In the Matter of:

Western Digital Technologies, Inc. vs

Godo Kaisha IP Bridge 1

Jeffrey Bokor, Ph.D.

June 24, 2025

---

68 Commercial Wharf • Boston, MA 02110
888.825.3376 - 617.399.0130
Global Coverage
Magnals.com

O'BRIEN & LEVINE
COURT REPORTING SOLUTIONS
A MAGNA LEGAL SERVICES COMPANY

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

WESTERN DIGITAL TECHNOLOGIES, INC., Petitioner,	
vs.	Case No. IPR2024-01494
GODO KAISHA IP BRIDGE 1, Patent Owner.	

REMOTE DEPOSITION OF

JEFFREY BOKOR, PH.D.

JUNE 24, 2025

Reported by:
Brooke Silvas, CSR 10988
Job No. 1355529

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

WESTERN DIGITAL TECHNOLOGIES, INC., Petitioner,	
vs.	Case No. IPR2024-01494
GODO KAISHA IP BRIDGE 1, Patent Owner.	

Deposition of JEFFREY BOKOR, PH.D., taken remotely via Zoom, commencing at 9:09 a.m., on Tuesday, June 24, 2025, before Brooke Silvas, Certified Shorthand Reporter No. 10988.

APPEARANCES OF COUNSEL:

(All appearances are via videoconference.)

For Petitioner Western Digital Technologies, Inc.:

ARMOND WILSON LLP
BY: DOUGLAS R. WILSON, ESQ.
MONICA ARNOLD, ESQ.
4685 MacArthur Court, Suite 399
Newport Beach, California 92660
949-386-1341
doug.wilson@armondwilson.com
monica.arnold@armondwilson.com

For Patent Owner Godo Kaisha IP Bridge 1:

WOLF, GREENFIELD & SACKS, P.C.
BY: ADAM WICHMAN, ESQ.
600 Atlantic Avenue, 23rd Floor
Boston, Massachusetts 02210
617-646-8000
adam.wichman@wolfgreenfield.com

I N D E X

WITNESS: JEFFREY BOKOR, PH.D.

EXAMINATION BY	PAGE
ATTORNEY WICHMAN	5

E X H I B I T S

DEPOSITION	DESCRIPTION	PAGE
3	The Japan Society of Applied Physics article Correlation between Barrier Width, Barrier Height, and DC Bias Voltage Dependences on the Magnetoresistance Ratio in Ir-Mn Exchange Biased Single and Double Tunnel Junctions	193

INSTRUCTION NOT TO ANSWER

(None)

INFORMATION TO BE SUPPLIED

(None)

REMOTE DEPOSITION; JUNE 24, 2025
9:09 A.M.

JEFFREY BOKOR, PH.D.,
having been duly administered an
oath remotely by the reporter, was examined
and testified as follows:

EXAMINATION

BY ATTORNEY WICHMAN:

Q Good morning, Dr. Bokor. My name is Adam Wichman. And I represent IP Bridge. Thank you for making time for us today.

A Good morning.

Q Before we get too far, tell me, what is your computer setup this morning?

A What is my setup? Can you be a little more specific?

Q Are you able to manipulate documents?

A Yes. I'm set up on a computer. A Mac computer. There's a directory. Where did it go? There's a -- there was -- hold on. Let me find it again. No. I had a window that showed all the documents that I think you folks sent over. But --

Q Can you pull -- can you keep that window open?
A I'm trying to find it. We opened up Zoom and there's AgileLaw.
ATTORNEY WILSON: It is on the desktop. There's a folder on the desktop.
THE WITNESS: There we go. That folder there. Okay. Good. I got it now. I've got that.
BY ATTORNEY WICHMAN:
Q Great.
A It has, you know, something like a hundred documents or so in there.
Q All right. Let's try to simplify things. For the most part, we will try to work from that file.
A Yeah.
Q I will identify exhibits by exhibit number. And you should be able to find them by the document name and the exhibit.
A Yes. That, I agree, is probably the simplest way to go.
Q All right. So within that folder, can you find a document entitled Paper Number 15.
A Yes.

Q Can you open that document?
A Okay. Patent Owner's Notice of Deposition.
Q Okay. So you understand that you're appearing for deposition today in case number IPR2024-1494?
A That's what it says on this document.
Q I'm asking about your understanding, sir.
A Well, I don't independently know the case number, but I know that I'm here for a deposition about the '909 patent today.
Q The '909 patent. So that is US patent 11,968,909; is that right?
A Yes.
Q Okay. And you just referred to it as the '909 patent. Throughout the deposition today, when I refer to the '909 patent, you understand that I mean the patent that we just identified on the -- on this deposition notice; right?
A Right.
Q Okay. You're appearing on behalf of Western Digital; is that correct?
A Correct.
Q And they -- they retained you to offer expert testimony; is that right?

A Via the Armond Wilson firm, yes.
Q Where are you located today?
A I'm at the offices of Armond Wilson in Newport Beach, California.
Q And I see you're in a conference room. Who else is in that conference room with you?
A Nobody.
Q Okay. Have you been deposed before?
A I have.
Q How many times?
A I couldn't give you an exact number but it's somewhere probably between 20 and 30 times.
Q When was the last time that you were deposed?
A Let me think about that for a minute. It's been a little bit of a while. Probably -- between a year and two is my best guess.
Q Have you --
A I testified recently in an arbitration hearing. Not exactly a deposition. Before that, yeah, it must have been -- it could be as much as two or three years ago.
Q Have you been deposed in a remote deposition before, like we're doing right now?
A You know, I have done it. It was quite a

while ago. It was right in the peak of the pandemic I did one like this. But it hasn't -- that's the last time. It was probably back in, you know, 2020 or '21.

Q So you understand that during this deposition, I will ask you questions; right?

A Sure.

Q And you agree that you will wait until I finish asking my question before you start to answer; right?

A I will do my level best.

Q Well, we have a court reporter, Ms. Silvas, here, who is getting down everything that we say. So it will make her job much more difficult if we speak over each other.

A Yes. I fully understand that. As I say, I've been deposed many times. Even live, we try to avoid talking over each other. So I understand, and I will do -- I will do my level best to follow that protocol.

Q You understand that when I -- when you answer a question, you have to answer verbally so that Ms. Silvas can transcribe the answer. Correct?

A (Witness nods head.)

10

Yes.
Q Will you agree to ask me to clarify a question if you did not understand the question?
A Of course.
Q Okay. Do you understand that during this deposition, I'm going to refer to exhibits?
A Yes. Of course.
Q Okay. And we just -- we just clarified that on the computer in front of you, you have a folder with many, if not all, of the exhibits that we will refer to today from this case; right?
A Right.
Q All right. Do you understand that counsel for Western Digital might object to a question that I ask during this deposition?
A Yes.
Q All right. Do you understand that unless you are instructed not to answer, you still need to answer my question after counsel finishes their objection?
A Understood.
Q Okay. We will try to take regular breaks during this deposition. Roughly on an hourly basis. Okay?
A Yes. Let me just comment on that. I --

I have a senior bladder. And so I hope you will indulge me if occasionally I might need a break sooner than one hour.

Q Well, I simply ask just tell me if you need to take a break. Okay?

A I will.

Q I would like you to agree if we are in the middle of a question and an answer, that you finish your answer before we take a break. Is that acceptable?

A Sure.

Q Okay. Do you understand that once, you know, we begin this deposition, we have begun this deposition, until I finish my cross-examination, you are not permitted to discuss any of the questions or your answers with lawyers for Western Digital?

A Understood.

Q Okay. Do you understand that this -- this rule includes during any break in the examination?

A Yes.

Q Okay. So if we break for lunch or to use the bathroom, you're not permitted to discuss the questions and answers with Western Digital's

counsel; right?
A Understood.
Q Okay. Do you agree not to discuss this deposition with anyone while the examination is ongoing?
A You mean other than Western Digital counsel? Yes.
Q Anybody not involved in the deposition.
A I agree. Yes.
Q What screens do you have open on your computer right now?
A Well, I have a setup with two displays. You want to know what windows I've got? Is that what you're asking? Or the screens themselves?
Q I want to know if you have a chat or an email window open?
A No.
Q Okay. Do you have anything other than the file folder, Adobe, and the AgileLaw, and Zoom applications open?
A No. I do not.
Q Okay. Do you agree not to open any other files or screens during the deposition other than the exhibits that we're discussing?
A Agreed.

Q What did you do to prepare for your deposition today?
A Well, I reviewed quite a few documents. And I met with counsel to prepare based on review of documents.
Q When you say met with counsel, who did you meet with?
A Well, Doug Wilson and Monica Arnold primarily. I briefly chatted with Michelle Armond.
Q Anybody else?
A No.
Q How much time did you spend in preparation?
A Well, probably 20 or 30 hours. It's hard for me to draw a line between the work that I've been doing -- okay. Since I prepared my declarations, I suppose all -- all the work that I have done since then would be considered in preparation for this deposition. So probably 40 hours or more.
Q How much time have you spent working on this particular dispute involving the '909 patent?
A Oh, I don't have that number handy. It's been over a year. I couldn't give you a number

for that. I would have to go back and review my invoices.

Q But you invoiced your time on this; is that right?

A Yes.

Q And have you been paid in excess of $50,000 for your time on this case so far?

A Probably not in excess of 50,000. It could be close -- it could be close to that. I don't remember for sure. To give a definitive answer, I would have to go back and review the invoices.

Q Can you give me a ballpark?

A That is the best ballpark that I can give you. 50K, plus or minus.

Q Okay. Dr. Bokor, I wanted to go through your CV for a little bit, if I could. And I wanted to ask you about some of your work. In particular, I'm interested in Paper 202 which is on your CV, which is 1025.

A Okay. Give me a moment to open that, please.

Q It is also PDF page 24.

A What number was that again, the number of the document?

Q The document is Exhibit 1025.
A Oh, sorry. The number on my CV. The number for my paper that you wanted to ask me about.
Q 202.
A See that, I already spoke over you once. I'm going to do my best to avoid doing that.
200 and --
Q Two.
A Two. Okay. Hisamoto. Yes.
Q So it is a paper entitled "FinFET - A self-aligned double-gate MOSFET scalable 20 nanometers." Right?
A Right.
Q This paper is interesting. How many times has this paper been cited?
A I don't know. We would have to look it up on Google Scholar. It's a well-cited paper.
Q Would you be surprised to know it was cited 2,459 times?
A No, I would not. It is a famous paper.
Q So this work that you did in this paper, is that sponsored by DARPA?
A In part.
Q In your CV at page 7, you list among your

professional associations, services, and awards a DARPA Most Significant Technical Accomplishment Award for 2000; right?

A Page 7?

Q Page 7.

A That's right. In 2000.

Q DARPA, D-A-R-P-A, that's the Defense Advanced Research Projects Association?

A Agency.

Q Agency. Agency. Yeah.

Was that DARPA award in 2000 related to the work that you published in this paper on FinFETs?

A Related to. We publish quite a few papers. The award wasn't specific to one paper. It was specific to the body of work.

Q Okay. What made that paper so significant or that work so significant?

A Well, it was a significant breakthrough in the technology used to scale CMOS transistors for use in high-performance microprocessors and other large-scale integrated circuits. And we -- we were the first to clearly demonstrate a new technology called FinFET, which was pretty radical at the time. At that time, CMOS transistors were

fabricated in a so-called planer process. And we showed how to relatively efficiently manufacture -- we showed a pathway to manufacture a much more scalable transistor in which the transistor body was no longer a flat plane on the surface of the silicon wafer, but a fin protruding out off the surface. And we showed how to make a transistor out of a fin like that. Which enabled ultimately the semiconductor industry to extend the scaling, the increase in the number of transistors on a silicon chip dramatically. And, in fact, it turned out indeed to have a huge impact on the industry. Now, still today, every integrated -- advanced leading edge integrated circuit, like the chips in your phone, in your computer, the chips that are in the data centers that are doing all the enterprise computing today all use transistors that are called FinFETs.

Q So when you say that the paper was a significant breakthrough, it was a significant breakthrough for all of the reasons that you just listed?

A I think so, yes.

Q When you say it is a famous paper, is it because of this significant breakthrough or

these -- I should say significant breakthroughs, plural?

A Well, one -- one way to answer that is it is a famous paper because over 2400 people have cited it. 2400, I think you said, subsequent scientific publications cite that paper. So a lot of people have read it, found it important enough to do work that is inspired by it such that they cite it as a reference in their paper. So that's one reason that it is a famous paper. But it's -- since somewhere in the -- I forget exactly when Intel started manufacturing FinFET-base chips. That significantly increased the notoriety of that paper. Since Intel, they were the first company to start selling commercial chips using FinFETs. It was quite -- quite a noteworthy milestone in the industry. And we get a significant amount of credit for having invented the technology.

Q So would you say that the -- the fact that more than 2400 people have cited in work in their own subsequent academic work is an indication of the significance of the work in your -- in your FinFET paper?

A Yeah. In the academic community, citation counts are currency of impact. So if you

have -- and 2400 is a -- you know, there are papers with tens of thousands of citations or more. So it is not -- by far it is not among the most famous papers ever. But within the integrated circuit engineering community, 2400 is a pretty good citation count.

Q Do you have any other papers that have been cited that many times?

A I -- I don't think so. I would have to check. I have some other pretty well-known papers. But that is probably my most heavily cited paper.

Q If you look at the paper you identified as number 57, this was a paper with Desai. "MoS2 transistors with 1-nanometer gate lengths," 2016.

A Tell me the number.

Q 57.

A 57. Okay.

Q It's the second from the bottom on page 12.

A I found it. Desai and a long list of authors. "MoS2 transistors with 1-nanometer gate lengths," in the Science magazine. I see it.

Q Would you be surprised to know that that has been cited 1,624 times?

A That would not surprise me.
Q Is this one -- is this one of your famous papers? Go ahead.
A That is another famous paper.
Q Famous paper.
Is Science -- is Science considered a high-impact journal?
A By many, yes.
Q So can you explain to me, what is this idea of a high-impact journal?
A Let me try to give a short answer to that. I think to try to make this simple, some journals have -- you know, the number of subscribers has one -- is one factor in the impact factor for a journal. Journals -- in the -- in the scientific publication space, different journals have an identified impact factor, a number. And to be honest with you, I'm not sure all the elements that go into the calculation of that impact factor. The number of subscribers to the journal is one. But I think the citation rate by other academic publications of papers in that journal contribute to the impact factor of the journal, the whole journal. So Science has a high-impact factor because lots of people read

that, subscribe to that magazine. Lots of people -- lots of scientific papers cite other papers that were published in Science. So that also makes it a high-impact journal. I don't know how they calculate, you know, all those different factors and roll them all into the impact factor. But people pay attention to the impact factor of journals in the scientific community.

Q Let me ask you, at one point you were the Chairman of the Electrical Engineering and Computer Sciences Department at Berkeley; right?

A That's correct.

Q Were you involved in hiring faculty?

A Yes.

Q Were you involved in recruiting faculty?

A Yes.

Q Were you involved in promotion decisions for faculty?

A Yes.

Q Did publication records play a role in a hiring decision?

A They play a role for sure.

Q Is it an important role?

A Yes.

Q And do publications play a role in

promotion decisions?
A They do.
Q Is it an important role?
A Yes.
Q And if a candidate had published in a high-impact journal, how would that have affected his candidacy for hiring?
A It would have a positive impact.
Q And if a candidate had been cited more than a thousand times in a high-impact journal, would that weigh in favor of promotion?
A That's fair to say.
Q How did you value these numbers of -- you know, number of citations in a high-impact journal?
A Well, personally, I'm -- I weigh that a little bit less heavily than many others. Throughout my career, I've been involved in making these kinds of evaluations. You can go back through my CV and see other experience I have where you could guess that I had a lot of say in hiring and promotions. Typically those hiring and promotion decisions are for people whose work is close enough to mine that I can understand the details. And so I like to put much more weight on

my own personal evaluation of the creativity, the significance, and the impact of a given scientist's publications rather than popularity, which is really what citation count.

Q So would you value work that had led to industry adoption and development of a new type of device like you described happening for your FinFET device?

A Yeah. I would give a lot of weight to something like that. It would be modulated by the creativity. Sometimes a really simple kind of almost obvious advance can make a big impact in industry. I don't say I discount that. But I like to look for work that is, you know, really inspired and creative and radical.

Q There's an article number 11 on your CV here, if you look at the top of -- or the bottom of page 8. Do you see the 2021 Nature article?

A I do.

Q Is this another one of your famous articles?

A Another one. I don't know what the citation count is, but it is probably up there close to the other ones. That's a relatively recent paper. It's gotten a lot of attention.

Q Is Nature considered a high-impact journal?
A Yes.
Q Is Nature Materials considered a high-impact journal?
A It is. Not quite. I mean, its impact factor is high, but probably not as high as Nature.
Q Within a technical field, are certain journals regarded as leading publications?
A Yes.
Q Is the IEEE Transactions on Electron Devices considered a leading journal on FinFET design?
A Yes.
Q Is Nature Materials considered a leading journal for magneto-resistive tunnel junction design? Or magnetic -- let me restate that.
Is Nature Materials considered a leading journal for magnetic tunnel junction design?
A It's one of them. Yes.
Q So yes?
A Yes. I said yes.
Q Okay. I want to ask you about your experience with magnetic tunnel junction. When I

refer to a magnetic tunnel junction, is that frequently treated -- strike that.

When somebody says an MTJ, you understand that they're referring to a magnetic tunnel junction in the context of the '909 patent?

A Yes.

Q Okay. So when I say MTJ, you will understand that I'm referring to a magnetic tunnel junction; right?

A Yes.

Q Okay. On your CV, at page 2, you list current research interests that include spintronics; is that right?

A Yep. Yes.

Q Is a magnetic tunnel junction a spintronics device?

A I would say so.

Q Okay. You list classroom teaching, graduate/undergraduate courses in semiconductor physics; right?

A I do.

Q In those classes, do you teach spintronics?

A Yes. I've taught -- I've taught about spintronics in classes.

Q What classes have you taught spintronics?
A We have a graduate class in semiconductor physics, semiconductor device physics. And I have talked about spintronics in that class. I have taught that class and I have talked about spintronics in that class.
Q When did you first start teaching -- strike that.
And when you have taught spintronics in this graduate class on semiconductor device physics, have you taught MTJ design?
A I would have to say my best recollection -- it's been a little while since I taught that class. I probably didn't go into much detail about MTJ design. I probably mentioned MTJ as one of a class of non-volatile memories. I can't recall as I sit here right now how deeply I went into the details of the design of MTJs.
Q And have you taught courses in semiconductor device fabrication?
A I have.
Q And in those courses on semiconductor device fabrication, have you taught the fabrication of an MTJ?
A That class -- again, it's been a couple

years since I taught that class. And I probably mentioned MTJs. But I don't think I went into -- as best as I recall, I don't think I went into much detail.

Q What?

A I have class -- I have class notes, you know, for those lectures. I haven't looked at them in a while. I could figure that out, but I don't recall as I sit here right now.

Q And when you brought up MTJs in these courses, what -- what materials did you teach from?

A What materials did I teach from? In those classes, if -- when I -- whatever I said about MTJs, I didn't -- I probably didn't have, you know, well, review these pages in this textbook. I was probably -- I'm quite sure I was just going by my own understanding that comes from having read a lot of literature. I couldn't point to a single particular one. Like I say, in both in the semiconductor physics and fabrication classes, I would have -- I probably would have mentioned MTJs, said that they were a magnetic memory device, non-volatile. And, you know, that kind of general information. Not citing to some

details that would be useful for the student to go back and read in some textbook or other document.

Q What -- what year did you first teach anything about MTJs in your semiconductor device physics classes?

A I honestly can't remember.

Q Would it have been after 2010?

A It seems likely.

Q Would it have been after 2015?

A Give me a moment. Most likely somewhere around 2015, plus or minus. Like I said, I can't tell you exactly. But 2015 or so looks like a reasonable rough estimate of when I would have first started talking about MTJs in classes.

Q When you were at Berkeley, did -- did the department have regular graduate seminars?

A Sure.

Q Did you have invited speakers?

A We do.

Q Do you recall Shinji Yuasa being an invited speaker in 2012?

A Not off the top of my head. It is quite possible. I might have even been at that talk. I can't remember for sure. 2012. That's a while ago.

Q So you don't recall speaking to Dr. Yuasa about MTJs in 2012?
A I don't have a specific recollection of that. Does he?
Q Did you sponsor that lecture by Dr. Yuasa?
A So there is a weekly graduate seminar -- actually, it is not limited to graduate students. We have a weekly seminar on solid state devices and technology. And for probably the entire time that I've been at Berkeley or close to it, I've been one of the faculty sponsors of that series. So in one sense, if you ask would I have been a sponsor of that talk, if he gave that talk at the solid state devices and technology seminar, I would have been a sponsor. Now, we have probably ten faculty who are sponsors of that seminar. I don't have a specific recollection if I was there for that seminar. Whether I went to lunch with him. Whether I met him or not. I can't remember any of that. Sometimes I -- you know, most speakers are invited by one or two of the faculty sponsors. It's possible that I invited Huwasa. I don't have a specific recollection of that one way or another. But I couldn't rule it out either. I

might very well have done that. I -- I don't think so, but it's possible.

Q Have you ever made a magnetic tunnel junction?

A So I don't make devices myself with my own hands. I haven't done -- I have in the early days of my career. When I was -- before I joined the faculty at Berkeley, I was an engineer at Bell Laboratories where I had a lab. And I went in that lab and I did my own experiments and fabricated structures and devices. It's not an absolute rule, but the vast majority of university professors -- I'll just talk about what I know for sure, electrical engineering -- I think this is actually true in a much broader context. Faculty generally advise graduate students who fabricate devices and make measurements and go in the lab and do things. And I advise them. So since I've been at Berkeley, I don't think I have made any devices since 1993.

Q When is the last time that you stepped into a clean room?

A Oh, I go in the clean room. I can't tell you exactly. Within the past few years, I've been in the clean room. I have a private laboratory,

which is not a clean room, for fabricating devices where measurements are made. And I -- I haven't been in that lab since July 1 of 2004, which is when I retired from the faculty and gave up my lab. But before that, I would go in that lab probably at least once a week. Sometimes -- every day for periods.

Q Is it fair to say that your hands-on bench work is more in characterizing solid state devices than fabricating solid state devices?

A I worked on doing device fabrication when I was at Bell Labs.

Q Okay. Sorry.

A My hands on -- my hands-on experience covered both.

Q So with regard to MTJs, is your experience more characterizing MTJs or fabricating MTJs?

A So as I just said, whether it is fabrication or characterization, I supervise others --

Q Uh-huh.

A -- with hands-on work.

Q Can you tell me what is your experience in designing MTJs?

A I have some experience in designing MTJs. I can't say that I -- no, that wouldn't be true. I have some experience in designing MTJs. Supervising students who fabricated MTJs or devices very -- very much like MTJs. I have some. I don't know how to characterize how much.

Q On your CV then, Exhibit 1025, can you point me to a project that was the first time that you designed an MTJ in any capacity?

A Probably. It's a paper from 2016.

Q What paper is that?

A Number 56. First author, Hong.

Q Okay. Paper number 56 was published on IEEE Transactions on Magnetics, volume PP in 2016; right?

A That is probably a typo. That's -- there should be a volume number there. I just noticed that. I just noticed that typo.

Q So tell me, in the -- in the MTJ that was involved in that work, was it a three-layer device?

A Most likely. I don't remember the details of the design as I sit here right now. I would have to look up that paper. But yeah, it would have been -- I don't recall. I'm going to

have to say I don't recall the design, whether we had more than three layers, pinning layers and so forth. I can't recall exactly what the design of the MTJ was in that paper.

Q What materials did you use for the bottom ferromagnetic electrode?

A I don't recall.

Q What material did you use for the barrier layer?

A I don't recall.

Q Okay. How did you learn how to make an MTJ?

A You can see I had a co-author there. The last author there is Khizroev. He was -- he was the key expert in design -- how to design it -- I learned how that device was designed from him.

Q So before 2016, you yourself had not designed an MTJ?

A I had not designed an MTJ that was -- that subsequently we fabricated and tested, that's for sure.

Q Did you design an MTJ in any capacity before 2016?

A So it kind of depends on what you mean by design. You know, if I sat down and sketched on a

paper, on a sketch pad what an MTJ looked like, it probably was before that. To do a design sufficiently detailed to use to fabricate something, probably not.

Q Have you ever designed or chosen the process steps to fabricate an MTJ?

A In collaboration with others, yes.

Q And when you say in collaboration with others, you're referring to working with Dr. Khizroev in this 2016 work?

A At least. I think there were people working together with him that participated as well.

Q And in that capacity, did you ever suggest using one material rather than another for ferromagnetic electrode?

A I don't recall specifically in that particular instance. But I think highly likely that we talked about what would be the materials available, who had -- who had what targets in their sputter chamber and so forth. That certainly would have been a discussion.

Q You list as one of your major research accomplishments demonstration of a 7 nanometer magnetic memory using scanned probe magnetic

tunnel junction readout in 2018. Is that right? It's on page 3 of your CV.

A I see that.

Q Was this related to the work in 2016 with Dr. Khizroev?

A I think it was a different -- I think that was with Khizroev. But that is referring to a different publication.

Q Is it referring to publication number 45?

A No.

Q Is there a publication associated with that work from 2018?

A I think I'm referring to publication 41. No. Wait a minute. That's not --

Q All right. Dr. Bokor, can I ask a different question?

