. 10 Q And I think you referred to, in fact, 11 one of these handbooks that had some of that 12 information? 13 A Yes. 14 Q And do you keep that handbook in your 15 office? 16 A I have it on my desk. I have had it 17 for probably 30 years. It's a CRC Handbook of 18 Physics and Chemistry. 19 Q In addition to these handbooks, are 20 there examples that you can look to, for 21 example, examples of ALD that might have been 22 performed that would inform your view on 23 precursors? 24 MR. LANG: Objection to form. 25 THE WITNESS: Yes.	Page 133 1 BY MR. LANG: 2 Q And we talked about the Min reference? 3 A Yes. 4 Q Is the Min reference an example that 5 might inform your view on what precursor would 6 be successful? 7 MR. LEN: Same objection. 8 THE WITNESS: Yes. 9 BY MR. LANG: 10 Q What does Min -- what would -- strike 11 that. 12 One of ordinary skill reading Min in 13 the late 1990s, what would that inform that 14 person in regards to the ALD window in metal 15 dicyclomine? 16 MR. LEN: Objection. 17 THE WITNESS: I looked at Figure 3, 18 for example, of Min, and as I guess the 19 graph labeled A indicates, there is a flat 20 portion of the curve between 170 degrees and 21 210 degrees where the film thickness per 22 cycle is independent of temperature. And 23 that's symptomatic of ALD. 24 So there would be a strong -- strong 25 evidence to a person of ordinary skill that

Page 134 1 you can achieve ALD of ti nitride using TMAT 2 in this case. But it goes beyond that. 3 If, instead of ti nitride, one was 4 interested in deposition of dielectrics such 5 as hafnium oxide or zirconium oxide, from 6 knowledge of basic chemistry that titanium 7 lies in the same column of the periodic 8 table as zirconium and hafnium, that would 9 tell someone that the chemical properties of 10 titanium, hafnium, zirconium are probably 11 going to be quite similar. 12 And then when it comes to nitride 13 versus oxides -- although it's true that 14 they are not identical -- as I was 15 describing to counsel a few minutes back, 16 they sort of belong to the same category of 17 materials in the context of 18 microelectronics. 19 So the point I'm trying to make is the 20 teaching of Min vis-a-vis ti nitride would 21 inform a person of ordinary skill that it 22 could smartly choose precursors for the 23 deposition of zirconium oxide or hafnium 24 oxide. 25	Page 135 1 BY MR. LANG: 2 Q And you testified earlier about the 3 notion of contaminants ending up in a film? 4 A Yes. 5 Q And if a process produces 6 contaminants, does that mean that no matter what 7 you do with those precursors, you're always 8 going to get contaminants? 9 MR. LEN: Objection. 10 THE WITNESS: Not at all. What it 11 means is I've probably not chosen my 12 deposition parameters appropriately, where 13 if I'm worried about carbon contamination, I 14 may want to choose different deposition 15 conditions where these methyl or ethyl 16 groups, ligands, are removed in a so-called 17 facile mode and they don't end up leading to 18 contamination in the field. 19 BY MR. LANG: 20 Q Thank you, Dr. Banerjee. Can you turn 21 to Senzaki, which is Exhibit 12. 22 A Yes. 23 Q And I would like to turn your 24 attention to Column 3, I believe it's Line 40 25 maybe, starting with "Surprisingly."
Page 136 1 A Okay. 2 Q And it talks about the invention and 3 it references a zirconium precursor, I believe. 4 A Yes. 5 Q And then immediately following that, 6 if you turn your attention to Column 4, and it 7 states at Line 4, "In addition to thermal low 8 pressure CVD, the above precursors could be used 9 for," and then it continues and states that it 10 could be used for atomic layer deposition. 11 A Yes. 12 Q Okay. What does that -- when it says 13 the above precursors, what is that "above 14 precursors" referring to? 15 A Well, in this exemplary case, it will 16 be the zirconium, ethyl, tetrakis -- it's ZR, 17 parenthesis, nitrogen, N, ET stands for ethyl, 18 subscript 2, parentheses, subscript 4. 19 So that's one of the precursors and 20 the other one is a similar silicon-containing 21 precursor. So one would read Column 4, the ALD 22 deposition referring to similar precursors like 23 this. 24 Q Okay. And then we take that context 25 and look at Example 1 on Column 5, does that	Page 137 1 inform your view on what this precursor for 2 Example 1 can be applied to? 3 MR. LEN: Objection, form. 4 THE WITNESS: As I've told counsel 5 before, ALD is a subset of CVD, so a lot of 6 CVD precursors are applicable to ALD with 7 appropriate optimization of the deposition 8 conditions. 9 BY MR. LANG: 10 Q And this precursor is referring to 11 zirconium? 12 A Yes. 13 Q Is that the same as one of these 14 precursors on Column 3? 15 A That's correct. 16 Q And in Column 4 we learn that that 17 exact precursor can be used for ALD? 18 A That's correct. 19 MR. LEN: Objection. 20 MR. LANG: That's all I have. 21 MR. LEN: I have two redirects. 22 FURTHER EXAMINATION 23 BY MR. LEN: 24 Q So, Doctor, just talking about this 25 Senzaki reference, which is Exhibit 12, I think