A I'm on the verge of answering this last one, if you give me one moment.

So I think the paper -- the 2018 paper that I'm mentioning there is number 41, which doesn't include Khizroev. "Self-assembled single-digit nanometer memory cells." If I recall correctly, those were a form of MTJ devices.

Q Did the MTJ devices in that work have three layers?

A I think so.
Q Do you recall what the layer of materials were?
A I do not.
Q Do you recall who decided what materials to use?
A Well, that would have been a decision I think all four co-authors participated in. I think Dr. You was the lead on the fabrication.
Q So what was your role on that project?
A Well, I was the -- I was the leader of the project. One of the leaders of the project. A collaborator. We met -- I can't remember whose idea initially it was to do that project. Probably Hong, the first author. And then we had meetings to discuss the project, what -- what we had the capability to do, what we would do, how it progressed along, how the progress was going. I participated in all of the discussions as the project evolved and including analyzing the data and writing the paper.
ATTORNEY WICHMAN: Okay. All right. Dr. Bokor, why don't we take a five-minute break. Is that enough time for people -- for you to use the bathroom if you need to?

THE WITNESS: That will work for me.
ATTORNEY WICHMAN: All right.
THE REPORTER: That's fine.
ATTORNEY WICHMAN: Let's go off the record for five minutes. Let's come back at five past the hour.
(A recess was taken.)
ATTORNEY WICHMAN: Back on the record.
Q Dr. Bokor, go back to your 2000 FinFET paper and transactions on electric devices. On your CV, at page 6, you list a number of patents that you have received. Do you see number 10? You list a patent number 600413802.
Let me restate that.
On your CV, at page 6, number 10, US patent number 6,413,802. Is that right?
A Yes, I have that. I see that.
Q Yeah. Is that patent related to the work that you published in your IEEE Transactions on Electron Devices paper in 2000?
A It is related in the sense that it does claim FinFETs.
Q So this was one of your famous papers; right?
A This is a patent. You're asking me about

the patent?
Q I'm asking you about the paper now. So the paper, the 2000 paper in Transactions on Electronic Devices, we talked about that. That is one of your famous papers?
A I remember talking about that.
Q Yeah. And you said that Intel went and commercialized FinFETs that you had developed and described in that paper; is that right?
A Correct.
Q And you obtained a patent on that same FinFET subject matter that you described in part in that paper; correct?
A Correct.
Q Okay. Can you open Exhibit 1026, please. Let me know when you have it.
A 1026. Bowen. Yes. I have it.
Q So you cite this paper in your declaration in this case; right?
A Yes.
Q So we will call -- when I refer to Bowen, I'm referring to this paper, Exhibit 1026. Okay?
A Fine.
Q So Bowen fabricated an MTJ with three crystal layers; right?

A Yes.
Q So the bottom layer was a crystalline iron layer that was oriented in 001; is that right?
A Yes.
Q And for a barrier layer, he grew a single crystal magnesium oxide that was oriented in 001; is that right?
A Yes.
Q And for the top ferromagnetic electrode, he grew an iron cobalt layer; is that right?
A That's my understanding, yes.
Q Okay. And he grew this tri-layer device epitaxially; is that right?
A That's what he says.
Q Do you have any reason to doubt him?
A No.
Q So Bowen characterized this device by estimating a barrier height for the magnesium oxide layer; is that right?
A That's my understanding, yes.
Q So if you look at Bowen page 1656, which is PDF page 3, Bowen fit something called the Simmons equation for tunneling current density; is that right?

A We're on page 1 -- sorry. Which page are we on?
Q Page 1656.
A Uh-huh.
Q The left-hand column, first full paragraph halfway down. Do you see the sentence starting with "The temperature dependence of I(V) curves?
A I see it now, yes.
Q Okay.
A Mentioned right there. Yes.
Q So Simmons' equations yield -- what he writes is, "Simmons' equations yield by approximately 1.1 electron volts for a barrier thickness d in approximately 15 angstroms."
A That's what it says.
Q And phi is the representation of barrier height in the Simmons model; is that right?
A That's my understanding, yes.
Q And here, Bowen is using phi to represent barrier height; is that right?
A Yes.
Q Okay. So fitting -- he also says -- sorry. If we -- he did this fitting at a -- for a bias of 10 millivolts; right?

It is the previous sentence. I'm sorry. One -- okay. Let me start over.

If you look in Bowen at page 1656, in the left-hand column, first full paragraph, the -- one, two, three -- fourth sentence down, it starts with "As shown in Figure 2(a)."

A Right.

Q Do you see that?

A Yes.

Q "The resistance of our MTJ (at 10 millivolts) saturates below 50 K." Do you see that?

A Yes.

Q Would you call that -- is that a low voltage -- a low bias voltage for the Simmons model?

ATTORNEY WILSON: Objection. Form.

THE WITNESS: I would -- 10 millivolts, that's fair to say that is a low voltage for an MTJ.

BY ATTORNEY WICHMAN:

Q The 10 millivolts if you were using the Simmons equation, you would use the low-voltage equation; is that right?

A That sounds fair.

Q And you understand that that's what Bowen did to obtain his estimate of 1.1 electron volts for the barrier height?

ATTORNEY WILSON: Objection. Form.

THE WITNESS: Well, that's -- that's a little bit of a confusion of the way I read what it says here.

BY ATTORNEY WICHMAN:

Q Tell me how you read it.

A Where he says Simmons equations -- okay. He -- if your question is did he use the low-voltage limit of Simmons equations to arrive at that barrier height, that -- that I would -- I think is fair. The way he -- so he gives an experimental barrier height of .9 eV, which is the one that he got using the 50 millivolts on the device. Sorry. The 10 millivolts on the device. So maybe I could ask you to repeat that question.

Q Well, let's do it this way: You see where he says -- Bowen says, "The temperature dependence of I(V) curves places the barrier height at Fe equals .9 electron volts"?

A I see that.

Q You understand that to mean that Bowen applied a I(V) and he measured current through the

MTJ device at different temperatures?
A That would be my understanding of that sentence.
Q And using that information, he estimates the barrier height as .9 eV; is that right?
A Right.
Q And then he also fit the Simmons equation to estimate barrier height; right?
A He used the Simmons equation to estimate barrier height, yes.
Q And when he did that, the barrier height estimate he determined was 1.1 electron volts; right?
A Right.
Q Approximately.
Okay. So if you look at page 1657 of Exhibit 1026, in the top right column. Do you see that?
A 1657.
Q The last page, yeah.
A Okay.
Q All right. On the right-hand column first full paragraph, it starts with "In conclusion." Are you there?
A I'm there.

Q Okay. If you go down, do you see the sentence that begins "Transport measurements show"?
A I see that.
Q So he -- so Bowen says that "Transport measurements show 27 percent TMR at 300 K which increases to 60 percent at 30K." Is that right?
A Right.
Q Okay. So 300 K, that's 300 Kelvin; right?
A Yes.
Q It is approximately 80 degrees Fahrenheit?
A Approximately what?
Q 80 degrees Fahrenheit?
A 300 K is 80 degrees Fahrenheit? I'll take your word for that. I would have to do the calculation.
Q 300 Kelvin is room temperature; right?
A It is about room temperature. 80 sounds a little high. I could calculate it. I'll take your word for it. It sounds a little high for 300 K, but whatever.
Q And 30 Kelvin is a cryogenic temperature; right?

A Correct.
Q Approximately negative 405 degrees Fahrenheit?
A Again, I'll take your word for that.
Q Liquid nitrogen at a standard atmosphere it liquifies -- it condenses into liquid at 77 Kelvin.
A Correct.
Q And liquid helium condenses into a liquid standard atmosphere at a temperature of 4.2 Kelvin; right?
A I do -- I'm aware of that, yes.
Q Okay. So 30 Kelvin, where Bowen made his measurements, is somewhere between liquid helium and the boiling point of liquid nitrogen; right?
A That is correct.
Q It's cold.
A Fair enough.
Q Okay. So --
A I don't know what -- the Fahrenheit temperature that that corresponds to without making a separate calculation. I could do that easily. But I -- you cited a temperature in Fahrenheit. That doesn't instantly click for me. But I don't doubt that you got the right number

there.
Q So Bowen is telling us that at room temperatures, his MTJ had a TMR of 27 percent; is that right?
A I believe that's basically the -- the gist of what he is saying.
Q Okay. If Bowen had achieved a barrier height of .85 electron volts, what would have been the room temperature TMR?
A If Bowen had obtained a barrier height of -- say that again, please.
Q If Bowen had achieved a barrier height of .85 electron volts, what would have been the room temperature TMR?
A So you're saying if the barrier height was .05 eV less than the one he measured, you're asking what he would have got for a -- for a TMR?
Q Yes.
A I can't answer that question. I don't know. I didn't -- I don't know. I don't believe he gives data on that in the paper.
Q Why -- why can't you answer the question?
A Because I don't think Bowen's paper tells us.
Q What would a person of ordinary skill in

the art expected the TMR to be?
A I -- I don't know. Well -- wait. Let me -- let me clarify that. I don't think a person of ordinary skill in the art at the time of this publication, 2001, would have been able to make that calculation.
Q Why not?
A The temperature dependence -- sorry. The -- the theory for that -- there was no reliable theory for that in the art, as far as I understand, in that time.
Q And what about in 2004?
A I would say it was similar. Your question is what TMR would they have expected, if I recall correctly. Is that right?
Q Let me ask again. In 2004, if Bowen had -- strike that.
If Bowen had achieved a barrier height of 0.85 electron volts for his MTJ, in 2004, what TMR would a POSA, person of ordinary skill in the art, have expected that device to provide?
A I think my -- my opinion in 2004, a POSA would have -- the only way that a POSA could have answered that question is doing the experiment. Expecting on the basis of theory, my -- my

understanding of the state of the theory at that time was a POSA would not have been able to reliably make an estimate of what that should have been.

Q Why not?

A I just said, I don't think the theory was sufficiently detailed and -- there wasn't adequate theory that could reliably make that depiction as far as I know at that time.

Q If Bowen had achieved a barrier height of 0.85 electron volts for his MTJ in 2004, would a person of ordinary skill in the art have expected the room temperature TMR to increase from 27 percent?

A A person of ordinary skill in the art at that time would not have been able to make a definitive determination of that. They would have expected -- it is reasonable to expect that the TMR would change. But I think that's the best they could do at that time.

Q In 2004, which direction would a person of ordinary skill in the art have expected the TMR to change?

A I think it would have been uncertain at that time.

Q Why do you say that?
A There -- as far as I know, there wasn't sufficient information in the -- in the -- sufficient published information in the literature to definitively indicate one way or the other.
Q In order to make this determination, what would a POSA have needed to know?
A They would have needed to know the detail dependence of TMR on barrier height.
Q And that was not known in 2004?
A Not definitively.
Q Explain.
A A person of ordinary skill at that time I believe would have had -- based on literature, they would have had an expectation that the TMR would depend on barrier height. But the -- the way that -- the detail mathematical dependence of barrier height on TMR was not definitively known or how to calculate it in detail. It might have been known how to calculate it, but it wasn't published. So there were theorists at the time who probably could have made that calculation, but I'm not aware of any publication where they explicitly gave that dependence. So a person of ordinary skill in the art I don't think would have

been able to make that calculation.
Q So what would a person of ordinary skill in the art in 2004 have expected the TMR of Bowen's device would have increased if Bowen had achieved a barrier height of .85 electron volts?
A I'm sorry. Please repeat one more time.
Q Okay. Let me break it up into little pieces here.
In 2004, if Bowen had achieved a barrier height of .85 electron volts, would a POSA have expected the TMR of Bowen's device to have increased from the 27 percent TMR that Bowen observed at room temperature?
A It is my opinion that a POSA would not have had sufficient information to definitively decide what direction the TMR would have gone.
Q And would they have had an expectation on which direction TMR would have changed even if that expectation was not definitive?
A What I'm saying is I think a person of ordinary skill in the art at the time would have had a reasonable expectation that the TMR would change. But it would be not -- they would not be able to be certain which way it would go, whether it would go up or it would go down. I think it

was understood that TMR could change as a function of barrier height. But the details -- how it depended on the details of the MTJ structure, how it depended on a whole variety of parameters was not fully understood.

Q What other --

A So that -- so that person of ordinary skill wouldn't be able to have a definite expectation one way or the other.

Q So a person of ordinary skill in the art in 2004 could not have said that the TMR would have increased or decreased; is that right?

A That's what I'm saying.

Q So a person of ordinary skill in the art in 2004 could not state the TMR -- could not exclude the possibility that the TMR would decrease; is that right?

A That's right.

Q And a person of ordinary skill in the art in 2004 could not say that TMR would have increased; is that right?

A That's my opinion.

Q So your testimony is that a person of ordinary skill in the art in 2004 would have thought something would have changed for the TMR

value, but they wouldn't know if it would go up or down?

A For Bowen's specific device?

Q Right.

A Right.

Q Okay. And you referred to the whole variety of parameters that were not fully understood. Tell me what some of those parameters were that you have in mind?

A The composition of the layers, the band structure of the layers, the thicknesses of the layers, crystal structures of the layers. Even with that, it was -- it was not -- it was not easy to make that calculation. A person of ordinary skill in the art in 2004, in my opinion, did not have the capability to make a calculation to determine which direction the TMR would go, even if they knew all the details of the -- of the structure of the MTJ. That's my -- that's my opinion.

Q Let me ask in terms of a reasonable expectation. Would have a POSA have a reasonable expectation that the TMR of Bowen's device would increase if Bowen had achieved a barrier height of .85 electron volts?

A It would have had a reasonable expectation.
Q Why?
A Because there are only two choices. It could have gone up. It could have gone down. And so a person of ordinary skill in the art would have a reasonable expectation that if their goal was to increase the TMR, it would be worth a try to lower the barrier height.
Q Is it your testimony that the person of ordinary skill in the art would have a reasonable expectation that the TMR would change?
A Yes.
Q Okay. Is it equally like -- would they have had a reasonable expectation that it was just as likely the TMR would go down as for the TMR to go up?
A I think so.
Q You're not sure?
A I think so. I think they would have had just -- to them, it would have -- it would have been hard to determine -- they wouldn't have had the capability to determine whether it would go up or down. But since it has to either go up or go down, it's reasonable -- it is a reasonable

expectation for it to go down. Now, just as -- just as likely to go up, but it is reasonable to expect it to go down.

Q If Bowen had achieved a barrier height of 0.80 electron volts in his MTJ, would a POSA in 2004 have expected the TMR of Bowen's device would increase?

A It is the same answer. No difference for .8 compared to .85.

Q No difference in terms of what?

A My answer.

Q Your answer. Okay.

A They would have the same -- the expectation that it might go up or it might go down.

Q Equally likely to go up as to go down?

A A POSA at that time I think could not have determined what the likelihood is in either direction. So in that sense, it would be equally likely.

Q If Bowen had achieved a barrier height of .75 electron volts in his MTJ, would a POSA in 2004 have reasonably expected the TMR to increase from the 27 percent room temperature TMR that Bowen estimated?

A They would have -- I believe a POSA would think it was reasonable for it to go down. Yes.
Q Would the -- the POSA would have thought it would be reasonable for the TMR to go down?
A Go up -- be careful. Be careful. You question -- please repeat your initial question.
Q I'm sorry. Ms. Silvas, are you able to repeat my last question.
(The record was read back as requested.)
THE WITNESS: My answer to that question is yes.
BY ATTORNEY WICHMAN:
Q Why?
A Same answer as I gave before. It's reasonable to expect that it would go -- the TMR would go up. Because the TMR could only go up or go down. And so it is reasonable to expect either way. I think a person of ordinary skill at the time would have a reasonable expectation that the TMR would change with the barrier height. It was not possible to predict with certainty or even some degree of probability which way, as far as I'm aware. So yes, the TMR is very, very likely to change. But which way it will go was -- was

not possible for a TMR to determine that with precision or with definitive. They couldn't assign a probability, I don't think. It could have gone up. It could have gone down. Reasonable to expect it's going to go down. Let's give it a try.

Q If Bowen had achieved a barrier height of 0.75 electron volts in his MTJ, in 2004, how much would a POSA have expected the TMR of Bowen's device to have changed?

A I don't think they could have made a -- a determination of how much with any degree of confidence. It was known that it would change. But -- my understanding of the state of the theory that was understood by a POSA at that time, they didn't have a theory that was sufficiently workable for a POSA to be able to make that calculation.

Q So is your testimony that a person of ordinary skill in the art in 2004 would have expected the TMR of Bowen's device would change if Bowen's barrier height changed, but that person of ordinary skill in the art could not say which direction the TMR would change and it could not say how much the TMR would change?

A Not quantitatively, no.
Q Not quantitatively that that is your opinion or not quantitatively that they --
A They wouldn't have quantitatively determined how much, including the sign, up or down.
Q Okay. If Bowen had achieved a barrier height of 0.70 electron volts in his MTJ, would a POSA in 2004 have expected that Bowen's TMR would have increased from 27 percent at room temperature?
A My opinion of the barrier height is the same. They would have had a reasonable expectation that the TMR could go up. It was reasonable to expect that the TMR would go up. By how much, I don't think anybody could calculate that in 2004, including the theoretical experts. But it was reasonable to expect that the TMR would go up. It might go down. But it was reasonable enough to go -- that it would go up, which would have been the desire of a -- of many at the time. Increasing TMR was a strong motivation for many in the art. And it would have been reasonable to try reducing the barrier height to increase the TMR.
Q So I just want to understand. You told

us that the person of ordinary skill in the art could not expect that the change would be up or down with any certainty. Is that right?

A Correct.

Q Okay. So when you say that it would have been reasonable for the POSA to have expected the TMR to increase, what you mean is something had to change. And it was as likely to be -- that the TMR went up as for the TMR to go down. Is that your testimony?

A Roughly, yes.

Q Well, explain it to me. If I'm not -- if I'm not understanding your testimony correctly, please -- please clarify.

A I think you're understanding my testimony.

Q Okay. So what -- other than the fact that the TMR had to change, what basis would a person of ordinary skill in the art in 2004 have had for expecting that the TMR would increase if Bowen's barrier height were lowered?

A I just said they had reasonable -- reason to expect that the TMR would change. It could go up. It could go down. That's what they -- that's what -- so because it would be of such

1 considerable value for the TMR to go up, a person
2 of ordinary skill would be motivated to do the
3 experiment and see. Bowen didn't do that. But a
4 person of ordinary skill, looking at Bowen, as
5 well as the rest of the literature at the time,
6 would have reason to expect that if you change the
7 barrier height, there's a good chance that you
8 will get an increased TMR.
9 Q And what literature would have given the
10 POSA that expectation?
11 A That the TMR would change?
12 Q You said TMR would increase.
13 A Well, okay. So I'll -- that will take me
14 some time to dig up.
15 Q Did you provide testimony on this issue
16 in your declaration?
17 A I'm pretty sure. So you'll have to give
18 me a little time to go through my declaration to
19 see where that's discussed. Okay?
20 Q I'm sorry. Dr. Bokor, are you looking
21 for this part of your declaration?
22 A Yeah.
23 Q Your testimony. Okay.
24 A Okay. So the way I -- the way I think
25 about that question is the following: If we go to

Exhibit 1038, that's a paper from Moodera.
Q 1038, you said?
A Yeah. And I'm looking at page 4728.
Q Give me a minute. So Exhibit 1038, page 4728. Where should I be looking?
A So Moodera says in -- if you go to the first full paragraph in the right-hand column, it starts with "The MR shows." And a little bit farther down -- one, two, three, four, five, six, seven, eight, nine, ten, eleven, twelve.
"Many causes can contribute to the decrease in the MR with bias. Among them, the bias dependence of the barrier height, creation of magnons, density of states effects in the FM, et cetera, may be responsible for the decrease in delta R over R."
So this is telling the POSA at least in some circumstance the delta R over R, the magnetoresistance could depend on barrier height. Now, in this experiment, he relies on the bias dependence of the MR to make that suggestion.
Now, the way that Moodera is -- what he is talking about is in varying the bias -- in varying the barrier height with bias is one -- it has to do with when you apply bias, the barrier

takes on a triangular shape so that the barrier across the insulator, across the MgO, the barrier is not flat. There's a variation of barrier. It goes down as you go through the MgO. It takes on a slope. So when you apply a bias, the average barrier height through that barrier is reduced because it is reduced by the bias, by some considerable amount. So that could change the -- the MR because the electrons are tunneling through the barrier with a lower barrier height. On the average in the MgO.

Now, a person of -- a POSA would then combine this teaching, that the barrier height in that context -- change the barrier height in that context could lower the MR. But then they would be aware of Butler.

So let me pull up Butler. Butler, Exhibit 1044.

Actually, one moment. Let me instead go to my declaration, the 909 declaration. Paragraph 68. Let me know when --

Q Go ahead. I've got it right here.

A Paragraph 68 says that "MgO has the special property that tunneling is governed by the majority (parallel) spin electrons." That's a

citation to Klaua.

Then it goes on, "Research groups led by Butler (Exhibit 1044) and Mathon (Exhibit 1046) in 2001 calculated optimistic TMR ratio is in excess of 1000 percent for an MgO barrier. Mathon at the Abstract; see also Butler at page 1, Figure 16." And also it cites to the Dieny textbook. "Their research established that a thin MgO barrier passed delta-1 electrons while largely blocking other electrons having opposite spin -- leading the way to high TMRs." Let's just finish out this paragraph. "As a 2001 paper by Klaua explained, unlike amorphous for aluminum oxide barriers, for crystalline MgO barriers: 'The tunneling resistance for the parallel orientation of the magnetic moments is estimated to be 100 times smaller than that for the antiparallel orientation of the magnetic moments due to the absence of scattering in the barrier.'"

So what I'm saying here is that it was understood that MgO was a special -- had special properties with regard to MR that depended on the detailed band structure of the MgO. MgO barrier selectively passed delta 1 electrons. Those are polar -- those are electrons polarized --

63

polarized electrons are selectively passed in the MgO while electrons have the opposite spin are blocked.

Now, a person of ordinary skill would understand that the details of the MgO band structure are energy dependent. The bands have dispersion. And depending on what energy we're looking at, the bands can vary. And in particular, one also understood from Butler that the parallel orientation of the magnetic moments having selectively being passed was -- was rather general throughout the MgO barrier. But what a person of ordinary skill in the art, other than Butler or people in his group, would have had a hard time understanding -- hard time predicting what would happen to the blockage of the antiparallel electrons as a function of energy within the MgO.

So a person of ordinary skill understanding as best they could with their skill in the art, understanding Butler, would have a reasonable expectation that if you vary the barrier height, not by the way that Moodera did it, by tilting the barrier through the MgO, but by changing the position of the Fermi level of the

metal relative to the MgO band structure. That's what, for example, barrier height means in Simmons. So by varying the position of the Fermi level relative to the MgO band structure, a person of ordinary skill would have a reasonable expectation that that blocking would be energy dependent and could be more effective with a change in barrier height.

And a person of ordinary skill would not have the ability, in my opinion, to make the detailed calculation to decide whether it will go up or down. Maybe Butler could have done that. But Butler had skill far beyond that of a POSA at the time, in my opinion.

So that's my basis for saying that a POSA would have a reasonable expectation for thinking about change of barrier height from Moodera. And then going and looking at Butler and saying what happens in Butler if I change the barrier height by moving the Fermi level relative to the MgO band structure?

That's a long explanation. I apologize. But it's -- that's -- that's my opinion of how a POSA would have considered this at the time.

Q Let me ask a few questions.

A Are we close to a good time for a break? Do you want to ask a couple questions or take a break now?

Q Fair. Let's go for a few more minutes and then take a break.

A Okay.

Q First, when a bias is applied across an MTJ and the Fermi level on one side lowers, the Fermi level in one ferromagnetic electrode lowers relative to the other, in your description, that will increase the barrier?

A No. That will decrease the barrier.

Q That will decrease the barrier.

A What Moodera is talking about that the barrier decreases with bias is that the average barrier through the MgO, it is now a function of distance through the MgO. You've got a lower -- lower bias on the second electrode. So the barrier -- let me back up. When there is zero voltage across the barrier, the two Fermi levels on either electrode are the same energy. And then there is a barrier from the -- from either side to get into the conduction band of the MgO. The barrier on either side, if the materials are the same, is the same. So for simplicity, let's just

assume that the Fermi magnet on either side is the same. We can modify that if we have different materials subsequently. So the barrier -- the energy of the conduction band in the MgO then is independent of distance. It's the same.

Now, once you apply a bias to lower the Fermi level on, let's say, the -- the second ferromagnet, the position of the Fermi level for each of the ferromagnetic relative to the MgO band structure is in the same place. Instead, what we have is an electric field causing the conduction bandage to vary its position with distance through the barrier. What Moodera is talking about in that case for an electron that tunnels from the Fermi level of the first ferromagnetic passing through the MgO, it is experiencing -- and it -- it goes through essentially the same energy. We're talking about elastic transport. So the average barrier height that that is experiencing as it is tunneling through the MgO is dropping because of that tilt. So that's what Moodera was talking about. And it is reasonable that the -- the MR goes down in that situation.

But Butler, what I'm saying is that if you move the Fermi level for the first

ferromagnetic electrode relative to the MgO band structure, which is what happens when you vary the barrier height by composition or chemical or defects or the like, the barrier height changes because the Fermi level of the metal is move -- is in a different position relative to the MgO band structure. Relative to the conduction bandage of the MgO. So now the physics that Butler was pointing out, that there's this blockage of the antiparallel electrons it is reasonable for a person of ordinary skill to expect that that blocking would not be the same. And that the TMR would change in that case.

Q All right. Let me ask you just a few more questions here.

In Exhibit 1038, this is the Moodera paper --

A Okay.

Q -- you referred to page 4728.

A Right.

Q And in the right-hand column, second full paragraph, the sentence that says, "Many causes can contribute to the decrease in the MR with bias."

A Yes.

Q MR is the TMR, the tunnel magnetoresistance ratio. Is that right? Or I'm sorry. Yeah. The tunnel magnetoresistance ratio, the TMR that we've been speaking about; right?

A Yes.

Q And Moodera is describing a situation where you're saying that there's a bias dependence of the barrier height; right?

A That's what Moodera says.

Q Right. And so Moodera is describing the MR decreasing when the barrier height decreases. Is that right?

A Importantly he calls it the effective barrier height.

Q Why is that important?

A Well, I -- I made my best effort to explain that in my long explanation earlier. But if you would like, I'll try to do it again. The effective barrier height, what I'm talking about is how the barrier height -- how the position of the conduction band relative to the Fermi level of the first electrode is varying with distance from the interface of the first electrode. And so the effective -- the effective barrier height is lowering with bias by that simple mechanism.

Q So does Moodera -- would Moodera have suggested to a person of ordinary skill in the art in 2004 that if Bowen had achieved a lower barrier height, the TMR would have decreased?

A So -- so the lower -- if Bowen had achieved a lower barrier height by having engineered the interface between the lower ferromagnetic electrode and the MgO, if he had lowered the barrier height by, for example, changing the defect density so that the Fermi level of the first ferromagnetic electrode changed its position at the interface relative to the conduction band of the MgO. That is the fundamental definition of barrier height in the art. I could point you to in my declaration where I explain that, if you would like. The fundamental definition of barrier height in this context is the difference in energy between the Fermi level of the metal on one side of the barrier and the conduction band of the insulator on the other side of the barrier. That energy difference was well known could be -- could change for the general case of any insulator. And if the barrier height was varied that way, that would be different than what -- what Moodera was talking

about.
I cited to the Moodera simply to suggest that a person of ordinary skill in the art at the time would have the idea that you could vary the MR. But looking at Butler, which was published subsequent to Moodera, then a person of ordinary skill would look at that and be able to expect, without being able to make a quantitative calculation, that there would be reason to expect the MR could go either way and have at least a 50 percent chance of going up.
Q If you could look at Butler Exhibit 1044.
A Okay. Sorry.
Q Page 1.
A Page 1.
Q PDF 1.
A Got it.
Q Do you see the abstract there?
A I do.
Q Last sentence, "We predict a large magnetoresistance that increases with barrier thickness."
A Yes.
Q Right.
A Right.

Q So that's the actual thickness of the barrier layer; right?
A Correct.
Q And in Bowen, that barrier layer magnesium oxide was 20 angstroms; correct?
A Yes.
Q So what Butler is predicting is that if that barrier level were thicker than 20 angstroms, Bowen would have achieved a higher TMR; is that right?
ATTORNEY WILSON: Objection. Form.
THE WITNESS: Yes. That's what that sentence means.
BY ATTORNEY WICHMAN:
Q Bowen doesn't make -- doesn't describe TMR changing with barrier height, though, does he?
A Bowen did not change the barrier height. He measured it, but he didn't vary it.
Q I'm sorry. Butler. Butler. Let me ask again.
A Please.
Q Butler's theory does not describe the effect of changing barrier height on TMR, does it?
A Butler's paper doesn't explore that particular scenario in the -- in the -- within the

confines of the paper. But my -- my opinion is that a person of ordinary skill reading Butler could understand that there should be an energy dependence on the blockage of the antiparallel electrons such that the MR could go up with decreasing barrier height. At least had a good chance.

Q Would that person of ordinary skill in the art in 2004 reading Butler have thought it was equally likely that TMR would increase as for it to decrease if Bowen's barrier height had decreased?

A I -- to be honest, I'm not completely sure. Bowen -- sorry. Butler is a pretty complicated paper. It's a very advanced level of theory. And I think the answer to the question, I think Bowen -- Butler's theory would have the capability to make that estimate, whether the MR would go up or go down. I consider myself to be a person of ordinary skill. I've read through Butler carefully. I have a hard time being able to hand-wave my way one way or the other.

Now -- so by that -- by that standard, I would have to answer I don't think a POSA would be able to do that either.

Q Okay. Just a few more questions. Because I know you had asked for a break.

But Butler's series is very specific to crystalline iron, crystal magnesium oxide, and crystalline iron sandwiches; right?

A Right.

Q And it's a first principles calculation --

A It is.

Q -- of that device?

Okay. Why would a -- well, and Bowen made crystalline iron, crystalline magnesium oxide, and then crystalline iron cobalt for his magnetic tunnel junction; right?

A Right.

Q Why would a person of ordinary skill in the art in 2004 have thought that Moodera had anything to say about how Bowen's device would work?

A I think it is fair to say that a person of ordinary skill in the art reading Moodera would -- would have that same conclusion. It is hard to -- it is hard to say what Moodera would tell me about Bowen's device.

Q And Moodera was describing MTJs with

aluminum oxide barriers; right?

A Right. I'm saying that Moodera puts the idea in the mind of a POSA to start thinking about how the MR might depend on barrier height. It is just a hint that, hey, think about how a -- changing the barrier height could influence the MR. Now go read Butler and see if you can get any hint there.

ATTORNEY WICHMAN: Okay. Why don't we take a break. It's been an hour. Is ten minutes sufficient? Would you prefer 15?

THE WITNESS: Ten will do.

ATTORNEY WICHMAN: Ten. Okay. So why don't we come back on the record at 25 past the hour.

THE WITNESS: Okay.

ATTORNEY WICHMAN: Okay. Thank you. Ferromagnetic.

(A recess was taken.)

ATTORNEY WICHMAN: Okay. On the record.

Q Dr. Bokor, I want to bring your attention back to Butler, Exhibit 1044, page 1. The abstract. That last sentence, we talked about that before the break. Right. The sentence says, "We predict a large magnetoresistance that

increases barrier thickness." Right?
A Right.
Q Okay. In 2004, if a person of ordinary skill in the art wanted to increase TMR in Bowen's device, why wouldn't they have just increased the thickness of the magnesium oxide barrier?
ATTORNEY WICHMAN: Objection. Form.
THE WITNESS: Well, there's lots of reasons why that -- they might not want to do that. The -- there are many things -- even if, as Butler explains, the TMR could increase, many other parameters of the MTJ device also decrease, which may or may not be useful for whatever application that POSA had in mind.
BY ATTORNEY WICHMAN:
Q So a person of ordinary skill in the art in 2004 couldn't just focus on increasing TMR to improve an MTJ device; is that right?
A Well, that's a pretty broad question. Depend -- depending on the application that that POSA had in mind, that's right.
Q What other considerations would have to be factored into the decision of -- strike that.
What other things would a POSA have had to balance against the idea of increasing TMR?

A Well, the most important one that comes to mind is parameter in the art called RA, which is basically the resistance -- the absolute resistance, not the change in resistance, but the absolute resistance of the junction. In many applications, that's a very important parameter. And that has to also meet certain specs depending on the application. But there are many applications that would increase the MR in a way that was not advantageous for the particular application. That's just one example that I can think of right off the top of my head.

Q So RA is resistance area product of the device?

A Correct.

Q Is that -- and tell me, why does RA product matter to an MTJ design?

A Let me try to answer that as -- I've already shown that I can go long. Let me try to answer that briefly and succinctly.

In an electronic circuit in which the MTJ is incorporated, voltages and currents are applied to the MTJ. The change in resistance has to be sensed by another circuit. And in particular in MRAM, Magnetoresistive Random Access Memory, you

have lots of MTJs and very thin wires that would connect them to other parts of the electronic circuit. The resistance of the MTJ, it becomes a very important relevant parameter to the performance of the overall circuit.

Q Are there any other parameters that a POSA would have had to take into account when deciding how to build or how to -- let me strike that.

What other parameters -- other than resistance area product, what other parameters for the MTJ device would a POSA have wanted to consider when determining the trade-offs for building that device?

ATTORNEY WILSON: Objection. Form.

THE WITNESS: Are we going to stick to just varying the barrier thickness now? Do you want me to give a full -- a full treatise on all of the parameters that a POSA would need to take into account in designing a MTJ? I will if you want, but I have a feeling you don't want me to do that.

BY ATTORNEY WICHMAN:

Q Let me ask, you agree that the designer has to balance -- has to make tradeoffs for the

different performance characteristics of the MTJ; right?

A That is exactly the job of a designer.

Q TMR is one performance metric for an MTJ; right?

A One of -- one of a number, yes.

Q The resistance area product is a parameter that characterizes an MTJ that has to be taken into account in the design; is that right?

A Yes.

Q What -- tell me one or two other important considerations that an MTJ designer would want to account for when balancing against the idea of maximizing TMR.

A Okay. I'll try to just narrow it down to just a few. The size of the MTJ is a critical parameter in many applications. The transverse dimensions are critical. Some of the parameters just have to do with fabrication. So you have to -- you have to be able to fabricate the MTJ. You have to be able to etch it. And etch -- almost every application today for MTJs, or even in 2004, typically require the fabrication of very small MTJs, very closely packed together. And so what materials you use and what their

thicknesses are have a major impact on how small you can make the device, how selectively you can etch and stop etches on particular layers, how close you can pack the MTJs. So that's another consideration, what impact it has on the fabrication.

Q Can I ask, does the manufacturability of the MTJ play into the POSA's thinking?

A If the POSA is trying to design a product that can be -- high volume manufacture, absolutely.

Q So the fabrication process itself is an important consideration; is that right?

A Yes.

Q Okay. I want to return to this -- this idea of different barrier heights in Bowen. But maybe we can try to speed it up. So I want to -- I've -- I think we got to .7. But if the -- if Bowen had achieved a barrier height of .5 electron volts in his MTJ in 2004, would a person of ordinary skill in the art have had any reason to believe that the TMR would decrease?

A My answer to this scenario where you decrease the barrier to .5 eV don't change. Compared to .7 eV. A person -- a POSA have a --

would have -- could have expected the MR to go up or go down.

Now, let me just -- I'll stop there. They could -- they could expect the barrier height to go up or to go down based on, as I said, an understanding of -- of Butler that I think a POSA could get from reading it. Would expect the MR to change with barrier height, up or down. And whether it is .7 or .5, the situation is the same.

Q Is the situation the same if Bowen would have achieved a barrier height of .3 electron volts?

A Not as far as I can tell, no.

Q It's not the same?

A It wouldn't --

Q Let me ask you that again. I think you said would it have changed. Maybe I did.

Is the situation that you described the same, meaning a person of ordinary skill in the art in 2004 would not have been able to state whether TMR would increase or decrease if Bowen had achieved a barrier height of .3 electron volts?

A That's my opinion, yes.

Q Okay. And then if Bowen had achieved a

barrier height of .1 electron volt, would the POSA have expected the TMR to increase or decrease?

A I never considered barrier height that small, so I'm reluctant to speculate about that. You know, once things get that small, other factors could come into play. I'm hesitant to answer that question. I don't think -- I don't think I can answer that question confidently.

Q What other factors would come into play?

A Well, let me just put it this way: If you break that -- if you bring that barrier height to zero -- let me just start there -- now there's no tunneling going on. And the transport through the barrier now is -- undergoes different physics. So as the barrier height gets smaller and smaller, down into the range where the barrier height is comparable to room temperature energy, things are going to change. And I haven't considered what that would mean for MR. But I think that the scenario is different enough that I don't -- I don't feel comfortable as I sit here right now to predict what would happen.

Q And you referred to yourself. But the question is about a person of ordinary skill in --

A Sorry. Please finish your question.

Q Well, I'm just saying your answer is in terms of what you would feel comfortable predicting today. But I'm asking about what a person of ordinary skill in the art would have expected in 2004. Do you think they -- would they have had the same expectation that you just articulated for yourself?

A What I'm saying is I haven't considered how a POSA would think about that scenario. I can't predict what a POSA would expect because I haven't thought about that. And I shared with you some of the reasons why I -- it's different enough that I haven't had -- that I couldn't feel confident projecting even what a POSA would think in that scenario.

Q Let's think about the barrier height in Bowen's device on a spectrum from .1 electron volts to .9 electron volts. Have you got that?

A Yes.

Q Is there any barrier height in that range at which a person of ordinary skill in the art in 2004 would have expected the TMR to fall to zero?

A Bowen's device we're talking about; right?

Q Yes.

A As I sit here right now, I can't think of a scenario where a POSA might expect the MR to drop to zero with barrier height in that energy range. I'm -- yeah. I don't -- I don't -- as I sit here right now, I can't think of any literature that addressed that question that I have reviewed. Based on the literature that we've been talking about so far, I don't -- I don't see anything that would indicate to a POSA that the MR would drop to zero with a hypothetical barrier height for Bowen's device in that range from .1 to .8, I think is your range, or .7 or whatever.

Q .9.

A .9. That -- yeah. The issue is as you go to very low barrier height like .1, I just -- I can't think of any scenario off -- as I sit here right now.

Q Can you open Exhibit 1031.

Just let me know when you have it.

A That's Simmons. Yes. I have it.

Q This is Simmons paper on a Generalized Formula for the Electric Tunnel Effect between Similar Electrodes Separated by a Thin Insulating Film; right?

A Right.

Q Published in 1963?
A 1963. Yes.
Q And that was before magnetic tunneling resistance had been discovered; right?
A I think that's right.
Q When was tunneling magnetoresistance discovered?
A That's a good question. I don't have an answer for that right off the top of my head.
Q Was it Julliere's paper in 1975?
A I can't state with certainty whether that was the first. But Julliere's paper does talk about MTJs.
Q Okay. In Simmons, can you go to page 1794. That is PDF 3.
A Okay.
Q I'm sorry. Yeah. In the top -- on the right-hand column, top paragraph, do you see where it says, "The electronic current can flow through the insulating region between two electrodes"?
A I see that.
Q He identifies two currents. He calls them "a" and "b." Is that right?
Two -- let me strike that.
That identifies two scenarios; right?

A A and B.
Q Yes. And the first one is that "The electrons in the electrodes have enough thermal energy to surmount the potential barrier and flow in the conduction band." Is that right?
A That's right.
Q Is that known as thermionic emission?
A That's fair to say, yes.
Q And does that effect increase as the barrier height decreases?
A It does.
Q Okay. And the second scenario that he describes, B, is that, "The barrier is thin enough to permit penetration by the electric tunnel effect." Right?
A That's what it says.
Q That's tunneling current; right?
A Right.
Q Okay. At what barrier height would a person of ordinary skill in the art have expected thermionic emission at a room temperature of 300 Kelvin to have become a significant portion of the current through Bowen's MTJ?
A I'm not prepared to answer that question just as I sit here. It would require a little bit

of calculation, which I haven't done.
Q Would a POSA have expected thermionic emission to be significant in Bowen's MTJ if it had a barrier height of .33 electron volts?
A I can't answer that question.
Q What would you need to know to answer that question?
A Well, I would have to do some calculations to calculate -- to try to compare the thermotic current to the tunneling current. That would depend on -- yeah. Off the top of my head, I don't have the -- you know, I don't have numbers for that in my head that I could do that calculation in my head. I didn't do it in preparing for this deposition. So I don't know the answer to that as I sit here. I could probably come up with it, given -- given some time.
Q Is this a current effect that is a reason -- okay. Strike that.
Are thermotic emission currents a reason that a POSA would want to -- let me strike that.
Would a POSA have been concerned that lowering the barrier height in Bowen's MTJ far enough would have resulted in a significant

fraction of the current through the MTJ being attributed to thermionic emission?

A Would have a POSA have been concerned about that?

Q Yes.

A I think that's a consideration that a POSA should consider.

Q So would this have been a reason to avoid lowering the barrier height in Bowen's MTJ?

A Well, in the general case, I would have to say yes. I've already said if the barrier height went to zero, then there would be no tunneling left. It would only be thermionic. So certainly that is a consideration that a POSA would need to take into account. And I'm -- I'm not willing to go as far as how -- how low the barrier height has to be before that becomes a significant consideration that a POSA would have to take into account.

Q All right. Would a POSA have expected that a barrier height of .33 electron volts in Bowen's device would have increased the thermionic emission current through the device?

A Would a person -- would a POSA have been -- repeat the question.

Q Okay. If Bowen's device had achieved a barrier height of .33 electron volts, would a POSA have expected that this device with the .33 electron volts would have had more thermionic emission current than the device that Bowen actually built?

ATTORNEY WILSON: Objection. Form.

THE WITNESS: I believe that a POSA would be aware that the thermionic emission current would increase as the barrier height decreases. Now, at .33, would they have -- they would know that the thermionic -- thermionic emission current would increase compared to .9. How significant that would be in their considerations is -- I can't say.

BY ATTORNEY WICHMAN:

Q If a POSA had wanted to achieve a barrier height of .33 electron volts in Bowen's device, how would they have done it?

A Well, that as I explain in my declaration, one way is to follow the teachings of Soukup, which involves fabricating on a barrier with some concentration of vacancy -- oxygen vacancies.

Q How many oxygen vacancy defects would a

POSA have added to Bowen's barrier layer to achieve barrier height of .33 electron volts?

ATTORNEY WILSON: Objection. Form.

THE WITNESS: That information is not available. That -- that's not strictly -- it's uncertain. It's uncertain what -- what -- what concentration of vacancies would be needed to get to that barrier height.

BY ATTORNEY WICHMAN:

Q So just quickly, you referred to Soukup. So when Soukup made its metal -- his metal insulator metal tunnel diodes, he had three -- he had panel devices where he increased the atmospheric pressure of oxygen in the chamber; right?

A Right.

Q And by increasing the oxygen pressure in the chamber, he theorized that there would be fewer oxygen vacancy defects; correct?

A Correct.

Q He calls that a more stoichiometric material; right?

A Yes.

Q And by more stoichiometric, he means the ratio of magnesium to oxygen in his insulator was

closer to a ratio of one to one; right?
A Right.
Q So tell me where Soukup describes the opposite, introducing oxygen vacancy defects rather than removing them.
A He assumes there is a certain concentration of defects to start with that he can decrease. But he doesn't give a -- a prescription for increasing them.
Q But your testimony is that to achieve a .33 electron volt barrier height in Bowen's device, the POSA would have introduced oxygen vacancies to Bowen's magnesium oxide layer; right?
A Well, let's bring up -- let me review Soukup, if that would be --
Q Exhibit 1028. Soukup.
A Actually, what I'm going to do before I go to Soukup is take -- take a moment to review my declaration for any discussion of that.
All right. I've done some review on my declaration and can -- and I'm prepared to address this issue. It would help if you would repeat the question, if you would.
Q So the question that -- there were two questions. I'm not sure which one you're

responding to here. I wanted you to tell me where Soukup describes oxygen defects rather than removing them.

A I -- okay. I lost Soukup. Okay. Okay. I do not see that Soukup gave a prescription for increasing the oxygen defects.

Q So if a POSA in 2004 were to increase oxygen vacancies in Bowen's magnesium oxide layer, how would they have done it?

A Well, there are a number of ways I think they could have done that. They could have used deposition parameters for the MgO to try to increase the oxygen vacancy defects. There are a variety of ways to deposit MgO that were known in the art at the time. Some people would evaporate magnesium and then oxidize it. Some people would sputter MgO targets to deposit an MgO film. There is -- let's see if Soukup talked about this. There is -- I would have to look. There certainly -- wait a minute. yeah. So Soukup was -- Soukup was evaporating MgO. Let me read that again.

Q Can I ask you a question?

A I'm sorry?

Q Can I interrupt with a question?

A Well, give me a moment. I'm close to what I was looking for. Yeah. Soukup used a -- just as he evaporated MgO.

Now go ahead and ask your question.

Q Okay. Do you have your declaration in front of you, Exhibit 1024?

A Yes.

Q All right.

A I have to pull that up because now I have quite a few windows. Okay.

Q Paragraph 173, it is at PDF page 93.

I'm sorry. Paragraph 172.

A 172.

Q Same page. Do you see that?

A Yes.

Q It says that, "A skilled artisan would have had a reasonable expectation of success in applying Soukup's teachings to Bowen to achieve a tunnel barrier height in the range of .1 to .85 electron volts"; right?

A Right.

Q What are the teachings in Soukup that a POSA would apply to Bowen to achieve let's just say a tunnel barrier height of .33 electron volts?

A Well, Soukup taught fabricating a MgO

barrier using evaporation. I think that's -- I have to go back and look at how Bowen did it. But anyway, that was Soukup's teaching for how to form the MgO barrier.

Bowen -- Bowen is just a little bit vague. Bowen seems to say that the structures were grown in a combined sputtering laser ablation system. So my -- it doesn't say whether they use laser ablation or sputtering to deposit the MgO. But I think a POSA would expect that they used sputtering. And Bowen gives a -- gives a temperature for that. And Soukup used a different process.

Q So Bowen grew his single-crystal magnesium oxide barrier layer at 400 degree Celsius through this sputtering laser ablation; correct?

A Correct. Page 1665 in Bowen.

Q So that's -- Bowen did epitaxial growth of a single-crystal magnesium oxide layer; right?

A Correct.

Q Okay. So --

A On a -- on a single-crystal ferromagnet.

Q Right.

So what would a POSA have changed in

Bowen to achieve a .33 electron volt barrier height in the magnesium oxide?

A Well, a POSA would be motivated to experiment using evaporation and varying the temperature in order to try to get a barrier height like Soukup did.

Q So Bowen's growing this epitaxial layer of magnesium oxide in a chamber?

A Right.

Q And it is at high vacuum?

A Presumably. Yeah. It says what the vacuum level was.

Q What was the vacuum level?

A Base pressure of two times 10 to the minus 9 millibar.

Q So that was even a higher vacuum than what Soukup used; right?

A Well, let's go back to Soukup just to -- well, Soukup's chamber reached a pressure of 6 times 10 minus 11 torr. I think that is actually not too far from Bowen's. Bowen had 2 times 10 minus 9 millibars. There's about a factor of a hundred between millibars and torr. So it's similar.

Q So Bowen was growing under vacuum

conditions that were already similar to what Soukup used. Is that what you're saying?

A I think that's fair to say.

Q So why would changing the temperature result in an increase in oxygen vacancies in Bowen's magnesium oxide layer?

A Well, Bowen was using a different process to deposit the MgO. He was doing sputtering.

Q Uh-huh.

A And Soukup was doing evaporation.

Q So it is your testimony that the -- go ahead. Sorry.

A Evaporation can easily have produced the higher concentration of defects.

Q Okay. Can you just tell me, where in your declaration do you say that Bowen would be modified to use evaporation to deposit the magnesium oxide?

A I'm at my declaration. Can you please repeat the question?

Q Where in your declaration do you say that the POSA would have modified Bowen to deposit his magnesium oxide using evaporation?

A What I say in my declaration is -- for example, paragraph 172, on page 82 [sic] -- let me

1 know when you're ready.
2 Q I'm ready. I'm right there.
3 A "A skilled artisan also would have had a
4 reasonable expectation of success in applying
5 Soukup's teaching to Bowen to achieve a tunnel
6 barrier height in the range of .1 to .85."
7 Soukup's teachings encompass the Soukup
8 method for doing the deposition. So I think my
9 declaration says what you asked. Teaches -- to
10 take the Soukup teachings and apply them to Bowen.
11 Q Right. But my question is, what are
12 those teachings? So you're saying that the
13 teachings are to use evaporation to deposit the
14 magnesium oxide?
15 A Well, among others. The teachings are
16 the teachings of Soukup. One of them is to use
17 evaporation. The other has to do with
18 temperatures and so forth. So I'm just -- I'm
19 just saying it -- okay. So that's my answer.
20 It -- I don't explicitly call out the use of
21 evaporation in my declaration. I just say
22 Soukup's teachings in general.
23 Q Did Soukup achieve single crystal
24 magnesium oxide oriented in a .001 plane?
25 A Soukup doesn't explicitly say.

Q Soukup actually never says when the magnesium oxide is crystalline or not; right?
A Soukup does not.
Q So is it fair to say that your testimony is a person of ordinary skill in the art would have modified Bowen by growing -- by depositing magnesium oxide the same way that Soukup did?
A Well, not exactly. I think a person of ordinary skill could do it -- could experiment to find ways to combine the teachings of Bowen and Soukup in a suitable way. So, for example, varying the substrate temperature during the evaporation and so forth.
Q I'm just trying to understand what the combination is that you -- that you -- I'm trying to understand what the modifications to Bowen are that, in your opinion, would have rendered claims obvious. So that combination is in paragraph 172, that the POSA would have applied Soukup's teachings to Bowen. Can you be any more specific than the POSA would have experimented?
ATTORNEY WILSON: Objection. Form.
THE WITNESS: Well, Soukup did the deposition with the evaporation at the substrate at room temperature, as near as I can figure out.

Bowen taught to do the deposition at 400 C and then anneal at 400 C. So the POSA could have tried to combine those two, either to increase the substrate temperature during the MgO deposition by evaporation or annealing. That's one such example of making a combination of the two that the POSA would experiment with.

BY ATTORNEY WICHMAN:

Q So I just want to be clear about Bowen. Bowen deposits iron at room temperature and then does in situ anneal at 400 Celsius to crystallize the iron bottom layer; correct?