Page 138 1 you still have it in front of you. 2 A Yes. 3 Q And specifically counsel just asked 4 you about Columns 3 and Column 4. Do you 5 remember that? 6 A Yes. 7 Q And Column 3 directed your attention 8 to approximately Line 40, there is a zirconium 9 precursor. Do you remember that? 10 A Yes. 11 Q Isn't it true that below that starting 12 around Column 3, Line 54, additional precursors 13 are also listed? Is that true? 14 A Yes. 15 Q And in fact, it states that in 16 preferred mode, the mixture of two or more metal 17 ligand and metalloid ligand complex precursors, 18 which preferably constitute a liquid at ambient 19 temperatures -- I apologize, it says: At 20 ambient conditions and ligands, which can be the 21 same or different, and are selected group 22 consisting of alkyls, alkoxides, halides, 23 hydrides, amides, imides, azides, nitrates, 24 cyclopentadienyls, carbonyls, beta diketones, 25 beta ketoiminates, beta dimines, pyrazoles and	Page 139 1 their fluorine, oxygen and nitrogen substituted 2 analogs. 3 Do you see that? 4 A Yes. 5 Q How many additional precursor mixtures 6 does that disclose? 7 A I didn't count. I guess about a dozen 8 or so. 9 Q So it's not just the one zirconium 10 precursor; isn't that true? 11 A Right. So the zirconium precursor we 12 talked about earlier is just an exemplary case. 13 Depending on the application, as you point out, 14 there could be other choices also. 15 Q And do you know if all of those 16 permutations of precursors listed in Column 3 17 from Line 54 through 62, if all of those work 18 for ALD? 19 MR. LANG: Objection to form. 20 THE WITNESS: I mean, a priori, I may 21 or may not know that. But as I told you 22 before, if one is interested in doing ALD, 23 what I do is I look to these handbooks or 24 the Internet and I look up the basic 25 properties of some of these and that would
Page 140 1 inform a person of ordinary skill to what's 2 likely to work for an ALD process. 3 Now, of course, one would not stop 4 with that. One would have to do some simple 5 experimentation along the lines that I 6 mentioned to confirm that it does work in an 7 ALD mode. 8 BY MR. LEN: 9 Q And thank you. Just to clarify, when 10 you said before there was a dozen precursors, 11 it's a dozen categories of precursors; is that 12 correct? 13 A That's correct. 14 Q Each one of those categories would 15 have several different sub permutations; is that 16 correct? 17 A That's correct. 18 MR. LEN: I don't have any further 19 questions at this time. 20 MR. LANG: I'm done. 21 THE WITNESS: Thank you. 22 (Proceedings concluded at 1:19 p.m.) 23 24 25	Page 141 1 REPORTER'S CERTIFICATE 2 I, the undersigned, a Certified 3 Shorthand Reporter of the State of 4 California, do hereby certify: 5 That the foregoing proceedings were 6 taken before me at the time and place herein set 7 forth; that any witnesses in the foregoing 8 proceedings, prior to testifying, were placed 9 under oath; that a record of the proceedings was 10 made by me using machine shorthand which was 11 thereafter transcribed under my direction; 12 further, that the foregoing is an accurate 13 transcription thereof. 14 I further certify I am neither 15 financially interested in the action nor a 16 relative or employee of any attorney or party to 17 this action. 18 IN WITNESS WHEREOF, I have this date 19 subscribed my name. 20 21 Dated: October 13, 2017 22 23 24 25 LYNNE MARIE LEDANOIS CSR No. 6811

36 (Pages 138 to 141)

1 NAME OF CASE:
 2 DATE OF DEPOSITION:
 3 NAME OF WITNESS:
 4 Reason Codes:
 5 1. To clarify the record.
 6 2. To conform to the facts.
 7 3. To correct transcription errors.
 8 Page 9 Line 20 Reason 3
 9 From answer to and
 10 Page 10 Line 7 Reason 3
 11 From director to direct
 12 Page 11 Line 14 Reason 3
 13 From sales to cells
 14 Page 12 Line 5 Reason 3
 15 From minute to minimum
 16 Page 21 Line 21 Reason 3
 17 From various to homogeneous
 18 Page 34 Line 17 Reason 3
 19 From to seeds to proceeds
 20 Page 38 Line 18 Reason 3
 21 From decision to reaction
 22 Page 44 Line 15 Reason 3
 23 From it to and
 24
 25 Sanjay Banerjee
 SANJAY BANERJEE, PH.D. 10/19/17

Pg. 89, l. 3, 3
 full → film
 Pg. 90, l. 1, 3
 thermal dynamics → thermodynamics
 Pg. 93, l. 24, 3
 building an → beryllium
 Pg. 106, l. 3, 3
 more → mode
 Pg. 107, l. 23, 3
 mol → mole
 Pg. 109, l. 3, 3
 mol → mole
 Pg. 114, l. 17, 3
 mol → mole
 Pg. 118, l. 2, 3
 thermal dynamics → thermodynamics
 Pg. 118, l. 16, 3
 can → can't

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Pg 50, l. 6, 3
 thermal → theoretical
 external → experimental
 Pg 55, l. 9, 3
 reabsorption → desorption
 Pg 64, l. 22-22, 3
 coordinate it could be → coordinatively
 Pg 66, l. 25, 3
 — → is in
 Pg 70, l. 9, 3
 foundations → conditions
 Pg 75, l. 14, 3
 I'm → I have
 Pg 88, l. 23, 3
 full → film

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Pg. 123, l. 21, 3
 THAT → TEMAT
 Pg. 125, l. 10, 3
 the conductor → conductivity
 Pg. 125, l. 19, 21, (3)
 THAT → TEMAT
 Pg. 126, l. 3, 3
 STMAT → TEMAT
 Pg. 128, l. 19, 3
 THAT → TEMAT
 Pg. 129, l. 6, 3
 THAT → TEMAT
 Pg. 134, l. 1, 3
 THAT → TEMAT
 Pg. 135, l. 18, 3
 field → film

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