A Right.

Q Bowen does not anneal the magnesium oxide layer; right?

A Well, okay. Bowen deposits at 400 degrees.

Q For epitaxial growth of a single-crystal magnesium oxide; right?

A Well, to achieve -- ultimately Bowen achieves a single-crystal magnesium oxide.

Q Okay. When you say the POSA could have tried to combine those two, where Soukup deposits magnesium oxide with evaporation at room temperature and Bowen rose magnesium oxide at

400 Celsius, what's -- what is the variation that they would try? Are you saying that the POSA would have changed Bowen to deposit magnesium oxide at room temperature?

A Well, that's one option. The other option is to evaporate magnesium oxide with the substrate temperature, high substrate temperature. That's another combination.

Q But that's not what Soukup teaches; right?

A Soukup evaporated MgO to deposit it.

Q At room temperature?

A At room temperature.

Q Okay.

A Bowen deposited at a high substrate temperature. So a reasonable combination would be to evaporate using the high substrate temperature, for example.

Q Are you done?

A Yeah.

ATTORNEY WICHMAN: Okay. All right. I believe it is 12:20 your time. We haven't discussed lunch. I think -- is 30 minutes sufficient for lunch or do you want 45?

ATTORNEY WILSON: I think 30 is

sufficient.

ATTORNEY WICHMAN: Why don't we go off the record and come back on at 10 minutes before the hour.

ATTORNEY WILSON: Okay. Thank you.

(A lunch recess was taken.)

ATTORNEY WICHMAN: Let's go on the record.

Q Dr. Bokor, during the break, did you speak to anybody about this deposition?

A No.

Q Did you consult any written materials related to this deposition during the break?

A No.

Q Before the break, you -- your testimony was that a reasonable combination for Bowen to use the teachings in Soukup would to be evaporate magnesium oxide using Bowen's high substrate temperature, meaning the 400 degrees Celsius temperature; right?

A I suggested that as an example of where a POSA could start doing experimentation.

Q And what evidence can you cite that that approach would have increased oxygen vacancies in Bowen's magnesium oxide layer?

A Only -- well, the results of Soukup. So Soukup got that low barrier height. And there was evidence in Soukup that that related to oxygen vacancy defects.

Q So as we discussed in Soukup, Soukup evaporated magnesium oxide at room temperature -- he actually had a gold electrode; right?

A That's right.

Q What evidence do you have or can you cite that evaporating magnesium oxide in Bowen's reaction chamber onto the crystalline iron electrode at 400 Celsius would have resulted in an increase in oxygen vacancies?

A I think that a person of ordinary skill in the art looking at Bowen in view of Soukup would have the -- a grasp of a variety of deposition fabrication technologies that would be routine to explore in order to work towards a -- an MgO layer with a high -- with vacancy defects that was single crystal using what were at the time routine experimental methods.

Q So you don't have any evidence -- a POSA would not have had any evidence that using Soukup's method of evaporating magnesium oxide in Bowen's method of fabricating an MTJ would

actually have increased the oxygen vacancies in Bowen's magnesium oxide layer; is that right?

A A person -- a POSA reading Soukup learned how to deposit an MgO layer with a barrier height of .33, which was attributed to a high concentration of Bowen of oxygen vacancies. What I'm saying is that such a POSA then looking at Bowen for the structure of an MTJ would have found it routine to -- by routine experimentation how to combine the deposition methods of Soukup with the teachings of Bowen about forming an MTJ to get an MTJ which had those properties. Which had the properties of high defect density and low barrier height. That's what I'm saying.

Q So your testimony is that the person of ordinary skill in the art would have had to experiment in order to -- strike that.

So your testimony is that a person of ordinary skill in the art would have had to perform experiments on modifying Bowen's method to achieve an increase in oxygen vacancies in Bowen's magnesium oxide; is that right?

A What I'm saying is that a skilled artisan would have had a reasonable expectation of success in applying Soukup's teachings to Bowen to achieve

a tunnel barrier height in the range .1 to .85. Period.

Q I'm asking if there's any evidence that would have shown the POSA how to do that without experimentation?

A I think it is reasonable to project that a POSA would have using routine methods done some experimentation to get to the result. So yeah, there would be some -- there would be some -- some amount of experimentation.

Q So you -- you cannot identify a document that would have taught a POSA how to do this, to achieve or -- to achieve an increase in oxygen vacancies in Bowen's magnesium oxide layer resulting in a barrier height of .33 electrodes; is that right?

ATTORNEY WILSON: Objection. Form.

THE WITNESS: Other than what I've already testified, Soukup in light of Bowen.

BY ATTORNEY WICHMAN:

Q So if -- other than Soukup, there's no document that you can point to that would have taught a POSA how to modify Bowen to increase the oxygen vacancies so as to achieve a barrier height of .33 electron volts; is that right?

A I don't think I have cited any additional documents beyond what I just said and what's in my declaration.

Q Okay. And you cannot identify a document that would have taught a POSA that reducing barrier height in Bowen's device would have increased TMR; right?

A Well, we spoke about that at some length this morning. That's -- that's -- that's my testimony that I gave you this morning. I have nothing to add to that.

Q We discussed Butler; right?

A We did.

Q And you said that a POSA could not have drawn a conclusion as to which direction the TMR would have changed based on Butler; right?

A I did say that.

Q Okay. I'm asking whether there's any other document that would have taught a POSA that reducing the barrier height in Bowen's MTJ would have increased TMR?

A I -- I don't have any other documents that I cite in my declaration that -- to that effect. That's -- that's my line of understanding.

Q Can you open the patent. This is 1017.
A 1017.
Q The '909 patent.
A Oh, 1017. Sorry. Okay.
Q All right. Can you go to Figure 8(A). That's at PDF page 13.
A Okay.
Q So this is a cartoon of the three layers of an MTJ; right?
A Right.
Q So there's a bottom ferromagnetic electrode, there's a tunnel barrier, and there's a top ferromagnetic electrode; right?
A Yes.
Q And in figure 8(A), the figure shows arrows in the top and bottom ferromagnetic electrode pointing to the same direction, in this case to the right of the page; right?
A Yes.
Q And this represents the MTJ being in a -- what we would call a parallel state; is that right?
A I believe so.
Q So when an MTJ is in this parallel state, the resistance to current through the device -- so

through the electrodes and the tunnel barrier -- is called a parallel resistance; is that right?

A That's right.

Q And in the figure below, Figure 8(B), this shows the same three layers, but this time the arrows in the top and the bottom ferromagnetic layers point in the opposite directions; right?

A Right.

Q And so this represents the magnetic tunnel function being in an antiparallel state?

A Yes.

Q And when an MTJ is in this antiparallel state, the resistance to current through the device, through both electrodes and the barrier, is called the antiparallel systems; right?

A Right.

Q And then the next page, in Figure 9(B), this shows a unit cell of magnetic random access memory; right?

A Yes.

Q And this is an example of where current through the MTJ would experience antiparallel resistance; correct?

A Correct.

Q If you could go to column 5, line 10.

This is at PDF 19.
A Line 10. I'm there.
Q So from lines 10 to 16, the patent is describing the magnetoresistance ratio of an MTJ device; right?
A Right.
Q And this is what we've been calling the tunnel magnetoresistance or TMR?
A Right.
Q And here, the abbreviations are Rp and Rap for parallel resistance and antiparallel resistance; correct?
A That's fair to say.
Q So it actually says that Rp and Rap indicate the tunnel junction resistance in the cases of parallel in antiparallel magnetization alignments, respectively, of the two electrodes; right?
A That's what it says.
Q And that's what we just walked through with Figures 8(A) and 8(B); correct?
A Yes.
Q All right. If you could go to your declaration at -- this is Exhibit 1024, at paragraph 36, which is at PDF page 29.

A So paragraph 36. Is that what you're --
Q Paragraph 36. So here you define tunnel magnetoresistance as TMR; correct?
A Yes.
Q And as we just discussed, this is what the patent calls magnetoresistance ration or MR ratio; right?
A Yes.
Q In the next paragraph 37, you recite this equation for TMR; correct?
A Correct.
Q And this is the same equation that we just looked at in the patent, Exhibit 1015, column 5, lines 10 to 16; right?
A Bear with me. What happened? Okay. I guess my Acrobat window can only hold so many open documents at once. So just give me a moment.
Okay. So you -- you're pointing me back to the patent.
Q Exhibit 1019 [sic], column 5, line 10, at PDF page 19.
ATTORNEY WILSON: Objection. Form.
THE WITNESS: 1017 is the patent, isn't it?

BY ATTORNEY WICHMAN:
Q Correct. Exhibit 1017, column 5, lines 10 to 16, which is PDF page 19.
A Sorry. There was just a -- okay. So I'm on the patent.
Q You agree that the equation in the patent, at column 5, between lines 10 and 16, is the same equation that you used to define TMR in paragraph 37 of your declaration; correct?
A I'm sorry. I'm just having a little bit of a hiccup with my setup here. If you will just bear with me. I don't know why this is happening.
There's my declaration and there's the patent.
Okay. So the equations that we were just looking at in my declaration on page 19 for the TMR. And we're comparing that to the equation in the patent for delta R over RP. That's what you're pointing me to; correct?
Q That's right. You agree it's the same equation; right?
A Same equation, yes.
Q Okay. Dr. Bokor, when an MTJ is in an antiparallel state, would a lower barrier height also reduce the antiparallel resistance?

A In general, it would be expected to do that, yes.
Q Paragraph 45 of your declaration -- this is at PDF page 32.
A Okay.
Q So in paragraph 45, you state that "MTJs operate based on tunneling." Correct?
A Correct.
Q So in your declaration, at paragraph 45, you do not allege that lowering a barrier height in an MTJ will reduce the parallel resistance by more than it reduces the antiparallel resistance; correct?
A Not in that paragraph.
Q In paragraph 46 of your declaration, you discuss Simmons paper, Exhibit 1031; correct?
A Correct.
Q And at the bottom of page 22, at the bottom of this paragraph, you -- you provide a modified and annotated version of Simmons' Figure 1; is that right?
A Yes.
Q So if you could go ahead and open up Simmons -- this is Exhibit 1031, at page 1794. That's PDF page 3.

A Okay. I've got Simmons open. Remind me what page you want to go to again, please.
Q 1794. It is PDF page 3.
A Yes.
Q I just want to talk about Figure 1 in the top left column.
A Okay.
Q Are you there?
A I'm there.
Q All right. I want to compare Figure 1 in Simmons to this figure in paragraph 46 of your declaration. Okay?
A Okay.
Q So you changed some things. So in Simmons, there's a label electrode -- electrode 1 and another label electrode 2. And in your declaration, you changed that to ferromagnetic electrode; right?
A Right.
Q But Simmons doesn't talk about ferromagnetic electrodes, does it?
A That's correct.
Q You changed -- where Simmons wrote insulator, you changed that to MgO barrier; right?
A Right.

Q Simmons is just talking generally about metal insulator metal devices. Simmons is not talking about magnesium oxide barriers, is it?
A That's correct.
Q And in Simmons, there's a label 5X, that in the -- in your figure, you change that to tunnel barrier height; is that right?
A Right.
Q And then you left out some things from Simmons' figure; is that right?
A There are some things that are not in my figure that are in Simmons Figure 1. That is fair to say.
Q Simmons labels Figure 1 "General barrier in insulating film between two metal electrodes." Right?
A Right.
Q You left that out of your declaration?
A I didn't put that in my declaration, that's correct.
Q Okay. And Simmons never talks about magnetoresistance, does it?
A It does not.
Q And Simmons, like we talked about before, was published in 1963; right?

A Right.
Q And tunneling magnetoresistance wasn't discovered until 1975?
A I took your word for that. I don't dispute it.
Q Do you know?
A I don't. Off the top of my head, I don't know when TMR, tunnel magnetoresistance, was first --
Q Sorry. Can you open Exhibit 1057.
A Got it.
Q All right. If you could go to page 42, which is at PDF 61.
A Okay.
Q First full paragraph starts, "The TMR effect was first discovered in 1975 by Julliere." right?
A That's what it says.
Q Do you have any reason to doubt that?
A No.
Q And you have no independent knowledge of any different discovery date of TMR?
A I do not.
Q This was 12 years after Simmons published its paper?

A Right.
Q And Simmons never talks about parallel resistance in an MTJ, does it?
A Obviously not. He didn't know about it.
Q Right. And Simmons doesn't talk about antiparallel resistance in an MTJ; right?
A It does not.
Q So in paragraph 46 of your declaration, you do not allege that lowering a barrier height in an MTJ will reduce parallel resistance by more than it reduces antiparallel resistance; correct?
A You asked about paragraph -- paragraph 46; right?
Q 46.
A Okay. That's correct.
Q Paragraph 47 of your declaration, you discuss Simmons' paper; correct?
A Briefly.
Q So in paragraph 47 of your declaration, you do not allege that lowering a barrier height in an MTJ will reduce parallel resistance by more than it reduces antiparallel resistance; correct?
A Correct.
Q Paragraph 48 of your declaration, you discuss tunnel barrier height; is that right?

A Yes.
Q And in paragraph 48 of your declaration, you do not allege that lowering a barrier height in an MTJ will reduce parallel resistance by more than it reduces antiparallel resistance; correct?
A Correct. Not in that paragraph.
Q Is there a paragraph where you do allege that relationship?
A Well, that conclusion has to come from considering some -- several elements of the declaration. I'm not sure it explicitly says that just in so many words. But it's in there.
Q Where?
A Well, let's start with paragraph 68. We discussed this, I think, this morning. "MgO has the special property that tunneling is governed by the majority (parallel) spin electrons."
And I'll just cut to the last part of the paragraph.
"As a 2001 paper by Klaua explained, unlike amorphous aluminum oxide barrier, for crystalline MgO barriers: 'The tunneling resistance for the parallel orientation of the magnetic moments is estimated to be 100 times smaller than that for the antiparallel orientation

of the magnetic moments due to the absence of scattering in the barrier.'"

One of ordinary skill would understand that lowering the barrier height would further lower the tunneling resistance for the parallel orientation. And as I testified this morning, the teaching that I refer to in paragraph 68, that the parallel orientation is estimated -- the resistance is estimated to be a hundred times smaller than that for the antiparallel orientation.

So what this is saying to one of ordinary skill is that the transport of the moments through the MgO barrier is due to the band structure that the person of ordinary skill would understand that from Mathon and Butler. The tunneling resistance is a hundred times smaller and is different for the parallel and the antiparallel. It's a different mechanism.

So my opinion is that a person of ordinary skill looking at this and understanding the basic properties of tunneling would understand that lowering the barrier by -- would thereby change the energy at which the spins or the electrons are entering the barrier relative to the

band structure. And thus, the amount -- that factor of a hundred that's referred to in the paragraph 68, as the tunnel barrier is reduced, that factor -- it is reasonable to expect that that factor will change. That's what we talked about at some length this morning. And as the tunnel barrier is reduced, that changes the energy alignments of the ferromagnetic electrode and the MgO.

And so a person of ordinary skill would understand that from reading Butler and have a reasonable expectation that the effect on the change of tunneling rate for the parallel and antiparallel electrons would be different.

So the conclusion that we're talking about here, a person of ordinary skill could come to that conclusion by that line of reasoning based on what a person of ordinary skill in the art understood at the time.

Q Dr. Bokor, this morning you told me that the person of ordinary skill in the art reading Butler could not draw any conclusion as to which direction TMR would go based on a change in barrier height; right?

A That's fair to say.

Q Okay. Maybe we should go back to your equation for TMR, in paragraph 37, at PDF -- at PDF 30.
A Okay.
Q So TMR is defined as the ratio of the quantity antiparallel resistance minus parallel resistance divided by the parallel resistance; correct?
A Correct.
Q So we could regard that as TMR is the ratio of antiparallel resistance to parallel resistance minus one; correct?
A Say it again, please.
Q We could rewrite this equation as TMR is equal to the ratio of antiparallel resistance to parallel resistance quantity minus one; correct?
A Okay.
Q The TMR will only increase if the ratio of antiparallel resistance to parallel resistance increases; correct?
A The ratio of antiparallel resistance to parallel resistance has to increase. Right?
Q Right. Do you agree with that?
A I do.
Q Okay. So if the antiparallel resistance

and the parallel resistance changed by the same amount proportionately, the TMR will not change; right?

A That's fair.

Q So if you decrease both the antiparallel and the parallel resistance by 10 percent, the TMR would be unchanged?

A Fair.

Q If -- if we're talking about reducing the resistances, the only way to increase TMR is if the parallel resistance is decreased by proportionately more than the antiparallel resistance; correct?

A Correct.

Q All right. So if your testimony concerning paragraph 68 of your declaration in Butler is that a person of ordinary skill in the art could not draw any conclusion as to which way the TMR would change if the barrier height changed, how can you say that the parallel resistance would decrease by more than the antiparallel resistance if the barrier height is reduced?

A All right. Let's try this again. Give me a moment. Well, let me just bring up

paragraph -- paragraph 170 in my declaration. I think it is PDF 92.

Q I'm there.

A Why am I not surprised?

The statement here, which is similar to the one we were just looking at, second sentence, "As explained in Section VII.E.3 of this Declaration, Butler and Mathon taught that MgO barriers would achieve higher TMRs due to improved symmetry matching between the MgO barrier and ferromagnetic electrodes, facilitating tunneling of parallel electrons across the barrier compared to antiparallel tunneling."

I explicitly compare the parallel and antiparallel there. What I've been trying to explain for some time today is that the teaching in Butler and Mathon, that a person of ordinary skill would understand that if you vary the barrier height -- and if -- let me -- let's -- let's go to -- I think it will help to go to Figure 3 in Simmons -- so Simmons is Exhibit 1031. And I'm referring to Figure 3 on page 1796.

Okay?

Got you. So in A, what you see is that what Simmons calls the barrier height, phi naught,

which we were looking at before. This is a slightly simplified picture because -- compared to Figure 1, but I think it is more helpful here. The barrier height, as you can see there, in Electrode 1, there's a horizontal line at the bottom of the arrow for phi naught. And I won't bother to try to find where Simmons says this. I think it is quite clear by now. A person of ordinary skill would understand that horizontal line at the bottom of the arrow for phi naught is the Fermi level for electrons in electrode 1. And then the horizontal line at the top of that phi naught arrow represents the conduction band, the bottom of the conduction band and the insulator.

So the -- the barrier height is generally understood by persons of ordinary skill to be given by that diagram and that expression phi naught is equal to E sub C, for the insulator, minus E sub F, for the electrode 1.

Now, notice that one of ordinary skill also understands from Simmons and from the literature on tunneling in textbooks that electrons will tunnel through the barrier from -- predominantly from the top of the conduction band

in the metal, at that EF level, enter the insulator at that energy, tunnel through and emerge on the other side into electrode 2.

Now, if the barrier height phi naught changes by doing something to that interface between the barrier and the electrode 1 -- and there's a variety of ways that that barrier height could be changed, including defects -- then the Fermi level in the electrode 1 would line up at a different location within that band gap of the insulator.

Butler -- now, if I go back to my -- where I was in my declaration, paragraph 170, "Butler and Mathon taught that the MgO barrier facilitates tunneling of parallel electrons across the barrier compared to antiparallel tunneling." And Butler and Mathon teach that the reason for this is related to the -- what is called the band structure of the MgO, which facilitates tunneling of parallel electrons much more than the antiparallel. And the ratio between the tunneling of the parallel and antiparallel tunneling, that ratio of Rp to Rap that we were talking and that you brought up, that ratio can be reasonably expected to vary as the barrier height changes

because the electrons tunneling through that barrier are interacting with the MgO energy bands at a different location in the gap, where things are different.

Now, I -- as I have said, I don't have enough information to be able to simply predict and I don't think a POSA had enough information just by reading Butler or Butler and Mathon to be able to confidently predict, project whether the facilitated -- whether the -- the facilitation of the parallel versus the antiparallel electrons would go -- would be -- would go one way or the other. That the antiparallel electrons would be more effectively blocked or less effectively blocked depending on what energy is going through that barrier. But it is definitely reasonable to expect that it would be different. That's the basis for my opinion. That if you vary the barrier height, you don't just change Rp and Rap proportionately, it is true that the tunneling rate for both would go up, if you reduce the barrier height. I can -- that is -- that I would -- I think is clear.

But the amount which the tunnel resistance changes as you vary the barrier height,

that ratio would also change. As the barrier height goes down, the amount that the Rp and the Rap change is not necessarily simply by the same proportion because of the -- of the sophisticated or this complicated relationship of tunneling through for -- for polarized spins to tunnel through MgO which has this very special preference for parallel versus antiparallel tunneling. That's my basis for the opinion that Rp and Rap don't -- likely don't change by the same proportion.

Q I want to make sure that you're done.

A Yes, I'm done.

Q Okay. Thank you.

So you referenced Simmons. But we just agreed that Simmons doesn't describe antiparallel or parallel resistances. It just describes tunneling; right?

A Correct.

Q Okay. The question -- go ahead.

A Go ahead.

Q The question that I have is, where in your declaration do you describe or assert that reducing the barrier height in Bowen's magnesium oxide barrier layer would increase the TMR? Not

just change it, but increase the TMR?
A I don't have a statement in my declaration that goes beyond that presentation that I just made. So I don't have an explicit prediction that the TMR would go up as the barrier height reduces. I -- I think it's reasonable to a person of ordinary art would reasonably -- have a reasonable expectation of success to lowering the --
Q Success in what?
A In increasing the TMR. Reasonable expectation. At least a 50 percent chance. That's reasonable.
Q Okay. I'm -- I'm asking about what they had a reason to believe would happen. I'm not asking about a coin flip; it might go up, it might go down. I'm asking specifically to identify any evidence that would have taught a person of ordinary skill in the art that decreasing the barrier height in Bowen's magnesium oxide barrier would have increased TMR.
A I don't have an explicit statement of that. I've said it many times. I don't say that it -- that a person would have -- would explicitly know that it would specifically increase. I'm

saying they have a reasonable expectation that it would increase. And I don't say that explicitly in my declaration. I'm saying that that -- that's my -- that's what I think a person of ordinary skill in the art would understand based on the presentation that I put in my declaration.

Q So if we could speak in terms of parallel and antiparallel resistances, try to quantify this that way. And we can stay with your paragraph 170 in your declaration. If Bowen reduced the barrier height in his MTJ from, say, .9 electron volts to .7 electron volts, how much would a POSA have expected the parallel resistance to fall?

ATTORNEY WILSON: Objection. Form.

THE WITNESS: I can't -- I can't quantify that. I do not have a basis for giving a number.

BY ATTORNEY WICHMAN:

Q And --

A And I don't think a POSA would have -- a priori would have a basis for predicting or estimating what that reduction would be.

Q And if Bowen had reduced the barrier of his magnesium oxide layer from .9 electron volts to .7 electron volts, how much would the POSA have expected the antiparallel resistance to fall?

A I don't -- same answer. I don't have a way to quantify that. I don't think a POSA had enough information to be able to estimate -- numerically estimate that quantity.

Q So a POSA would have been unable to form an estimate of -- to -- of whether the antiparallel resistance would fall by more than the parallel resistance?

A That's another way to say the same thing I've been saying all day.

Q And the POSA would not have had a way to form an estimate of whether the antiparallel resistance would fall by less than the parallel resistance; is that right?

A Correct.

Q The POSA didn't know?

A A POSA did not have the resources to be able to make a scientifically responsible estimate of that.

Q Okay. So you pointed me to paragraph 68 and paragraph 170. Is there anywhere else in your declaration where you discuss this issue?

A Well, the issue depends. I mean, the definition -- it depends on how -- where you draw the boundaries for the issue.

Q Strike the question.
A I can argue that most of the declaration addresses that issue.
Q Okay. Other than paragraph 68 and 170 in your declaration, is there anywhere where you address the question of how a POSA would have expected TMR to change based on a reduction in Bowen's barrier height?
A The points that are explicit in paragraph 170 and -- what was it? 60?
Q 68.
A 68? Okay.
I have a recollection -- I was looking for it earlier, that there -- that there might be some other place in the declaration that also addresses this point -- looking at paragraph 68 again -- that the MgO barrier passes delta 1 electrons while largely blocking other electrons. There might be something else that says something very similar to that in the declaration. I can't remember exactly where it is. Or even if -- I have this sense that. You know, I would have to look pretty hard to find it. There may or may not be another place. But in any event, it is essentially the same point. I don't have any

add-on to that, if that's what you're looking for. The -- the opinion that I'm giving today that I believe is based solidly on what's in -- and is disclosed in my declaration is the one that we have -- that I have repeated now multiple times. The MgO barrier passes delta 1 electrons much more efficiently -- much more strongly than the electrons having the opposite spin. And that that ratio between the Rp and the Rap for electrons tunneling through MgO is energy dependent.

One of ordinary skill in the art reading Butler would have the reasonable interpretation that that ratio should be energy dependent and varying the barrier height is going to vary that energy. That's -- that's the long and short of my opinion. I -- I don't go farther than that in my declaration or here today.

Q And -- well, based on that, it is also your testimony that the person of ordinary skill in the art would not have known how TMR would have changed if barrier height were reduced in the MgO barrier layer of Bowen; right?

A It would not have known quantitatively how much the -- how much the TMR would change or the sign.

Q And by sign, you mean they wouldn't have known if it would have increased or decreased?
A Increased or decreased.
Q Okay. Can we go back to paragraph 49. It's at PDF page 34.
A 49. We're back to Simmons. Okay. I'm there.
Q So you just introduced a correction to the Simmons formula for tunnel junction current density in the low voltage range; right?
A That's in paragraph 49, yes.
Q And you actually provide the correction in that paragraph; right?
A I did.
Q And this is a correction to Simmons equation 25?
A Okay. If you want me to confirm the equation number, I'll do that.
Q Yeah. It's Simmons page 1797 and PDF page 6; right?
A Okay. So we're talking about Simmons equation 25.
Q Right.
A Right. That is Simmons equation 25. The one that is in my declaration is literally

photographically copied from Simmons equation 25.
Q Did you make that copy?
A Did I -- you mean was I the one who captured --
Q Cut and paste?
A And dropped it in?
Q Yeah.
A I frankly don't remember.
Q Okay.
A Maybe not.
Q I just want to point out there are two corrections in the corrective formula, right. First, there was a factor of three halves that's is removed from Simmons equation 25.
A Yeah.
Q Is that right?
A Yes.
Q And in Simmons equation 25, the barrier height phi occurs twice. But Simmons left off -- for the first occurrence Simmons left off the subscript zero; right?
A Correct.
Q And you fixed that. Or the corrected version fixes that; right?
A Yeah. The corrected version comes from

the literature. And I give the reference. I didn't -- I didn't come up with that all on my own. That comes from the literature. And this is my -- I believe this is widely accepted in the --

Q There's only one barrier height though in this equation?

A Correct.

Q Okay.

A One barrier height.

Q So in this paragraph 49, you do not allege that lowering a barrier height in an MTJ will reduce parallel resistance by more than it reduces antiparallel resistance; correct?

A Not in this paragraph. I agree. That was your question, wasn't it?

Q Yes.

A Okay. We agree.

Q Go to paragraph -- go ahead.

A I was just going it say we're in agreement.

Q Okay. Paragraph 169. This is PDF page 91 of your declaration.

A 169.

Q Okay.

A Okay. I'm at 169.

Q All right. In paragraph 169, you do not allege that lowering a barrier height in an MTJ will reduce the parallel resistance by more than it reduces antiparallel resistance; correct?

A Okay. This is the paragraph that I was thinking of when I said I think there is another paragraph that addresses this. So let me be very careful here. I just read this paragraph carefully. Please ask your question one more time.

Q In paragraph 169 of your declaration, you do not allege that lowering a barrier height in an MTJ will reduce parallel resistance by more than it reduces antiparallel resistance; correct?

A That's correct. This paragraph just says if you reduce the resistance for parallel compared to antiparallel, that would increase the TMR. That's what this paragraph says. And that's -- it doesn't say what you just said. I agree with that.

Q In paragraph 171, which --

A 171?

Q 171. Starts at the bottom of PDF 92.

A Okay.

Q In paragraph 171 of your declaration, you

do not allege that lowering a barrier height in an MTJ will reduce the parallel resistance by more than it reduces antiparallel resistance; correct?

A Correct.

Q Paragraph 172 of your declaration. This is PDF page 93.

Okay. In paragraph 172, you do not allege that lowering a barrier height in MTJ will reduce parallel resistance by more than it reduces antiparallel resistance; correct?

A Correct.

Q And in the next paragraph, 173, in your declaration, you do not allege that lowering a barrier height in an MTJ will reduce the parallel resistance by more than it reduces antiparallel resistance; correct?

A Correct.

ATTORNEY WICHMAN: Okay. Why don't we take a five-minute break here. Unless -- does anybody need more time than that?

ATTORNEY WILSON: No.

ATTORNEY WICHMAN: All right. Why don't we come back -- well, it's 4:53 my time. Why don't we come back at the top of the hour.

ATTORNEY WILSON: Okay.

ATTORNEY WICHMAN: Off the record.
(A recess was taken.)
ATTORNEY WICHMAN: Back on the record.
Q If we could stay with paragraph 169 in your declaration. Are you there?
A I am now.
Q Okay. So you referred to Soukup. The abstract page 3232 and 3236 in this paragraph; right?
A Right.
Q All right. So I don't know -- I don't remember if we covered this or not. But Soukup doesn't teach making MTJs at all; right?
A Right.
Q Soukup was published in 1970?
A Yeah. Yes.
Q And -- and it was before tunneling magnetoresistance was discovered?
A Yes, as we established earlier.
Q And Soukup made thin film diodes; right? Is that right?
A I'm just checking.
Yeah. Thin film emission diodes is what he called them. Yes.
Q And Soukup used gold for his electrodes;

right?
A Correct.
Q Gold is not ferromagnetic, is it?
A It is not.
Q You cannot make an MTG with gold electrodes -- an MTJ with gold electrodes; right?
A Not that I've ever heard of.
Q Would there be a tunneling magnetoresistance effect between gold electrodes separated by an insulator?
A Not under most common conditions, no.
Q All right. In this paragraph 169 in your declaration, the second sentence you just recite the TMR equation; right?
A Correct.
Q And you follow it with a cite to more documents?
A Yes.
Q So let's come back to Moodera. But let's start with Nagahama. Why did you cite Nagahama, Exhibit 1027, paragraph 2?
A Referencing Nagahama paragraph 2 because the same equation appears there.
Q So you just cite Nagahama because it provides the equation for TMR at paragraph 2; is

that right?
A Yes.
Q Is there any other reason that you're citing Nagahama?
A Well, not there.
Q Okay. You cite the patent, the '909 patent, Exhibit 1017, at column 5, lines 8 to 16. Encompasses lines 10 to 16 that we looked at earlier; right?
A Yeah. That's -- that's where the patent also provides that equation with text to help identify the parameters, yes.
Q So you're citing the '909 patent just because it cites the TMR equation; right?
A In this citation, yeah.
Q Okay. At -- in paragraph 169, you cite Exhibit 1057.
A I do.
Q Page 13.
A Right.
Q It is PDF page 32. Can you pull that up?
A Sure. I had it, but I think I closed that.
Q Are you there?
A Yes.

Q So equation 1.9 provides the equation for the TMR equation. Strike that.

Equation 1.9 is the equation for TMR; right?

A Correct.

Q Is this the reason you were citing Exhibit 1057 in your paragraph 169?

A Yes.

Q Is there anything else on this page 13 of Exhibit 1057 that you are relying on, other than the equation for TMR, for your paragraph 169?

A Not for paragraph 169, no.

Q Okay. In your declaration, you refer to this as a textbook, Dieny textbook.

A Yes.

Q Just out of curiosity, who -- did you pick this textbook as a reference for your declaration?

A I honestly -- I honestly do not recall. Let's see. This declaration was completed September of 2004 -- '24. I don't recall who picked it. We did discuss it.

Q Have you used Exhibit 1057 in your work?

A You mean my general professional work, career?

Q Yes.
A Yeah. This is a well-known textbook. I happen to know the guy.
Q Have you taught courses using this textbook?
A No, I haven't done that.
Q Is it actually a textbook? Is it used for courses?
A Well, I don't know that I can answer that question definitively. I haven't used it in a course. I don't know if it is used in anybody else's course. It's -- I mean, if you want to quibble over the attribution to it as a textbook, we could debate that. I wouldn't push too hard on that. It is a comprehensive book that could certainly be used as a textbook. It's not the only use for a book like this. It's got a lot of paragraph -- it's got a lot par- -- sections written by multiple authors, intending to be a comprehensive sort of treatise. Is that a textbook or not? I don't know. I'm not sure. Is that relevant? I'm happy to -- I mean, if you want --
Q I want to understand how you have used this book, this reference?

A I use it as a reference source.
Q Okay.
A I have -- I have been -- as we discussed before, I've been interested in -- in MRAM for quite a -- quite some time, long before I started publishing in it. And this is a very good comprehensive text. It's relatively recent. So it's got some, you know, some of the more recent developments in there. So it's a good reference that is relatively up to date. That's how -- that's my use for it.
Q All right. We can go back to paragraph 169 in your declaration. So of these citations to Exhibit 1035 (Moodera), 1027 (Nagahama), the patent, and 1057 (the textbook), it's your testimony that the only reason that you're citing Nagahama, the patent, and the textbook are for they provide the equation for TMR; is that right?
A In this paragraph.
Q Right. In this paragraph.
A Right. Basically this equation is very well known. Lots of people cite it. Everybody agrees to it. That's kind of the point of this paragraph.
Q All right. Can you open Exhibit 1035.

A I have it.
Q Okay. You cite the -- in paragraph 169 of your declaration, you cite Exhibit 1035 at page 3273. So let's look at Exhibit 1035, page 3273. That's the first page.
A Okay.
Q So tell me why are you citing this page 3273 of Exhibit 1035 in your declaration paragraph 169.
A Okay. I think I know where you're going. Same -- I cited for the same reason, to show that this equation is well known. I'm anticipating your next question. But I'll wait.
Q So you're citing equation -- you're citing this for equation 1 on 3273 of Exhibit 1035; right?
A It is.
Q And this is a different formulation for TMR; right?
A It is.
Q It's dividing through by the antiparallel resistance rather than the parallel resistance; right?
A Correct.
Q Was that a mistake to cite it or did you

intend to cite this representation?
A No. It's -- I only just relatively recently -- I am aware of this discrepancy. I relatively recently noticed it. And so it is -- it is a bit different than what is now the conventional definition, which is the one in my declaration. I recently noticed this discrepancy and was wondering about it. You know, this is a rather early paper. I mean, it is well past discovery of the MTJ. So it is not that early. But I don't know why Moodera put the equation that way. It's a -- I'll call it a discrepancy. I don't know why he defined it that way. It is not the way that most researchers define it. Probably shouldn't have cited it there. But there it is. I noticed that it is -- it is not exactly the same equation. So yes. It's not the same equation.
Q Is there any other reason that you're citing page 3273 of Moodera in your paragraph 169?
A No. No.
Q Okay.
A My intention, as I said -- my intention was to show this was a well accepted, well agreed on formula for TMR. When I wrote this, it escaped my attention that there was this discrepancy.

Q Do you agree that nothing in Exhibit 1035 (Moodera) states that lowering the barrier height of a barrier layer will increase TMR?
A I -- nothing in here discloses that. I agree with that.
Q Okay. And specifically now I want to focus your attention on the top right column of Moodera.
A Which page?
Q Fair. Page 3273.
A Top right column. Yes.
Q Okay. Do you see the sentence that says, "Another theory of FM-FM tunneling has been proposed by Slonczewski?
A Yes.
Q Okay. FM-FM tunnels means ferromagnetic to ferromagnetic tunneling?
A Correct.
Q So he is talking about magnetoresistive effects here; right?
A Right.
Q Okay. He is describing Slonczewski and says, "This model analyzes the transmission of charge and spin currents through a rectangular barrier separating free-electron-like

ferromagnetic metals." Is that right?
A Yes.
Q Are you familiar with Slonczewski?
A Generally.
Q Okay.
A I've read it.
Q You didn't -- you didn't discuss Slonczewski in your declaration, though, did you?
A No, I didn't.
Q Why not?
A It's similar to Butler. It's a very advanced, dense theoretical paper. And I didn't feel the need to cite it and get into it. And, you know, other papers cite to it. Like this one. So I didn't -- I didn't explicitly cite it in my declaration. But I don't have any reason to -- I don't have any disagreement with it.
Q I'm sorry.
A Any disagreement -- I didn't -- I didn't leave it out because I have any problem with it.
Q The next sentence here, it says that, "It" -- referring to Slonczewski's theory -- "predicts strong influence of tunnel height on the orientation of the spins tunneling across the FM-I interface, thereby affecting the spin polarization

and also the exchange coupling between the ferromagnets, and was consistent with the low values of delta R divided by R seen previously." Right?

A I see that.

Q Okay. FM-I, that refers to the ferromagnetic insulator interface?

A Correct.

Q So that is the interface between Bowen's device. That is the interface between, say, the bottom iron electrode and the magnesium oxide barrier layer; right?

A Right.

Q What does this mean, strong influence of tunnel barrier height on the orientation of the spins tunneling across the FM-I interface?

A It means that the -- it means what it says.

Q Okay. So how does the barrier height have a strong influence on the orientation of the spins tunneling across the interface?

A How does that happen? Slonczewski -- as I said, it's a dense theoretical paper. Slonczewski explains that. I can't expand on it. I haven't read Slonczewski in a while. I don't

have it in front of me. It is not in my declaration. I'm hesitant to give further opinions about Slonczewski. If you really want me to discuss Slonczewski, then if you're willing to, you know, give me -- give me the document, I'll be happy to take a look at it and answer questions.

Q This is what I want to know. This sentence here, "It predicts strong influence of tunnel barrier height," through the end, do you agree that this does not state that reducing barrier height will increase TMR?

A That sentence does not say what you just said. I agree.

Q Okay. So let's back up here. So this whole passage then in Moodera, page 3273, the right-hand column, top paragraph, from the sentence "Another theory of FM-FM tunneling," through the end of that paragraph, it is your opinion that that passage does not state that decreasing the barrier height will increase TMR; is that right?

A That sentence does not say that, what you just said. I agree.

Q So it is three sentences then.

A The three sentences don't say whether the

orientations of spins go up -- get stronger or weaker with tunnel barrier height. It doesn't say the spin polarization gets stronger or weaker with barrier height. It just says it is affecting the spin polarization.

Q And a POSA reading this would have understood that this does not predict which way TMR would change with barrier?

A Not quite in so many words. It does say that it was consistent with low values of delta R over R seen previously. It does say that.

Q And what does that mean to you?

A It means that this is one possible way to understand low values of delta R over R seen previously. It doesn't -- it doesn't really -- it doesn't say much more than that. It is not a hundred percent clear. I don't take it as a prediction that if you vary the barrier height in the particular MTJ, whether -- whether you would for sure get high or low values for delta R over R. It is not a hundred percent crystal clear on that.

Q So a person of ordinary skill in the art familiar with this passage would not have concluded that Moodera is describing TMR

increasing if barrier height is reduced; right?
A True. I do recall enough about Slonczewski that Slonczewski does -- does not consider the MgO barrier, which Butler does. So that statement applies to a simple barrier like aluminum oxide. And it doesn't -- you know, it doesn't anticipate -- Butler was published well after this. So this was the understanding based on Slonczewski as of 1995.
Q So would a person of ordinary skill in the art then have concluded since Moodera, Exhibit 1035, and Slonczewski both concerned aluminum oxide barriers, that they would not have been relevant to forming predictions of TMR in Bowen's magnesium oxide MTJ?
A I wouldn't say irrelevant, but they wouldn't capture the subtleties that we've been discussing for most of today.
Q Moodera and Slonczewski did not provide the first principles analysis of crystal iron, crystal magnesium oxide, crystal iron that Butler did; right?
A Correct.
Q And Butler -- the Butler analysis is what a POSA would have thought would have been relevant

to Bowen's MTJ; right?
A Right.
Q Okay. Can we look at paragraph 276 of your declaration. That's at PDF page 135.
A 276 did you say?
Q Yes.
A Okay. I'm there.
Q You agree in paragraph 276 you do not state that reducing the barrier height in Nagahama's MTJ would increase TMR; right?
A Yeah. Consistent with other paragraphs that we've looked at. Same -- same exact situation.
Q And you agree that in paragraph 276, you do not testify that reducing Nagahama's barrier height would reduce the parallel resistance by more than it would reduce the antiparallel resistance; right?
A This paragraph, I do not say that. I just say if lowering the barrier height for parallel -- I just say lowering the resistance for parallel spin electrons compared to antiparallel would improve the TMR. I do say that.
Q In the next paragraph, 277, the second sentence, you say that "Nagahama sought to

increase TMR by modifying properties of the MgO barrier layer." Right?
A Right.
Q And you cite Nagahama, Exhibit 1027, paragraphs 15 to 17; right?
A Right.
Q Can you open Exhibit 1027, please.
A Okay.
Q All right. So PDF 3, you find Nagahama paragraph 15; right?
A Yes.
Q So Nagahama's first objective here was varying the barrier layer thickness; correct?
A Correct.
Q So when Nagahama varies the barrier layer thickness, that has nothing to do with changing barrier height; right?
A Correct.
Q And in paragraph 16, Nagahama's second objective was precisely controlling the barrier layer thickness; right?
A Correct.
Q And the barrier layer thickness has nothing to do with barrier height; right?
A Well, those are two independent

parameters, yes.
Q And Nagahama's third objective was in paragraph 17; right?
A Yes.
Q And in paragraph 17, Nagahama states that a third objective was discovering a suitable material and developing a technique for allowing highly oriented crystals to grow evenly; right?
A That's what it says.
Q And developing a technique for allowing highly oriented crystals evenly has nothing to do with barrier height; right?
A Not directly, no.
Q And indirectly?
A Indirectly, if the element doesn't have a highly oriented flat interface that's not affected by the structure in roughness, that could affect the effective barrier height indirectly.
Q So would -- go ahead. Sorry.
A We've seen that in other references.
Q Well, if Nagahama developed a technique that allowed highly oriented crystals to grow evenly, would that increase or decrease barrier?
A I hesitate to predict that. If -- if you have a rough -- a rough film, a rough element

which is affected by the structure and roughness of an amorphous or poly crystal underlayer, the consequences are, at a minimum, you could have a variable, not consistent barrier height. That would be bad. Here, he's not referring to that explicitly. But one of ordinary skill in the art would understand that having a highly oriented flat interface, not affected by roughness, would have benefits conceive -- conceivably also in terms of control of the barrier height. Indirectly.

Q In your opinion, does Nagahama at paragraphs 15 to 17 describe reducing a barrier height?

A No.

Q So in your paragraph 277 in your declaration, when you say that Nagahama sought to increase TMR by modifying properties of the magnesium oxide barrier layer, that does not include reducing the barrier height; is that right?

A All right. Please ask your question again.

Q In paragraph 277 of your declaration, when you say that Nagahama sought to increase TMR

by modifying properties of the magnesium oxide barrier layer, that did not include reducing the barrier height; correct?

A That's correct.

Q All right. In the next sentence you assert, "It was understood to one of skill that lowering the barrier height to increase tunneling would have increased the TMR." Did I read that correctly?

A Yes.

Q Okay. What is the evidence for that?

A Same evidence that we've been discussing. Would have had a reasonable expectation to increase TMR is what it should say.

Q I thought your testimony was that the person of ordinary skill in the art, the most they could do is read Butler and conclude that TMR would change, but would not have any reason or expectation that the TMR would either increase or decrease.

A Well, we've been having a debate about whether that is a reasonable expectation that it would increase.

Q Well --

A That's my perspective on it.

Q So this testimony here, what you're saying is the POSA would have had a reasonable expectation that lowering the barrier height would increase TMR because the POSA knew that TMR had to change and, look, it was either up or down, so 50/50, one of those would have increased TMR. Is that -- is that your testimony?

A That's my testimony.

Q Okay. So the POSA -- just to be clear, because it reads quite differently here. I want to be clear that your testimony -- it is your opinion that a POSA did not actually know that reducing the barrier height would increase TMR?

A I do not have evidence for that.

Q You do not have evidence -- I'm sorry. You do not have evidence that a POSA would have known that reducing barrier height would increase TMR; right?

A That's what I've been testifying.

ATTORNEY WICHMAN: Okay. Why don't we take five minutes now, and then I want to turn to some different topics, if we can.

ATTORNEY WILSON: Okay.

ATTORNEY WICHMAN: So could we be back in five minutes. Thanks. Off the record.

ATTORNEY WILSON: Okay.
(A recess was taken.)
ATTORNEY WICHMAN: All right. On the record.
Q I would like to talk about Dr. Soukup's work. It's Exhibit 1028. If you could pull that up.
A Okay. I have it.
Q Okay. If we go to -- if you can keep that up and also go to your declaration at paragraph 168. That's at PDF page 91.
Are you there?
A I'm there.
Q All right. It's your testimony that Soukup taught that fewer oxygen vacancies in magnesium oxide resulted in a higher barrier height; is that right?
A That's -- that's fair.
Q And we discussed this before. What Soukup actually did was he -- for a panel of devices, he increased the oxygen pressure in the reaction chamber when he made the devices; right?
A Right.
Q And when he increased that oxygen pressure, the expectation was that there would be

fewer oxygen vacancies in the material?
A Right.
Q And so this result about barrier height is comparing the barrier heights that he estimated from the devices that he made in this manner varying the oxygen pressure; is that right?
A Right.
Q Okay. And you refer to Soukup at page 3232 in this paragraph 168.
A Yes.
Q Okay. And you -- the second sentence, you say Soukup suggested there was a 'higher barrier' question for the devices fabricated with more oxygen present during the magnesium oxide deposition which could mean more stoichiometric oxide films. Right?
A Yes.
Q Okay. If you could -- in Soukup now, if you could turn to page 3232, which is PDF page 5 of Exhibit 1028.
A I'm there.
Q So here in the bottom paragraph on the left column of page 3232, Soukup describes this experiment to determine the effect of nonstoichiometry on the device characteristics;

right?
A Right.
Q And as we discussed before, Soukup does not actually describe any step in which he removed the oxygen from the reaction chamber; right?
A Not -- he explicitly adds oxygen. He doesn't lower the oxygen below that of the base pressure of his vacuum system.
Q In this paragraph on page 3232, he describes two devices that he fabricated. One he labeled PY-G-22(2). Correct?
A Right.
Q The other he labeled PY-G-25(3); correct?
A Correct.
Q And the first one, PY-G-22(2) was grown in the presence of oxygen gas that was emitted to the vacuum system to a pressure of 10 to the minus 8 torr; correct?
A That's right.
Q And a torr is a unit of pressure?
A Correct.
Q It is 1/760 of a standard atmosphere; is that correct?
A Correct.
Q And the second device PY-G-25(3) was

grown in the presence of oxygen gas that was emitted to the system to a pressure of 10 to the minus 7 torr; right?

A Right.

Q And 10 to the minus 7 torr is a higher pressure than 10 to the minus 8 torr; correct?

A Correct.

Q Ten times higher?

A Ten times higher.

Q All right. So device PY-G-25(3) was grown under conditions where the oxygen pressure was ten times higher than the oxygen pressure under which device PY-G-22(2) was grown; right?

A Right.

Q And so higher oxygen pressure means there was more oxygen present in the chamber during the device fabrication; right?

A During the deposition of insulator, yes.

Q Okay. So the idea now is that if the magnesium oxide layer was deposited in conditions where the oxygen pressure was higher, then it would be expected that the magnesium oxygen layer would have fewer oxygen vacancies; right?

A That's the basic idea here, yes.

Q Okay. And so when Soukup refers to this

more stoichiometric oxide films, he means the magnesium oxide layer had fewer oxygen vacancies; right?

A Right.

Q And was that magnesium oxide layer was more -- was closer to a uniform material that had a ratio of one to one magnesium and oxygen; right?

A I'm not sure he meant -- I'm not sure he talks about uniformity.

Q Okay. But do you -- do you agree -- go ahead. Sorry.

A Is there a particular place that you can point to where he discusses -- considers the uniformity of the oxygen?

Q Let's forget the idea of uniformity. Let's just say that more stoichiometric means that the magnesium oxygen layer would have been a material that was closer to having a ratio of one to one magnesium and oxygen; right?

A That's what it means, yes.

Q Okay. So in your declaration, Exhibit 1024, at paragraph 168, you testified that "Soukup found that a lower level of oxygen vacancy defects may result in a higher barrier height. This suggested a higher level of oxygen vacancy defects

lower the barrier height." Right?
A Right.
Q So on Soukup, page 3233, which is PDF page 6, on the bottom right, there's a Table 1; right?
A Right.
Q And Table 1 is titled "Summary of device data"; correct?
A Correct.
Q And the left column, the first column is device number; is that right?
A Correct.
Q And the second and third devices from the bottom are this PY-G-22(2) and PY-G-25(3); correct?
A Correct.
Q And those are the two devices that we just discussed that were grown under different oxygen pressures; right?
A Correct.
Q The rightmost column in Table 1 has a letter -- has a header of PO2, with a subscript O2. So that is the oxygen pressure; right?
A Right.
Q And if you drop down, the entry of oxygen

pressure associated with PY-G-22(2) is 10 to the minus 8; right?
A Right.
Q And that's 10 to the minus 8 torr that we just discussed for that device; right?
A Right.
Q And the next entry down, the oxygen pressure is identified as 10 to the minus 7 for device PY-G-25(3); correct?
A Correct.
Q And that's the 10 to the minus 7 torr that we just discussed per this device I'll call G-25?
A Right.
Q Okay. If you go back to the previous page of Soukup, page 3232, on the bottom left paragraph again, in the second-to-last sentence, this is -- it states that "The zero-field intercept of the Schottky plots is a function of oxygen pressure with the lower intercept (higher barrier?) present for the devices fabricated with more oxygen present during MgO deposition, which could mean more stoichiometric oxide films." Right?
A That's what it says, yes.

Q And this is the sentence that you quote the last half of it in your declaration at paragraph 168; right?

I'm sorry. Did you agree that this is the sentence that you're quoting?

A I just want to confirm and be sure.

Q Okay.

A Yes.

Q So you left out the part about the zero-field intercept of the Schottky plots being the source of the barrier height information; right?

A In my declaration, in that paragraph, I do.

Q Okay. So back to Dr. Soukup's paper, page 3233, in Table 1, again, the fourth column here has a header 5 sub 1; right?

A Right.

Q And footnote C explains that this is the barrier obtained by the zero-intercept method in electron volts; right?

A Right.

Q So this is the barrier height value that Soukup determined by evaluating the zero-field intercept of the Schottky plots; right?

A Fair. Yes.
Q This is the value that Soukup is referring to on the previous page 3232 in that sentence that you quote the last half; right?
A Right. From Figure 6.
Q Right. So just to summarize, when Soukup is speculating that a higher barrier -- the function of oxygen pressure with lower intercept higher barrier could mean a more stoichiometric oxide films, he is referring to the barrier height determined by the zero-field intercept of the Schottky plots that is reported in column 4 of Table 1; right?
A Right.
Q All right. And then if you look at Soukup, page 3231, which is PDF 4, he describes -- in the right-hand column, he describes the zero-field intercept method; right?
A Basically. I would say that is reasonable -- a reasonable description.
Q So in this second paragraph on page 3231, Dr. Soukup describes an apparent barrier sub R star; right?
A We're talking about in the right-hand column on 3231?

Q Yeah. Below equation 5.
A Yeah. He -- that's correct.
Q Okay. Go ahead. Go ahead. Sorry.
A No. Phi R star, yes.
Q Okay. And Soukup says that the barriers obtained in this manner range from .69 to .72 electron volts; right?
A Yes.
Q If you go back to page 3233, Table 1, column 4, you see a range of barrier heights that are from .69 to .72 electron volts; right?
A Right.
Q All right. So in Table 1, Soukup is telling us that for device PY-G-22(2), the barrier obtained by the zero-intercept method in electron volts was .780 electron volts; right?
A Right.
Q And in Table 1, Soukup tells us that for device PY-G-25(3), the barrier obtained by zero-intercept method in electron volts was 0.823 electron volts; right?
A Right.
Q So this shows that the barrier obtained by the zero-intercept method in electron volts increased when the device was grown under a higher

oxygen pressure; right?
A Right.
Q And so this is the result that you're relying on in your declaration at paragraph 168; correct?
A Right.
Q So when you state in paragraph 168 that Soukup found that a lower level of oxygen vacancy defects may result in a higher barrier height, you are relying on the zero-field intercept result in Soukup; right?
A Right.
Q And when you state, "In sum, Soukup taught that there was an inverse correlation between oxygen vacancy defects and the barrier height of the magnesium oxide layer," you are relying on the zero-field intercept result in Soukup; right?
A Correct.
Q Okay. And when you state, "In sum, Soukup taught that there was an inverse correlation between oxygen vacancy defects and the barrier height of the magnesium oxide layer," you were relying on Soukup's barrier height estimates that were ascertained using this intercept method;

right?
A That's fair.
Q In Soukup Table 1 -- again, on page 3233 -- on the bottom right, there's a fifth column that has a header Phi sub 2. Do you see that?
A Yes.
Q And that barrier height is explained in footnote D, like delta; right?
A Right.
Q And so this barrier -- this entry, this column reports barrier heights for each device that are obtained from the slope of Arrhenius plots in electron volts; right?
A Right.
Q And so the slope of an Arrhenius plot is described at page 3232, the top left paragraph. Right?
Let's do it step by step. So --
A Okay.
Q -- the first sentence of the top left paragraph of 3232 says -- refers to the functional dependence of I upon V indicates a Schottky mechanism, which is very temperature dependent, so that the I-V characteristics were measured at a

number of temperatures. Right?
A Right.
Q So V is the voltage that Soukup applied to the device?
A Correct.
Q And I is the current that he measured to characterize the device?
A Correct.
Q And he did this at different temperatures; right?
A That's what he did, yes.
Q And he found that the I-V characteristics are temperature dependent?
A Right.
Q So then he says, well, if a plot of the zero-field intercept current I naught obtained from the figure that he has, Figure 4, was made on a log I naught over T squared versus 1 over T plot, the result should be a straight line; right?
A Right.
Q And a plot of device characteristics 1 over T is known as an Arrhenius plot; right?
A You're not reading now. Now you're --
Q I'm just asking you -- I'm asking you to -- what is an Arrhenius plot?

A Yes, that's correct. That's what he means by an Arrhenius plot.
Q Then he goes on to say the slope of the line on the Arrhenius plot will determine the apparent barrier height phi sub R; right?
A Correct.
Q And then if you look now again on page 3233, Table 1, fifth column, the values in that fifth column are the slope of the line in these Arrhenius plots that he made; right?
A Well, those numbers come from the slope. The slope -- let's see. The slope involves phi R K volt constant. So he extracts.
Q He extracts.
Okay. Well, so back on page 3232, left column, first paragraph, final sentence, he says, with reference to Figure 5, the slope of the straight line drawn in the figure gives a barrier of .33 electron volts; right?
A Right.
Q And if you go back to page 3233, Table 1, fifth column, you will see that the -- for example, the top device, PY-G-11(1), the value in column 5 is .33 electron volts; right?
A Right.

Q That is the value obtained of the slope -- from the slope of the Arrhenius bolts?
A Yes.
Q Okay. So in Soukup Table 1 then, for device PY-G-22(2), the barrier height obtained from the slope of Arrhenius plots was 0.21 electron volts; right?
A That's what it says.
Q And then for device PY-G-25(3), the barrier height obtained from the slope of Arrhenius plots was 0.11 electron volts; right?
A Right.
Q So Table 1 is telling us that when the oxygen pressure increased by a factor of 10, the barrier height obtained from the slope of Arrhenius plots decreased. Is that right?
A If we look at just Table 1, that's what it shows. But Soukup amplifies on that, expands on the discussion about that.
Q Are you saying that he found a different barrier height for these last two devices that we just discussed?
A He found that his numbers for the barrier height for those devices was not reliable, was not accurate.

Q And where does he say that?
A If we go to page 3234, the second full paragraph on the right column, starting with "According to Figure 5." "According to Figure 5, the dependence of I upon temperature is not that of a Schottky process. Figure 12 is a plot of log I over T squared versus 10 to the 3 over T for the two devices fabricated with O2 gas present during oxide deposition and also for device PY-G-11(1). It can be seen that these curves do not plot as straight lines. From Figure 5 one gets" -- and there's an equation there. If you want, I can read it out. But I don't imagine we need that. "Figure 5 one gets this equation and the curves in Figure 12 should be straight lines. However, if phi sub R is a function of temperature" -- another equation. "Thus, the slope of these plots would not be proportional to the barrier height and would not be a straight line."
So he hypothesizes that if d phi dT where T is temperature of phi R is positive, if the barrier increases with increasing temperature, then d phi of T divided by 1 over T is negative and the slope of log I T squared versus 1/T plots will give a number which is smaller than the

actual barrier, this was seen here.

So a person of ordinary skill reading this would say -- would understand that Soukup finds that the data for the two devices which are the ones that you were pointing to from the table, those devices G-22 and G-25, they don't -- they don't follow the straight line in Figure 12.

Now, Soukup hypothesizes a barrier height that depends on temperature to try to help explain why they're not straight lines. But to one of ordinary skill, a barrier height that is -- depends on temperature is -- is not generally discussed or understood or talked about. That's -- that's a hypothesis which is somewhat spec- -- let's just say rather speculative. And so that's what I mean when I say that Soukup is -- is suspicious, doesn't -- is basically telling one of ordinary skill that the data for those two devices analyzed this way is somewhat unreliable.

Q And he also says that for the third device, PY-G-11(1); correct?

A Well, PY-G-11(1) does form a straight line in Figure 12. The data fixes straight line in Figure 12, unlike PY-G-22 and PY-G-25.

So I believe a person of ordinary skill reading this paragraph starting according Figure 5, the dependence of I is not that of a Schottky process. Figure 12 is a plot of phi over T squared versus T to the 3 over T for the two devices with oxygen present. It can be seen that these curves do not plot as straight lines. From Figure 5 one gets that equation and the curves in Figure 12 should be straight lines.

Q So it is your testimony --

A Let me -- hold on.

Q Sorry.

A Give me another moment to finish this.

Q Sure.

A So when he says it can be seen that these curves do not plot as straight lines, I believe that that is excluding the mention of PY-G-11 in the previous sentence. So when he says it -- in the sentence immediately after, where it says two devices fabricated with O2 gas present during oxide deposition and also for device PY-G-11, it can be seen that these curves do not plot as straight lines, these curves are the ones for the two devices fabricated with O2 gas present. So he is not -- he is not disparaging the data for that

device PY-G-11(1) as plot -- as plotting as a straight line. It's just PY-G- and 25 that don't seem to fit the theory.

So one of ordinary skill reading this section would be led to have doubts about the barrier height phi R star extracted from this data for those two devices. That's my basis for why I say that Soukup expresses doubt about that data.

Q So for this entire panel, the barrier height estimated by the zero-intercept method in column 4 are quite different from the barrier heights estimated by the -- or from the slope of the Arrhenius plot in column 5; right?

A That is true.

Q Okay. So let's look at device PY-G-11, on the top row.

A Okay.

Q The barrier height estimate from the zero-intercept method is 0.714 electron volts; right?

A Right.

Q And the barrier height estimate for extracted from the slope of the Arrhenius plot is 0.33 electron volts; right?

A Correct.

Q Which one is right?
A Good question.
Q They both can't be right, can they?
A That is true.
Q Okay.
A Soukup discusses this. Right?
Q You tell me.
A I can tell you, Soukup discusses this.
Q Uh-huh.
A And I can go -- I can point you to that, if that's -- if you're asking me to do that.
Q I -- I want to know which of these is the POSA would have regarded as correct.
A So reading Soukup, the -- Soukup himself says he's not sure which is correct. So a POSA reading Soukup would have the same -- could only have that same uncertainty. Which one is correct? Soukup isn't sure. And I'm -- you didn't ask, but I'm going to cite it anyway. If you look at the very last paragraph of the entire publication, last sentence, "No direct evidence that this is happening was obtained so no definite conclusions as to the type of current flow mechanism present in these devices can be made."
So a POSA reading this would, I believe,

have the following interpretation: The Schottky emission fits a lot of the data. There's a great deal of evidence that the Schottky emission is the right -- is the -- is capturing what is actually happening in these devices in terms of that current. From several of the figures.

However, when he looks at the temperature dependence and extracts barrier height that way from the same model, he gets a different barrier height. And he -- he has -- he's not sure which -- which data is more reliable.

A POSA reading this paper I think can come to the conclusion that the -- the Schottky emission model seems to be correct. But there's something wrong in his experiment where -- that gave rise to this inconsistency. And Soukup himself, it is clear from that sentence, he doesn't know what went wrong either.

But a lot can be determined from the data. There's a lot of good data here. The Schottky emission model does seem to be correct. But there is something wrong with his -- with one of the datasets. And what -- where the problem is, Soukup wasn't able to figure out, so neither can a POSA. A POSA has trouble, has difficulty

deciding which of those two columns to rely on.
Q Okay. Sorry. You were on a roll.
A I'm -- I'm -- that -- that's -- that was the complete -- that's the extent of my response to your last question.
Q All right. You would agree that the values of the barrier height that is estimated in column 4 and column 5 of Table 1, those values are not -- strike that.
The barrier height estimates obtained from the slope of the Arrhenius plot as reported in Figure 5 of Table 1 depend on the zero-intercept of his IV measurements; correct?
A That's correct.
Q So these estimates are not independent, are they?
A Not completely independent. But they're not -- they're connected, but they're -- they also have a separate part. The data in column 5 relies on the variation of the temperature. So that's what distinguishes the two.
Q Let's go back to page 3232. The way they generate those plots is by plotting the zero-field intercept current I naught over different temperatures; right?

A Right.
Q That's the same zero-field intercept that's used to estimate the barrier height in column 4 for each device; right?
A The zero-field intercept.
Q Right.
A More or less, yes.
Q So if there's a problem with the zero-field intercept data, then there's also a problem with the Arrhenius plot data?
A Well, that's one way -- that's one way to look at it. It's not -- it's not definitive. Soukup himself is unsure where -- where the discrepancy comes from. He can't make a definite conclusion. And I think a POSA reading this paper, and especially that last sentence, where Soukup is essentially admitting that it is hard to make definite conclusions about these two conflicting results. So a POSA is, as I said before, is left unsure which -- which one of those numbers to rely on.
Q But you state that a POSA would have relied on the zero-field intercept numbers for the proposition that increasing oxygen vacancies in the magnesium oxide would reduce bare?

A Right.
Q So you are relying on the zero-field intercept data for that proposition; right?
A True.
Q And then in your declaration, you just rely on the different data to assert that Soukup obtained a barrier height of 0.33 electron volts; right?
A Right. There's a reason for that.
Q Tell me the reason.
A If we didn't have the problem for the two devices that essentially were used -- the three devices that were used to try to determine how the barrier height varied with oxygen vacancies, it's those three devices. The slope of the Arrhenius plot data for those two devices is where we have the greatest uncertainty. Where we have the greatest -- we have -- we have data that doesn't fit the model. All the -- everywhere else the data pretty well fits, but in particular these two devices when analyzed by the slope of the Arrhenius plot give a dependence that doesn't seem right. There's just something wrong with that temperature dependent data. For those two -- sorry. For the oxygen-dependent data for those

two devices. So that's why I -- I think the data for phi 1, for the oxygen vacancy effect, is more reliable.

Q Why do you limit your estimate of reliability just to the oxygen vacancy effect?

A Well, I don't. I'm saying when I'm trying to consider the oxygen vacancy effect, the data for the three devices measure -- obtained from the zero-intercept method is more reliable because he -- Soukup himself casts considerable doubt on the two numbers for those devices that were made with increased oxygen concentration during deposition.

Q The -- the numbers for those devices that are estimated based on the Arrhenius plot?

A Right.

Q Okay.

A He plots -- again, bringing your attention to Figure 12. Those two devices -- this is the Arrhenius plot data. Those two devices don't have the right temperature dependence. There's something going on in those devices. We really can't tell what. What happened to those devices. Analyzed this way. The analysis of this -- of the barrier heights for these two

devices measured this way has some serious discrepancies. That's why the -- that's why I say the -- the data for these two devices analyzed from the zero-intercept method seems more reliable.

Q Okay. So before, I asked you about the discrepancy between the numbers obtained from the zero-intercept plot and the slope of the Arrhenius plots or the barrier height estimates, and you said there is something wrong with one of his datasets. And where the problem is, Soukup was not able to find out -- figure it out. And so neither can a POSA. A POSA has trouble -- has difficulty deciding which of these two columns to rely on; right?

A Fair.

Q Okay. So why did you choose to rely on the .33 electron volt barrier height value in your testimony?

A Well, because it's at least -- a POSA looking at this says, well, I can't really decide for sure which one is right. But this paper at least suggests a barrier height of .33 is at least a possibility. It's not definitively determined as .33. But you read that, and you say, well, it

might be .33. And here, it's not 50 -- I don't think it is 50/50. I think it's -- well, there's a definite number there. It was -- we got a consistent value of .33 for a bunch of devices. So there's a good chance that that -- that number is correct. So a POSA --

Q Sorry.

A A POSA reading this paper, in my opinion, would come away thinking, this paper teaches me that if I -- if I do the -- if I grow the -- if I grow the MgO the right way, there's a way of growing the MgO that at least has a good chance of giving me a barrier height as low as .33.

Q By a good chance, what -- can you quantify that?

A I really can't quantify that.

Q A 50 percent chance?

A It might be 50. It might be better. It's hard to say. I don't think it is quite the same thing as -- as what we have for Butler and the TMR effect. I think there's -- there's -- a POSA looking -- very specific numbers. They're consistent for a whole bunch of devices. It is hard to say for sure, but there's a good chance that the low barrier height might be right. I

can't -- I can't assign a probability to this one.
Q If the Arrhenius plot estimates depend on the same data for the zero-intercept plot estimates, how can they be more accurate?
A The problem is that I, Soukup, and I think a POSA doesn't have a reliable way to resolve that question. So you would look at this and you would say you can get a barrier height as low as .33. And that seems like a good thing to try, as we discussed earlier, to improve TMR. So I think a person -- a POSA has a good motivation to try to repeat Soukup's technique to get a higher TMR. It is a motivation to try.
Q I'm sorry. Did you just say to get a higher TMR?
A Yeah. Well, that -- we talked a lot about that earlier today. So I'm extrapolating to that. To get a lower barrier height, which might lead to -- the motivation for a POSA to do that, to try to get that low TMR -- low -- sorry -- to get that low barrier height, this is a POSA who is trying to get -- make a better MTJ. Right. We're combining this with Bowen. So the motivation of the POSA is, how can I improve the TMR? I have some evidence that changing the barrier height has

a good chance of increasing the TMR. Let's not go back and revisit that entire story. But my opinion is that a person -- a POSA has a -- thinks there's a reasonable chance of success. And here, Soukup teaches that you have a reasonable chance of getting a barrier height as low as .33. That's a big effect. That's worth a try.

Q When you say that the data or the barrier height estimates obtained by the Arrhenius plot are consistent, how are they more consistent than the zero-field intercept barrier height estimates for the same?

A They're not. The zero barrier height numbers are also pretty consistent for a large number of devices.

Q So that can't be a reason for a POSA to say that one of the results is more accurate than the other or more likely accurate than the other?

A I don't think a POSA can really decide for sure which one is more accurate. But this -- this low barrier height is so compelling and tantalizing that I think a POSA would be highly motivated to try to reproduce that.

You know, when you have -- as a scientist, when you have an experiment, you do an

experiment, you measure a whole bunch of things and you have this kind of inconsistency, what do you do? Repeat the experiment. A POSA is highly motivated to try to repeat this, to see if they could get that .33 eV and see what effect it has on the TMR. Highly motivated. That's my -- that's my opinion.

Q So why wouldn't a POSA have looked at these results in Soukup and come to the conclusion the data doesn't fit the model?

A There's too much about the data -- I don't think a POSA reading this paper would reasonably come to the conclusion and say I've got to throw all of this out. The whole experiment is junk. I ignore it completely. Because a lot of the plots fit this pretty complicated model. So it's not all wrong. It's -- a POSA looking at this can't quite decide where there's some discrepancy. Somewhere in this experiment, something is not quite right. But so much of the data is -- you know, if all of the data was scattered everywhere and didn't follow any of the -- you know, these -- you look at a figure like Figure -- especially like Figure 4, Figure 3, these are straight lines on a log plot over three

decades of data. Same thing for Figure 4. You know, it's remarkable how good the fit is to that straight line. So that -- and, you know, same with Figure 6. So a POSA looking at this paper would say, well, there's a lot of good data in this paper. There's some kind of a -- something wrong in the paper. But it's got enough -- enough of it is consistent with this Schottky model to suggest that these numbers are -- should be taken seriously.

Q So if the data is consistent with the Schottky model, doesn't that mean that the current transport mechanism in devices was Schottky emission?

A That -- it means that the dominant current mechanism in these devices was Schottky emission.

Q So just to summarize, you rely on the zero-intercept barrier height estimates for the effect of oxygen vacancies on barrier height, but then you just choose to rely on the Arrhenius plot estimate of .33 electron volts for your testimony about the combination; is that right?

A I wouldn't -- I wouldn't put it that way. No. I disagree with that characterization of my

testimony and my opinion.
Q What -- what is inaccurate about it?
A I don't discount the zero-intercept method data.
Q Uh-huh.
A You get -- you get work -- you get barrier heights there that are .7. That's not nothing. That's less than the data, for example, from Bowen. So I don't discount that data. What I -- what I'm saying is a POSA would look at all of this data and say there's enough here in this experiment from -- there's enough in this experiment, which dates way back to 1970, to suggest that it is not all wrong. Barrier heights as low as .7 are highly likely. Even possibly as low as .3 -- .33. And so this seems to be promising. I should try repeating this and see what I get. Probably, you know, in something that is closer to Bowen. I should try using -- I should try incorporating this into an MTJ to see what I get.
Q And in paragraph 169 of your declaration, you rely on the barrier height from Soukup of 0.33 electron volts?
A I say a skilled artisan would have had a

motivation to take Soukup's teachings with a barrier height of .33 and apply it to Bowen's MgO barrier. What I said earlier that .33 eV barrier is particularly compelling. So I read that paper. And I say, wow, if I can get a barrier height as low as .33, boy, let's try that. That -- that should really -- that should really make a difference.

Q A difference in what?

A That's the -- that's the -- that really soups up the motivation to try.

Q Would make a difference in what, Dr. Bokor?

A To an MTJ.

Q What about the MTJ?

A Okay. We will go back to the same place where we were all day. There's a -- there's a strong suggestion from Bowen -- from Butler that if you vary -- if you lower the barrier height, you could get a significant effect on the TMR. Soukup is teaching a way that potentially you could really make a big change in the barrier height. If there's a dependence on the barrier height, if you could reduce the barrier height to .33, you could really test that concept. That's

what I'm saying.
Q And if Bowen had achieved a barrier height of 0.33 electron volts in his MTJ in 2004, what would a POSA have believed would have been the effect on TMR?
A A POSA would have believed the effect on TMR should be significant. It has a good chance of getting a higher TMR. And I want the higher TMR so much that I'm willing to give -- give it a good try.
Q What do you mean by good chance of a higher TMR?
A I've been saying consistently, it is at least 50 percent.
Q So it is also a good chance that it would be a lower TMR; is that right?
A Yeah. Look, you do experiments. Sometimes things work out. Sometimes they don't. It's worth a try.
Q Uh-huh.
A It is a good idea to try this. My understanding -- and I'm no -- I'm no attorney. So my understanding is that a claim is obvious if a person of ordinary skill in the art has a good motivation to expect success. Good reason to try.

That's the -- that's the context here that I'm giving this opinion.

Q And so your testimony is that a good reason to try was there's a 50 percent chance that TMR might go up?

A At least 50 percent chance, yes.

Q Okay. Why would it be higher than 50 percent?

A I don't know. I don't have enough information to say with certainty what the chance the TMR would go up.

Q So I'm not -- I'm not asking about what you know or -- and I'm not asking about certainty. I'm asking about what a POSA would have had reason to believe in 2004.

A That's what I keep saying. A POSA would have a pretty good reason to believe that the TMR would go up. How high is the chance? Well, it's -- maybe it is only 50 percent. I can't say what it is. Objectively, that could be determined. I mean, you know, there's -- there's an objective answer to that. It will -- it will either go up or go down. If somebody does the experiment, they will find out. So there is -- like I said, if somebody like Butler might have

been able to repeat that calculation, change the barrier height, and see what it gets. We don't know what that would be. But I would say there's -- you know, it's not -- it's not unknowable.

Q Have you ever cited Soukup's paper?

A In any of my papers?

Q Yes.

A Not that I recall.

Q When is the first time that you saw or read Soukup's paper?

A Probably in the context of this case.

Q Who found it?

A I don't -- I don't remember that. I did a lot of -- I did a fair amount of literature searching for this. I found some of the papers. I can't remember who found Soukup. I mean, I didn't do all the -- I was not solely responsible for literature searching. So it could have been somebody else. Somebody else. The attorneys. Maybe even one of the attorneys who found it. I don't know. I don't remember.

Q So you just testified that the POSA would have wanted higher TMR so much that they -- you said, I'm willing to give it a try. In other

words, try Soukup's magnesium oxide or barrier layer; right?

A Right.

Q Well, if that was such a compelling motivation, why didn't Bowen do it?

A I can't -- I can't possibly answer that question. Who knows if Bowen was aware of this paper.

Q Uh-huh. What do you know about the authors on the Bowen paper? Do you recognize any of the names?

A Some of them.

Q Was Bowen a leading result in MTJs when it was published in 2001?

A I can't answer that definitively. Look, Albert Fert as a co-author was quite a well known -- was quite well known, even back then. So my guess is -- I didn't -- I didn't know about this paper in 2001. I'm not sure when I became aware of it. But it's not -- you know, it's published in Applied Physics Letters. That's a prominent journal. Reasonable impact factor. Maybe not like Science or Nature. But lots of people read APL. So this paper had some -- you know, definitely had some impact.

Q Was this paper the first empirical test of Butler's predictions?
A I can't say that for sure. I don't know for sure.
Q Were they -- did they intend to test -- did they do this in order to test Butler's predictions?
A Well, they cite Butler. So they were influenced by Butler. I can't say whether they were the first -- I can't say right as I sit here now whether they were the first ones to try crystalline MgO. Actually epitaxial single crystal. The whole structure is single crystal. To get to the closest to Butler's predictions, you should do all single crystal.
Q Which is what they did?
A Which is what they did. So it is pretty good chance that they were trying to explore, test Butler's predictions. But I don't know. I don't know these people personally, so I couldn't tell you what they were thinking. It seems likely, but it is pure speculation.
ATTORNEY WICHMAN: All right. We've been going for an hour. Why don't we break for five minutes. Let's go off the record.

(A recess was taken.)
(Deposition Exhibit 3 was marked for identification by the court reporter.)
ATTORNEY WICHMAN: Okay. On the record.
Q Dr. Bokor, I put an exhibit in the chat of the Zoom. It is marked Deposition Exhibit 3. Are you able to open that document?
A Let me try here. Okay. I have it.
Q So you see that this is a paper in the Japanese Journal of Applied Physics, Volume 39, in the year 2000; right?
A I do.
Q It is entitled "Correlation between Barrier Width, Barrier Height, and DC Bias Voltage Dependences on the Magnetoresistance Ratio in Ir-Mn Exchange Biased Single and Double Tunnel Junctions." Right?
A That's the title. I see that.
Q And the last name of the first author is Saito, S-A-I-T-O?
A Yeah. I would pronounce it Saito, but yes.
Q Have you seen this paper before?
A I have to say it looks vaguely familiar. But I didn't study it. It is not in the record of

the case.
Q It is not. So I will be asking you a series of hypothetical questions about it.
A I have not looked at this paper recently. If you like -- if you want to ask me questions about it, I would ask for some time to read it.
Q Well, let's just follow along with my questions. And if you feel they're unfair, let me know. Okay?
A Okay.
Q So first, just to point to the abstract on page 1 of the PDF here, he is describing tunnel junctions that have aluminum oxide barrier layers. Right? Do you agree with that?
A That's what is disclosed in the abstract.
Q Okay.
A Sometimes there's more in the -- there might be other insulators discussed in the body of the paper. But in the abstract, it only talks about aluminum oxide. I can -- I can answer that.
Q Can you turn to the second page, the marking on the document is L1036. It is PDF page 2.
A Okay.
Q And I want to talk about the left-hand

column, the last paragraph in, and the Figure 1 underneath it.

A All right.

Q So first, if we talk about the words in the paragraph, just for context, Saito says that the Figure 1 shown here shows a barrier height dependence on TMR ratio at two temperature measurements in a single tunnel junction; correct?

A Okay.

Q And he says that the TMR ratio increased with increasing barrier height; right?

A That's what it says.

Q That's what it says. And if you look at Figure 1, he tells us that the dots are data taken at 250 Kelvin and the squares are data taken at 3.7 Kelvin; right?

A Okay.

Q And the plot in Figure 1, the Y axis is the TMR ratio in percentage and the X axis is barrier height in electron volts; right?

A Okay.

Q And if you go back up to the paragraph, he tells us that the solid line is a theoretical calculation, resulting from using a free electron model, assuming iron electrodes. That's what he

says; right?
A I'm sorry. Help me. Where are you reading from now.
Q The paragraph just above the figure.
A Just above the figure. Okay.
Q Yeah. Third sentence.
A "The tunneling currents were calculated"?
Q No. "The solid line in Figure 1 represents the" --
A I missed -- that's the third one. I apologize. I shouldn't have interrupted you.
Q Okay. So you see he's -- he states that that solid line in Figure 1 is a calculation that he made using a free electron model, assuming iron electrodes; right?
A Well --
Q That's what he says; right?
A He didn't -- he points to another reference, reference 11.
Q Okay. Yes.
A So I think he's pointing to a calculation made in reference 11.
Q That is the calculation that he is showing; right?
A The solid line in Figure 1 represents the

calculation result using the free electron model, assuming iron electrodes, reference 11. So the solid line seems to come from reference 11.

Q Right. And then he says that the tunneling currents were calculated on the basis of a particular equation; right?

A Right.

Q And then he says, "This suggests that the result is roughly consistent with the free electron model; that is, transmission coefficients of up and down spin depend on the barrier height for the STJs," and then cites reference 19. Right?

A Right.

Q And if you look on page L1038, which is PDF 4, reference 19 is Slonczewski's 1989 paper; right?

A Yeah.

Q And that's the same Slonczewski paper that Moodera cited in Exhibit 1035; right?

A Right.

Q All right. Now let's talk about this Figure 1. I want you to assume this hypothetical. Assume that this data is relevant to Bowen's magnetic tunnel junction. Got that?

A Well, I got it.
Q Okay.
A It's a leap because it is aluminum oxide barrier. But go ahead.
Q So if this data -- if -- okay. If a POSA in 2004 thought that this model and calculation shown in the solid line in Figure 1 was descriptive of the behavior of Bowen's magnetic tunnel junction, then the POSA would have concluded that reducing the barrier height from .9 to .85 electron volts would have reduced TMR; right?
ATTORNEY WILSON: Objection. Form.
THE WITNESS: The solid line does show the TMR going down between .9. And what was your other number? .7?
BY ATTORNEY WICHMAN:
Q .7. In any event, there's -- there's a trough here, there's an inflection point in this theoretical calculation; right?
A Uh-huh.
Q So in this calculation, TMR does not have a linear dependence of barrier height, does it?
A That's what the plot in that figure shows. I can confirm that.

Q Okay. So the theory is that the barrier height -- starting from .9 electron volts and reducing barrier height, the TMR is -- first, it's going to fall; right?

ATTORNEY WILSON: Objection. Form.

THE WITNESS: I would just point out that it goes back up.

BY ATTORNEY WICHMAN:

Q At low barrier heights, the theory says TMR will then increase again.

A Yeah.

Q Okay. But the data doesn't increase as you reduce barrier height, does it?

ATTORNEY WILSON: Objection. Form.

THE WITNESS: Well, you know, on its face, the data can be seen. I haven't studied the paper. I'm not comfortable making conclusions. On its face, the data -- just looking at this figure, the data is highly scattered. It does generally the trend does have it going down. It doesn't follow the theory though.

BY ATTORNEY WICHMAN:

Q So a POSA looking at this plot of data in Figure 1, if the POSA believed that this was representative of the behavior of Bowen's magnetic

tunnel junction, then the POSA would have concluded that the best way to increase TMR would be to increase barrier height; correct?

ATTORNEY WILSON: Objection. Form.

THE WITNESS: I can't -- just looking at this figure, I can't -- I can't agree with that. A POSA would get the idea that if I can reduce the barrier height below .5, I would increase TMR.

BY ATTORNEY WICHMAN:

Q Just based on the data.

A Based on the data. Okay. Your hypothetical, I -- I strongly object to your hypothetical. You're suggesting that a POSA would look at this and then try to imagine what would happen in Bowen's. But as we spent the whole day talking about, Bowen uses MgO. The whole point about using MgO for a tunnel barrier is because it has special properties, unique properties about how the -- what happens to the TMR. And as I suggested strongly many times today, the dependence of how the TMR would vary with barrier height according to Butler for MgO barriers could -- is -- well, to put it simply, it's not described by the -- either of the data or the theory in this experiment for aluminum oxide

barrier. It's hardly -- it's hardly applicable. So I complete -- I just reject your hypothetical.

Q You reject the idea that a POSA would have thought this would be relevant to Bowen's magnetic tunnel junction?

A Yes. I reject the hypothetical that the POSA -- that a POSA would look at this paper and have -- you know, I talked about how POSA would have reasonable expectation to expect this or that. I don't see how a POSA has a reasonable expectation to accept any of this for the Bowen MTJ.

Q Because --

A Especially the data.

Q Why is that?

A Yeah. Because it's for -- it's for an aluminum oxide barrier. As you said. I mean, I should -- I should hold up over there. I conceded that the abstract talked about aluminum oxide. I would like to take a little bit of time to see -- to understand what is going on in Figure 1, what kind of devices and what was the barrier, if -- if you will --

Q Well, I mean -- I don't mind taking the time to do it. But, I mean, what if we just make

this a hypothetical. If -- if this data involves aluminum oxide barrier, then your testimony is a POSA would have regarded this as not relevant to the behavior of Bowen's magnetic tunnel junction?

A That statement is way too broad.

Q Okay.

A I don't think that -- I mean, a POSA would not rely on this data to speculate or project or guess what would happen for an -- how the TMR would depend on barrier height for an MgO MTJ. This is a -- based on -- as you -- as you pointed out, the theory here was -- they pointed to Slonczewski.

Q Yes.

A A free electron model. It has nothing to do with -- well, I won't say it has nothing to do with. But it is missing a lot of the physics that is in an MgO tunnel barrier, as Butler pointed out. So I -- I hesitate to -- I haven't read the paper. I hesitate to say a POSA would have no use for this, anything in this paper. I won't say that.

Q Okay.

A It's -- you know, for all I know, it's a good paper. But for the dependence of the TMR on

the barrier height, I think a POSA would find this -- maybe find this data interesting. But to try to -- but then to use this as a basis for thinking about how to modify Bowen, that -- that I think is -- I don't think a person -- a POSA looking at this would have a reasonable expectation of success extrapolating from Figure 1 to Bowen.

Q And the reason for that is because this is not purporting to describe the behavior of magnesium oxide?

A Exactly. What makes Bowen special is the M -- is the single crystal electrodes and the single crystal MgO barrier. There's a major -- as we discussed before, you know, it was a major paper. I conceded that. It was done by credible people in the field. And it made a significant jump in the field by going to the MgO -- single crystal MgO barrier. Whether it was the first paper to test Butler's theory or not, I think it was -- I think we came to an agreement that it was a paper intended to test Bowen -- Butler. This paper -- I don't see how this paper helps to figure out what to expect for an MgO barrier.

Q Okay. If I could just ask you to look

back at Exhibit 1035. We talked about this.
A 1035. Moodera.
Q Moodera 1995. Page 3273. The right-hand column. This language about another theory of FM-FM tunnels has been proposed by Slonczewski.
A Right.
Q That's the same Slonczewski pre-electron theory that Saito is describing in his Figure 1; right?
A Well, as we went through, it seems -- the calculation seems to be based on Slonczewski's theory.
Q Okay. So do you agree that this Moodera paper, this discussion here, another theory of FM-FM tunneling in Moodera has as little relevance to the behavior of Bowen's magnesium oxide MTJs, as you just explained for Saito's paper, Deposition Exhibit 3?
A Well, we have to be a little careful about what -- what we're -- what relevance we're talking about. Okay.
Q Uh-huh.
A If you're referring back to the discussion we had earlier about this paper, what I said was the take-away from this paper for a POSA

was simply that Moodera is bringing up the fact -- is bringing up the proposition that -- yeah. Strong influence of tunnel barrier height on the orientation of the spins. And what I said was the -- I -- I pointed to this paper simply to say that the -- that the paper suggested the concept to a POSA that, hey, the TMR might depend -- is likely to depend on barrier height. That's all. That motivated the POSA to then, as we discussed earlier, think about it -- how that might happen in more detail. In particular, for an MgO barrier, in light of Butler theory. So the only -- the only relevance that I put forward for when I cited this paper was just to give -- just that hint.

Now, you point to another paper, this Saito paper from 2000. And here is a subsequent paper later on. But also -- the main point of the paper is to suggest that MR ratio could depend on barrier height. So in that light, yeah, here is another paper that gives a POSA an indication, a motivation, hey, let's think about how the MR ratio would depend on barrier height and look at Bowen.

Now, Slonczewski's theory, Saito's theory

here is not -- not quite on point to that. It motivates -- it seems to me it motivates a POSA to say let me figure out how barrier height would -- you know, would vary TMR in this more complicated MgO crystal tunnel barrier described by Butler. So this paper in my mind, the impact of this paper on a POSA is similar to Moodera that says, hey, see what happens -- see if barrier height can make a difference.

Q But it is your testimony that a POSA would not have looked at this prediction of a free electron model and concluded -- or looked at the data in Saito and concluded this suggests the best way to increase TMR would be to increase the barrier height of Bowen's MTJ?

A I think a POSA looking at this might say this is one suggestion. But it's for a simplified theory. Free electron theory. I'm looking at Bowen. Bowen is a very interesting paper. It is one of the earliest, if not one of the first papers, to look at the crystal MgO to test Butler. So maybe -- maybe the dependence of TMR on barrier height is as simple as this. But there's good reason to believe it would be more complicated in light of Butler. So that's -- that's the way I

would characterize how a POSA would look at this paper in light of Butler.

Q So if you were to read this paper in light of Butler, would a POSA have thought it was more likely than not that decreasing the barrier height would decrease TMR? Would this tilt the scales of the expectation in the direction of TMR will fall if I reduce barrier height?

A No. Because it can go back up. The -- the place where that minimum occurs is -- you know, is .5 eV for this free electron model. But for MgO, with a complicated band structure, who knows. Maybe it could -- maybe -- maybe the -- maybe for MgO, you would get a -- a curve like this. It is sort of a parabolic curve. Where is the minimum going to be? Maybe the minimum is 1 eV. And you would get a TMR that goes up as you reduce the barrier height from 1 eV. It is just -- it's just -- I can't say -- I don't see how a POSA could make a conclusion one way or the other. I don't see this changes the percentages that we were talking about earlier about what a POSA would think for MgO based on Butler.

Q So you're focusing on the theory, the solid line. If you focus on the data, the data

1 does not have an increase in TMR, and the barrier
2 height falls below .5 eV; right?
3 A Well, that's what this data shows for an
4 aluminum oxide barrier. That's true. But --
5 Q So for this data, in view of Butler,
6 would this have tilted the scale of probability so
7 that the POSA would have concluded it is more
8 likely than not that if I reduce Bowen's barrier
9 height, I will reduce the TMR?
10 A Okay. I'm going to fall back on not
11 having had the opportunity to study this paper in
12 detail, I'm not prepared to offer an opinion on
13 the influence on the probability of increasing TMR
14 by reducing barrier height for MgO based on this
15 paper. I can't give an opinion one way or the
16 other. I mean, I would need time to study the
17 paper. Probably read some of the references
18 before I could feel comfortable giving you a -- an
19 opinion on that.
20 ATTORNEY WICHMAN: Okay. Mr. Wilson,
21 I'll tender the witness.
22 ATTORNEY WILSON: We have no questions.
23 ATTORNEY WICHMAN: Very well. That
24 concludes our deposition. Off the record.
25 ATTORNEY WILSON: We reserve the right to

read and sign.

(The proceedings concluded at 4:23 p.m.)

-oOo-

I have read the foregoing deposition transcript and by signing hereafter, subject to any changes I have made, approve same.

Dated: _____

_____
(Signature of Deponent)

DEPOSITION OFFICER'S CERTIFICATE

STATE OF CALIFORNIA)
) SS.
COUNTY OF RIVERSIDE)

I, BROOKE SILVAS, a certified shorthand reporter for the State of California, do hereby certify:

That prior to being examined, the witness named in the foregoing deposition solemnly stated to testify to the truth, the whole truth, and nothing but the truth;

That the said deposition was taken down by me remotely in stenotype at the time and place therein stated and thereafter reduced to typewriting under my direction, and that the deposition transcript is a true and correct record of the proceedings here held.

I further certify that I am not of counsel or attorney for any of the parties hereto or in any way interested in the event of this cause and that I am not related to any of the parties thereto.

Dated: June 25, 2025

_____
BROOKE SILVAS
CSR No. 10988

DEPOSITION OFFICER'S CERTIFICATE

STATE OF CALIFORNIA)
) SS.
COUNTY OF RIVERSIDE)

I, Brooke Silvas, hereby certify:

I am the deposition officer that stenographically recorded the testimony in the foregoing deposition.

Written notice pursuant to Code of Civil Procedure, Section 2025.520(a), having been sent, the deponent took the following action within the allotted period with respect to the transcript of the deposition:

( ) In person, at the office of the deposition officer, made the changes set forth on the original of the transcript. (The parties attending the deposition have been notified of said changes.)

( ) Approved the transcript by signing it.

( ) Refused to approve the transcript by not signing it.

( ) By means of a signed letter, made the changes and approved or refused to approve the transcript as set forth therein. (Said letter has been attached to the original transcript and copies

thereof mailed to all parties attending the deposition.)

( ) Failed to approve the transcript within the allotted time period.

Dated: June 25, 2025

Brooke Silvas

BROOKE SILVAS
CSR NO. 10988

Exhibits

Dep EXH3 Saito_et_al_Jpn_J_Appl_Phys_2000_v39
193:2,6 204:18

$

$50,000
14:7

0

0.11
169:11
0.21
169:6
0.33
173:24 178:7 186:23 188:3
0.70
57:8
0.714
173:19
0.75
56:8
0.80
54:5
0.823
164:20
0.85
47:19 48:11
001
39:3,7 96:24
02
160:23 172:20
05
46:16

1

1
31:3 40:1 62:6,24 70:14,15,16 74:22 81:1 82:17 83:11,15 92:19 96:6 103:1 110:21 111:5,10,15 112:12,14 121:3,5,11,20 122:6,9 128:17 129:6 141:15 160:4,7,21 162:16,17 163:13 164:9,13,18 166:3 167:18,21 168:8,21 169:4,13,17 170:23 176:8,12 179:2 194:12 195:1,6,14,18 196:8,13,25 197:23 198:7 199:24 201:21 203:7 204:8
1,624
19:25
1-nanometer
19:15,22
1.1
40:14 42:2 43:12
1.9
138:1,3
1/760
157:22
1/T
170:24
10
37:12,15 40:25 41:10,18,22 42:17 94:14,20,21 100:3 106:25 107:2,3 108:14,20 109:3,7 119:6 137:8 157:17 158:2,5,6 161:1,4,8,11 169:14 170:7
100
62:16 115:24
1000
62:5
1015
108:13
1017
105:1,2,4 108:23 109:2 137:7
1019
108:20
1024
92:6 107:24 159:22
1025
14:20 15:1 32:7
1026
38:15,17,22 43:17
1027
136:21 140:14 150:4,7
1028
90:16 155:6 156:20
1031
83:18 110:16,24 120:21
1035
140:14,25 141:3,4,8,16 143:1 148:12 197:20 204:1,2
1038
60:1,2,4 67:16
1044
61:18 62:3 70:12 74:22
1046
62:3
1057
113:10 137:17 138:7,10,23 140:15
11
23:16 94:20 196:19,22 197:2,3
11,968,909
7:13
12
19:20 113:24 170:6,15 171:7,24,25 172:4,9 179:19
12:20
99:22
13
105:6 137:19 138:9
135
149:4
15
6:24 40:15 74:11 150:5,10 152:13
16
62:6 107:3 108:14 109:3,7 137:7,8 150:19
1656
39:22 40:3 41:3
1657
43:16,19
1665
93:18
168
155:11 156:9 159:22 162:3 165:4,7
169
132:21,23,25 133:1,11 135:4 136:12 137:16 138:7,11,12 140:13 141:2,9 142:19 186:22
17
150:5 151:3,5 152:13
170
120:1 122:13 126:9 127:21 128:4,10
171
133:21,22,23,25
172
92:12,13 95:25 97:18 134:5,7
173
92:11 134:12
1794
84:15 110:24 111:3
1796
120:22
1797
130:19
19
107:1 108:21 109:3,16 197:12,16
1963
84:1,2 112:25
1970
135:15 186:13
1975
84:10 113:3,16
1989
197:16
1993
30:20
1995
148:9 204:3

2

2
25:11 94:21 111:16 122:3 136:21,22,25 166:5 194:23
2(a)
41:6
2,459
15:20
20
8:12 13:15 15:12 71:5,8
200
15:8
2000
16:3,6,11 37:9,20 38:3 193:11 205:17

2001
47:5 62:4,12 115:20 191:14,19
2004
31:3 47:12,16,19,22 48:11,21 49:10 50:3, 9 51:11,15,20,24 52:15 54:6,23 56:8, 20 57:9,17 58:19 69:3 72:9 73:17 75:3,17 78:23 79:20 80:20 82:5,22 91:7 138:21 188:3 189:15 198:6
2010
28:7
2012
28:21,24 29:2
2015
28:9,11,12
2016
19:15 32:10,14 33:17,23 34:10 35:4
2018
35:1,12,19
202
14:19 15:5
2020
9:4
2021
23:18
2025
5:1
21
9:4
22
110:18
24
5:1 14:23 138:21
2400
18:4,5,20 19:1,5
25
74:14 130:16,22,24 131:1,14,18 173:2
250
195:15
27
44:6 46:3 48:14 50:12 54:24 57:10
276
149:3,5,8,14
277
149:24 152:16,24
29
107:25

3

3
35:2 39:23 80:11,22 84:15 110:25 111:3 120:21,22 150:9 170:7 172:5 184:24 186:16 193:2,6 204:18
3.7
195:16
30
8:12 13:15 44:24 45:13 99:23,25 118:3
300
44:6,9,16,19,23 85:22
30K
44:7
32
110:4 137:21
3231
163:16,21,25
3232
135:8 156:9,19,23 157:9 161:16 163:3 166:17,22 168:15 176:22
3233
160:3 162:16 164:9 166:4 168:8,21
3234
170:2
3236
135:8
3273
141:4,8,15 142:19 143:10 146:15 204:3
33
86:4 87:21 88:2,3, 11,18 89:2 90:11 92:24 94:1 102:5 103:15,25 168:19,24 180:18,23,25 181:1, 4,13 182:9 183:6 184:5 185:22 186:16 187:2,3,6,25
34
130:5
36
107:25 108:1,2
37
108:9 109:9 118:2
39
193:10

4

4
163:12,16 164:10 167:17 173:11 176:8 177:4 184:24 185:1 197:16
4.2
45:10
40
13:20
400
93:15 98:1,2,11,17 99:1 100:19 101:12
405
45:2
41
35:13,20
42
113:12
45
35:9 99:24 110:3,6,9
46
110:15 111:11 114:8,13,14
47
114:16,19
4728
60:3,5 67:19
48
114:24 115:2
49
130:4,6,11 132:10
4:53
134:23

5

5
79:19,24 80:9 106:25 108:14,20 109:2,7 137:7 156:19 162:17 164:1 168:17,24 170:4,11, 14 172:3,8 173:13 176:8,12,19 200:8
50
41:11 42:16 70:11 125:12 181:1,17,18 188:14 189:4,6,8,19
50,000
14:8
50/50
154:6 181:2
50K
14:15
56
32:12,13
57
19:14,17,18
5X
112:5

6

6
37:11,15 94:19 130:20 160:4 163:5 185:4
6,413,802
37:16
60
44:7 128:10
600413802
37:13
61
113:13
68
61:21,23 115:14 116:7 117:3 119:16 127:20 128:4,11,12, 16
69
164:6,11

7

7
15:25 16:4,5 34:24 79:18,25 80:9 83:12 126:12,24 158:3,5 161:8,11 186:7,15 198:16,18
72
164:6,11
75
54:22

77
45:6
780
164:16

8

8
23:18 54:9 83:12 137:7 157:18 158:6 161:2,4
8(A)
105:5,15 107:21
8(B)
106:4 107:21
80
44:12,15,16,20
82
95:25
85
46:8,13 50:5,10 52:25 54:9 92:19 96:6 103:1 198:11

9

9
42:15,22 43:5 82:18 83:13,14 88:13 94:15,22 126:11,23 198:10,15 199:2
9(B)
106:17
909
7:11,12,16,17 13:23 25:5 61:20 105:3 137:6,13
91
132:22 155:11
92
120:2 133:23
93
92:11 134:6
9:09
5:2

A

A.M.
5:2
abbreviations
107:10
ability
64:10
ablation
93:7,9,16
absence
62:19 116:1
absolute
30:12 76:3,5
absolutely
79:11
abstract
62:6 70:18 74:23 135:8 194:11,15,19 201:19
academic
18:21,24 20:22
accept
201:11
acceptable
11:10
accepted
132:4 142:23
access
76:25 106:18
Accomplishment
16:2
accomplishments
34:24
account
77:7,20 78:9,13 87:15,19
accurate
169:25 182:4 183:17,18,20
achieve
88:17 89:2 90:10 92:18,23 94:1 96:5, 23 98:20 102:21,25 103:13,24 120:9
achieved
46:7,12 47:18 48:10 50:5,9 52:24 54:4,21 56:7 57:7 69:3,6 71:9 79:19 80:11,22, 25 88:1 188:2
achieves
98:21
Acrobat
108:16
actual
71:1 171:1
Adam
5:11
add
104:11
add-on
129:1
added
89:1
additional
104:1
address
90:21 128:6
addressed
83:6
addresses
128:3,16 133:7
adds
157:6
adequate
48:7
administered
5:5
admitting
177:17
Adobe
12:19
adoption
23:6
advance
23:12
advanced
16:8 17:14 72:15 144:12
advantageous
76:10
advise
30:16,18
affect
151:17
affected
22:6 151:16 152:1,8
affecting
144:25 147:4
Agency
16:9,10
Agilelaw
6:4 12:19
agree
6:21 9:8 10:2 11:7 12:3,9,22 77:24 109:6,20 118:23 132:14,17 133:19 143:1,5 146:10,13, 23 149:8,14 159:10 162:4 176:6 194:14 200:6 204:13
agreed
12:25 124:16 142:23
agreement
132:20 203:21
agrees
140:23
ahead
20:3 61:22 92:4 95:12 110:23 124:20,21 132:18 151:19 159:11 164:3 198:4
Albert
191:16
alignments
107:17 117:8
allege
110:10 114:9,20 115:3,7 132:11 133:2,12 134:1,8,13
allowed
151:22
allowing
151:7,10
aluminum
62:13 74:1 115:21 148:6,13 194:13,20 198:3 200:25 201:17,19 202:2
amorphous
62:13 115:21 152:2
amount
18:17 61:8 103:10 117:1 119:2 123:24 124:2 190:15
amplifies
169:18
analysis
148:20,24 179:24
analyzed
171:19 178:21 179:24 180:3
analyzes
143:23
analyzing
36:20
angstroms
40:15 71:5,8
anneal
98:2,11,14

annealing
98:5
annotated
110:20
answering
35:17
answers
11:16,25
anticipate
148:7
anticipating
141:12
antiparallel
62:17 63:17 67:10 72:4 106:10,12,15, 22 107:11,16 109:24,25 110:12 114:6,11,22 115:5, 25 116:10,18 117:14 118:6,11,15,19,21, 25 119:5,12,22 120:13,15 122:16, 21,22 123:11,13 124:8,16 126:8,25 127:7,12 132:13 133:4,14,17 134:3, 10,15 141:21 149:17,22
APL
191:24
apologize
64:22 196:11
apparent
163:22 168:5
appearing
7:5,21
appears
136:23
applicable
201:1
application
75:14,20 76:8,11 78:22
applications
12:20 76:6,9 78:17
applied
42:25 65:7 76:22 97:19 167:3 191:21 193:10
applies
148:5
apply
60:25 61:5 66:6 92:23 96:10 187:2
applying
92:18 96:4 102:25
approach
100:24
approximately
40:14,15 43:15 44:12,14 45:2
arbitration
8:19
area
76:13 77:11 78:7
argue
128:2
Armond
8:1,3 13:10
Arnold
13:8
Arrhenius
166:13,16 167:22,25 168:2,4,10 169:2,6, 11,16 173:13,23 176:11 177:10 178:15,22 179:15,20 180:8 182:2 183:9 185:21
arrive
42:12
arrow
121:6,10,13
arrows
105:16 106:6
art
47:1,4,10,20 48:12, 15,22 49:25 50:3,21 51:10,14,19,24 52:15 53:6,11 56:20, 23 57:23 58:1,19 63:13,21 69:2,15 70:3 72:9 73:17,21 75:4,16 76:2 79:21 80:20 82:4,21 85:20 91:15 97:5 101:15 102:16,19 117:18,21 119:18 125:7,19 126:5 129:11,20 147:23 148:11 152:6 153:16 188:24
article
23:16,18
articles
23:21
articulated
82:7
artisan
92:16 96:3 102:23 186:25
ascertained
165:25
assert
124:23 153:6 178:6
assign
56:3 182:1
Association
16:8
associations
16:1
assume
66:1 197:23,24
assumes
90:6
assuming
195:25 196:14 197:2
atmosphere
45:5,10 157:22
atmospheric
89:14
attention
21:7 23:25 74:21 142:25 143:7 179:19
attorney
5:10 6:5,10 36:22 37:2,4,8 41:17,21 42:4,8 55:13 71:11, 14 74:9,13,17,20 75:7,15 77:15,23 88:7,16 89:3,9 97:22 98:8 99:21,25 100:2, 5,7 103:17,20 108:22 109:1 126:14,17 134:18, 21,22,25 135:1,3 154:20,23,24 155:1, 3 188:22 192:23 193:4 198:13,17 199:5,8,14,22 200:4, 9
attorneys
190:20,21
attributed
87:2 102:5
attribution
139:13
author
32:12 33:14 36:15 193:19
authors
19:22 139:19 191:10
average
61:5,11 65:15 66:19
avoid
9:18 15:7 87:8
award
16:3,11,15
awards
16:1
aware
45:12 49:23 55:24 61:16 88:9 142:3 191:7,20
axis
195:18,19

B

back
9:3 14:1,11 22:19 28:2 37:5,8,9 55:9 65:19 74:14,22 93:2 94:18 100:3 108:18 118:1 122:12 130:4, 6 134:23,24 135:3 136:19 140:12 146:14 154:24 161:15 162:15 164:9 168:15,21 176:22 183:2 186:13 187:16 191:17 195:22 199:7 204:1,23
bad
152:5
balance
75:25 77:25
balancing
78:13
ballpark
14:13,14
band
52:10 62:23 63:5 64:1,4,20 65:23 66:4,9 67:1,6 68:21 69:13,20 85:5 116:14 117:1 121:13,14,25 122:10,18

bandage
66:12 67:7
bands
63:6,8 123:2
bare
177:25
barrier
33:8 39:6,19 40:14, 17,21 42:3,13,15,21 43:5,8,10,11 46:7, 10,12,15 47:18 48:10 49:9,16,18 50:5,9 51:2 52:24 53:9 54:4,21 55:21 56:7,22 57:7,12,24 58:21 59:7 60:13,19, 24,25 61:1,2,3,6,10, 13,14 62:5,8,23 63:12,23,24 64:2,8, 17,19 65:11,12,13, 15,16,19,20,22,24 66:3,13,19 67:3,4 68:8,11,14,19,20,24 69:3,6,9,14,17,20, 21,24 70:21 71:2,4, 8,16,17,23 72:6,11 74:4,6 75:1,6 77:17 79:16,19,24 80:4,8, 11,22 81:1,3,11,14, 15,16 82:16,20 83:3, 10,15 85:4,10,13,19 86:4,24 87:9,11,17, 21 88:2,10,17,22 89:1,2,8 90:11 92:19,24 93:1,4,15 94:1,5 96:6 101:2 102:4,13 103:1,15, 24 104:6,20 105:12 106:1,14 109:24 110:10 111:24 112:7,14 114:9,20, 25 115:3,21 116:4, 14,23,25 117:3,7,24 119:19,22 120:10, 12,19,25 121:4,16, 24 122:4,6,7,14,16, 25 123:2,16,19,22, 25 124:1,24,25 125:5,20 126:10,22 128:8,17 129:6,14, 21,22 131:18 132:5, 9,11 133:2,12 134:1, 8,14 143:2,3,25 145:12,15,19 146:9, 11,20 147:2,4,8,18 148:1,4,5 149:9,15, 20 150:2,13,15,17, 20,23,24 151:12,18, 23 152:4,10,13,19, 20 153:2,3,7 154:3, 13,17 155:16 156:3, 4 159:24 160:1 161:21 162:11,20,23 163:7,9,10,22 164:10,14,19,23 165:9,15,23,24 166:8,11,12 168:5, 18 169:5,10,15,21, 23 170:18,22 171:1, 8,11 173:6,9,11,18, 22 175:8,9 176:7,10 177:3 178:7,14 179:25 180:9,18,23 181:13,25 182:8,18, 21,25 183:6,8,11,13, 21 185:19,20 186:7, 14,23 187:2,3,5,19, 22,23,24 188:2 190:2 191:1 193:14 194:13 195:6,11,20 197:11 198:4,10,23 199:1,3,9,13 200:3, 8,17,21 201:1,17,22 202:2,10,18 203:1, 14,19,24 205:3,8,12, 20,23 206:3,5,8,15, 22
barrier'
156:13
barrier.'
62:19 116:2
barriers
62:14 74:1 112:3 115:22 120:9 148:13 164:5 200:22
base
94:14 157:7
based
13:4 49:14 80:5 83:7 104:16 110:7 117:17,23 126:5 128:7 129:3,18 148:8 179:15 200:10,11 202:11 204:11
basic
116:22 158:24
basically
46:5 76:3 140:21 163:19 171:18
basis
10:24 47:25 58:18 64:15 123:18 124:9 126:16,20 173:7 197:5 203:3
bathroom
11:24 36:25
Beach
8:4
bear
108:15 109:12
begin
11:13
begins
44:2
begun
11:13
behalf
7:21
behavior
198:8 199:25 202:4 203:10 204:16
believed
188:4,6 199:24
Bell
30:8 31:12
bench
31:9
benefits
152:9
Berkeley
21:11 28:15 29:11 30:8,19
bias
40:25 41:15 60:12, 13,20,23,24,25 61:5, 7 65:7,15,18 66:6 67:24 68:7,25 193:14
Biased
193:16
big
23:12 183:7 187:22
bit
8:16 14:17 22:17 42:6 60:8 85:25 93:5 109:10 142:5 201:20
bladder
11:1
blockage
63:16 67:9 72:4
blocked
63:3 123:14,15
blocking
62:9 64:6 67:12 128:18
body
16:16 17:5 194:18
boiling
45:15
Bokor
5:4,11 14:16 35:15 36:23 37:9 59:20 74:21 100:9 109:23 117:20 187:13 193:5
bolts
169:2
book
139:15,17,25
bother
121:7
bottom
19:19 23:17 33:5 39:2 98:12 105:11, 16 106:6 110:18,19 121:6,10,14 133:23 145:11 156:22 160:4,14 161:16 166:4
boundaries
127:25
Bowen
38:17,21,24 39:18, 22,23 40:20 41:3 42:1,20,24 44:5 45:13 46:2,7,10,12 47:16,18 48:10 50:4, 9,12 52:24 54:4,21, 25 56:7 57:7 59:3,4 69:3,5 71:4,9,15,17 72:14,17 73:11 79:16,19 80:10,21, 25 88:5 92:18,23 93:2,5,6,11,14,18,19 94:1,21,25 95:7,16, 22 96:5,10 97:6,10, 16,20 98:1,9,10,14, 16,20,25 99:3,15 100:16 101:15 102:6,8,11,25

103:19,23 126:10,22 129:22 182:23 186:9,19 187:18 188:2 191:5,7,10,13 200:16 201:11 203:4,8,12,22 205:24 206:19
Bowen's
46:23 50:4,11 52:3, 23 54:6 56:9,21,22 57:9 58:21 72:11 73:18,24 75:4 82:17, 23 83:11 85:23 86:3, 24 87:9,22 88:1,18 89:1 90:11,13 91:8 94:7,21 95:6 100:18, 25 101:10,25 102:2, 20,21 103:14 104:6, 20 124:24 125:20 128:8 145:9 148:15 149:1 187:2 197:24 198:8 199:25 200:15 201:4 202:4 204:16 206:15
boy
187:6
break
11:2,5,9,20,23 36:23 50:7 65:1,3,5 73:2 74:10,24 81:11 100:9,13,15 134:19 192:24
breaks
10:22
breakthrough
16:19 17:20,21,25
breakthroughs
18:1
Bridge
5:12
briefly
13:9 76:20 114:18
bring
74:21 81:11 90:14 119:25
bringing
179:18 205:1,2
broad
75:19 202:5
broader
30:15
brought
27:10 122:24
build
77:8
building
77:14
built
88:6
bunch
181:4,23 184:1
Butler
61:16,17 62:3,6 63:9,14,21 64:12,13, 18,19 66:24 67:8 70:5,12 71:7,19 72:2,9,14,21 74:7,22 75:11 80:6 104:12, 16 116:16 117:11,22 119:17 120:8,17 122:12,14,17 123:8 129:12 144:11 148:4,7,21,24 153:17 181:20 187:18 189:25 192:8,9 200:22 202:18 203:22 205:12 206:5,21,25
Butler's
71:22,24 72:17 73:3 192:2,6,14,19 203:20

C

calculate
21:5 44:21 49:19,20 57:16 86:9
calculated
62:4 196:7 197:5
calculation
20:19 44:18 45:22 47:6 49:22 50:1 52:14,16 56:18 64:11 70:9 73:8 86:1,14 190:1 195:24 196:13,21,23 197:1 198:6,20,22 204:11
calculations
86:9
California
8:4
call
38:21 41:14 96:20 105:21 142:12 161:12
called
16:24 17:18 39:23 76:2 106:2,15 122:18 135:24
calling
107:7
calls
68:13 84:22 89:21 108:6 120:25
candidacy
22:7
candidate
22:5,9
capability
36:17 52:16 53:23 72:18
capacity
32:9 33:22 34:14
capture
148:17
captured
131:4
capturing
175:4
career
22:18 30:7 138:25
careful
55:5 133:8 204:19
carefully
72:21 133:9
cartoon
105:8
case
7:5,9 10:11 14:7 38:19 66:14 67:13 69:23 87:10 105:18 190:12 194:1
cases
107:16
casts
179:10
causing
66:11
cell
106:18
cells
35:22
Celsius
93:16 98:11 99:1 100:19 101:12
centers
17:16
certainty
55:22 58:3 84:11 189:10,13
cetera
60:15
Chairman
21:10
chamber
34:21 89:14,18 94:8, 19 101:11 155:22 157:5 158:16
chance
59:7 70:11 72:7 125:12 181:5,12,14, 17,24 183:1,4,5 188:7,11,15 189:4,6, 10,18 192:18
change
48:19,23 50:23 51:1 53:12 55:21,25 56:13,21,24,25 58:2, 8,18,23 59:6,11 61:8,14 64:8,17,19 67:13 69:22 71:17 76:4,23 79:24 80:8 81:18 112:6 116:24 117:5,13,23 119:2, 19 123:19 124:1,3, 10 125:1 128:7 129:24 147:8 153:18 154:5 187:22 190:1
changed
50:18 51:25 56:10, 22 69:11 80:17 93:25 99:3 104:16 111:14,17,23,24 119:1,20 122:8 129:21
changing
63:25 69:10 71:16, 23 74:6 95:4 150:16 182:25
characteristics
78:1 156:25 166:25 167:12,21
characterization
31:20 185:25
characterize
32:6 167:7
characterized
39:18

characterizes
78:8
characterizing
31:9,17
charge
143:24
chat
12:15 193:5
chatted
13:9
check
19:10
checking
135:22
chemical
67:3
chip
17:11
chips
17:15,16 18:12,15
choices
53:4
choose
180:17 185:21
chosen
34:5
circuit
17:15 19:5 76:21,24
77:3,5
circuits
16:22
circumstance
60:18
citation
18:25 19:6 20:21
23:4,23 62:1 137:15
citations
19:2 22:14 140:13
cite
18:6,9 21:2 38:18
100:23 101:9 104:23
136:16,20,24 137:6,
16 140:22 141:2,3,
25 142:1 144:13,14,
15 150:4 174:19
192:8
cited
15:16,20 18:5,20
19:8,12,25 22:9
45:23 70:2 104:1
141:11 142:15 190:6
197:20 205:14
cites
62:7 137:14 197:12
citing
27:25 137:4,13
138:6 140:16 141:7,
14,15 142:19
claim
37:22 188:23
claims
97:17
clarified
10:8
clarify
10:2 47:3 58:14
class
26:2,4,5,6,10,14,16,
25 27:1,6
classes
25:22,25 26:1 27:14,
22 28:5,14
classroom
25:18
clean
30:22,23,25 31:1
clear
98:9 121:8 123:23
147:17,21 154:9,11
175:17
click
45:24
close
14:9 22:24 23:24
29:11 65:1 79:4 92:1
closed
137:22
closely
78:24
closer
90:1 159:6,18
186:19
closest
192:14
CMOS
16:20,25
co-author
33:13 191:16
co-authors
36:8
cobalt
39:11 73:13
coefficients
197:10
coin
125:16
cold
45:17
collaboration
34:7,8
collaborator
36:13
column
40:5 41:4 43:17,22
60:7 67:21 84:18
106:25 108:14,20
109:2,7 111:6 137:7
143:7,11 146:16
156:23 160:10,21
162:16 163:12,17,25
164:10 166:5,12
168:8,9,16,22,24
170:3 173:11,13
176:8,19 177:4
195:1 204:4
columns
176:1 180:14
combination
97:15,18 98:6 99:8,
16 100:16 185:23
combine
61:13 97:10 98:3,23
102:10
combined
93:7
combining
182:23
comfortable
81:21 82:2 199:17
comment
10:25
commercial
18:15
commercialized
38:8
common
136:11
community
18:24 19:5 21:8
company
18:14
comparable
81:17
compare
86:9 111:10 120:14
compared
54:9 79:25 88:13
120:12 121:2 122:16
133:16 149:22
comparing
109:17 156:4
compelling
183:21 187:4 191:4
complete
176:4 201:2
completed
138:20
completely
72:13 176:17 184:15
complicated
72:15 124:5 184:16
206:4,24
composition
52:10 67:3
comprehensive
139:15,20 140:7
computer
5:16,20,21 10:9
12:11 17:16 21:11
computing
17:17
conceded
201:18 203:16
conceivably
152:9
conceive
152:9
concentration
88:23 89:7 90:7
95:14 102:6 179:12
concept
187:25 205:6
concerned
86:23 87:3 148:12
conclude
153:17
concluded
147:25 148:11
198:10 200:2
206:12,13
conclusion
43:24 73:22 104:15
115:9 117:15,17,22
119:18 175:13
177:15 184:9,13
conclusions
174:22 177:18

199:17
condenses
45:6,9
conditions
95:1 136:11 158:11, 20
conduction
65:23 66:4,11 67:7 68:21 69:13,20 85:5 121:13,14,25
conference
8:5,6
confidence
56:13
confident
82:14
confidently
81:8 123:9
confines
72:1
confirm
130:17 162:6 198:25
conflicting
177:19
confusion
42:6
connect
77:2
connected
176:18
consequences
152:3
considerable
59:1 61:8 179:10
consideration
79:5,13 87:6,14,18
considerations
75:22 78:12 88:14
considered
13:19 20:6 24:1,4, 13,16,19 64:24 81:3, 18 82:8
considers
159:13
consistent
145:2 147:10 149:11 152:4 181:4,23 183:10,14 185:8,11 197:9
consistently
188:13
constant
168:13
consult
100:12
context
25:5 30:15 61:14,15 69:18 189:1 190:12 195:5
contribute
20:23 60:11 67:23
control
152:10
controlling
150:20
conventional
142:6
copied
131:1
copy
131:2
correct
7:22,23 9:24 21:12 38:10,13,14 45:1,8, 16 58:4 71:3,5 76:15 89:19,20 93:17,18, 21 98:12 106:23,24 107:12,21 108:3,10, 11 109:2,9,19 110:7, 8,13,16,17 111:22 112:4,20 114:11,15, 17,22,23 115:5,6 118:8,9,12,16,20 119:13,14 124:19 127:15 131:22 132:7,13 133:4,14, 15 134:3,4,10,11,16, 17 136:2,15 138:5 141:24 143:18 145:8 148:23 150:13,14, 18,22 153:3,4 157:11,13,14,18,21, 23,24 158:6,7 160:8, 9,12,15,16,20 161:9, 10 164:2 165:5,19 167:5,8 168:1,6 171:22 173:25 174:13,15,17 175:14,21 176:13,14 181:6 195:8 200:3
corrected
131:23,25
correction
130:8,12,15
corrections
131:12
corrective
131:12
correctly
35:23 47:15 58:13 153:9
correlation
165:14,22 193:13
corresponds
45:21
counsel
10:14,19 12:1,7 13:4,6
count
19:6 23:4,23
counts
18:25
couple
26:25 65:2
coupling
145:1
courses
25:19 26:19,22 27:11 139:4,8
court
9:12 193:3
covered
31:15 135:12
creation
60:13
creative
23:15
creativity
23:1,11
credible
203:16
credit
18:18
critical
78:16,18
cross-examination
11:14
cryogenic
44:24
crystal
38:25 39:7 52:12 73:4 96:23 101:20 147:21 148:20,21 152:2 192:13,15 203:13,14,19 206:5, 21
crystalline
39:2 62:14 73:4,5, 12,13 97:2 101:11 115:22 192:12
crystallize
98:11
crystals
151:8,11,22
curiosity
138:16
currency
18:25
current
25:12 39:24 42:25 84:19 85:17,23 86:10,19 87:1,23 88:5,9,12 105:25 106:13,21 130:9 167:6,16 174:23 175:6 176:24 185:12,16
currents
76:22 84:22 86:21 143:24 196:7 197:5
curves
40:8 42:21 170:10, 14 172:7,8,16,22,23
cut
115:18 131:5
CV
14:17,20 15:2,25 22:20 23:16 25:11 32:7 35:2 37:11,15

D

D-A-R-P-A
16:7
DARPA
15:23 16:2,7,11
data
17:16 36:20 46:21 160:8 171:4,19,24 172:25 173:6,8 175:2,11,20 176:19 177:9,10 178:3,6,16, 18,20,24,25 179:1,8, 20 180:3 182:3 183:8 184:10,11,21 185:1,5,11 186:4,8, 9,11 195:14,15 197:24 198:5 199:12,16,18,19,23

200:10,11,24 201:14 202:1,8 203:2 206:13
datasets
175:23 180:11
date
113:22 140:10
dates
186:13
day
31:7 127:10 187:17 200:15
days
30:7
DC
193:14
deal
175:3
debate
139:14 153:21
decades
185:1
decide
50:16 64:11 180:21 183:19 184:18
decided
36:5
deciding
77:8 176:1 180:14
decision
21:21 36:7 75:23
decisions
21:17 22:1,23
declaration
38:19 59:16,18,21 61:20 69:15 88:21 90:19,21 92:5 95:16, 19,21,24 96:9,21 104:3,23 107:24 109:9,13,16 110:3,9, 15 111:12,17 112:18,19 114:8,16, 19,24 115:2,11 119:16 120:1,8 122:13 124:23 125:3 126:3,6,10 127:22 128:2,5,15,20 129:4, 17 130:25 132:22 133:11,25 134:5,13 135:5 136:13 138:13,18,20 140:13 141:3,8 142:7 144:8, 16 146:2 149:4 152:17,24 155:10 159:21 162:2,13 165:4 178:5 186:22
declarations
13:18
decrease
51:17 60:12,15 65:12,13 67:23 72:11 75:12 79:22, 24 80:21 81:2 90:8 119:5,21 151:23 153:20
decreased
51:12 69:4 72:12 119:11 130:2,3 169:16
decreases
65:15 68:11 85:10 88:10
decreasing
68:11 72:6 125:19 146:20
deeply
26:17
defect
69:10 102:13
defects
67:4 88:25 89:19 90:4,7 91:2,6,13 95:14 101:4,19 122:8 159:23,25 165:9,15,22
Defense
16:7
define
108:2 109:8 142:14
defined
118:5 142:13
definite
51:8 174:22 177:14, 18 181:3
definition
69:14,17 127:24 142:6
definitive
14:10 48:17 50:19 56:2 177:12
definitively
49:5,11,18 50:15 139:10 180:24 191:15
degree
55:23 56:12 93:15
degrees
44:12,15,16 45:2 98:17 100:19
delta
60:16,18 62:24 109:18 128:17 129:6 145:3 147:10,14,20 166:9
delta-1
62:9
demonstrate
16:23
demonstration
34:24
dense
144:12 145:23
density
39:24 60:14 69:10 102:13 130:10
department
21:11 28:16
depend
49:16 60:19 74:4 75:20 86:11 176:12 182:2 197:11 202:10 205:7,8,19,23
depended
51:3,4 62:22
dependence
40:7 42:21 47:8 49:9,17,24 60:13,21 68:7 72:4 166:23 170:5 172:3 175:8 178:22 179:21 187:23 195:7 198:23 200:21 202:25 206:22
Dependences
193:15
dependent
63:6 64:7 129:10,13 166:24 167:13 178:24
depending
63:7 75:20 76:7 123:15
depends
33:24 127:23,24 171:9,12
depiction
48:8
deposed
8:8,14,23 9:17
deposit
91:14,17 93:9 95:8, 17,22 96:13 99:3,11 102:4
deposited
99:15 158:20
depositing
97:6
deposition
5:1 7:3,5,10,16,19 8:20,24 9:6 10:6,15, 23 11:13,14 12:4,8, 23 13:2,20 86:15 91:12 96:8 97:24 98:1,4 100:10,13 101:17 102:10 156:15 158:18 161:22 170:9 172:21 179:13 193:2,6 204:18
deposits
98:10,16,23
Desai
19:14,21
describe
71:15,22 124:16,23 152:13 157:4 203:10
describes
85:13 90:3 91:2 124:17 156:23 157:10 163:16,17,22
describing
68:6,10 73:25 107:4 143:22 147:25 194:12 204:8
description
65:10 163:20
descriptive
198:8
design
24:14,18,20 26:11, 15,18 32:23 33:1,3, 15,22,25 34:2 76:17 78:9 79:9
designed
32:9 33:16,18,19 34:5
designer
77:24 78:3,12

designing
31:25 32:1,3 77:20
desire
57:21
desktop
6:5,6
detail
26:15 27:4 49:8,17, 19 205:11
detailed
34:3 48:7 62:23 64:11
details
22:25 26:18 28:1 32:23 51:2,3 52:18 63:5
determination
48:17 49:6 56:12
determine
52:17 53:22,23 56:1 156:24 168:4 178:13
determined
43:12 54:18 57:5 162:24 163:11 175:19 180:24 189:21
determining
77:13
developed
38:8 151:21
developing
151:7,10
development
23:6
developments
140:9
device
23:7,8 25:16 26:3, 10,20,23 27:24 28:4 31:11 32:21 33:16 39:13,18 42:17 43:1 47:21 50:4,11 52:3, 23 54:6 56:10,21 73:10,18,24 75:5,12, 18 76:14 77:12,14 79:2 82:17,23 83:11 87:22,23 88:1,3,5,18 90:12 104:6 105:25 106:14 107:5 145:10 156:25 157:25 158:10,13,17 160:7, 11 161:5,9,12 164:14,19,25 166:12 167:4,7,21 168:23 169:5,9 170:9 171:22 172:21 173:1,15 177:4
devices
24:13 29:9,15 30:5, 11,17,20 31:1,10 32:5 35:23,24 37:10, 20 38:4 89:13 112:2 155:21,22 156:5,13 157:10 160:13,17 161:21 169:21,24 170:8 171:4,6,19 172:6,20,24 173:7 174:24 175:5 178:12,13,15,16,21 179:1,8,11,14,19,20, 22,24 180:1,3 181:4, 23 183:15 185:13,16 201:22
diagram
121:18
Dieny
62:7 138:14
difference
54:8,10 69:18,22 187:8,9,12 206:9
differently
154:10
difficult
9:15
difficulty
175:25 180:14
dig
59:14
Digital
7:22 10:14 11:17 12:6
Digital's
11:25
dimensions
78:18
diodes
89:12 135:20,23
direct
174:21
direction
48:21 50:16,18 52:17 54:19 56:24 104:15 105:17 117:23
directions
106:7
directly
151:13
directory
5:21
disagree
185:25
disagreement
144:17,19
disclosed
129:4 194:15
discloses
143:4
discount
23:13 186:3,9
discovered
84:4,7 113:3,16 135:18
discovering
151:6
discovery
113:22 142:10
discrepancies
180:2
discrepancy
142:3,7,12,25 177:14 180:7 184:19
discuss
11:15,24 12:3 36:16 110:16 114:17,25 127:22 138:22 144:7 146:4
discussed
59:19 99:23 101:5 104:12 108:5 115:15 140:3 155:19 157:3 160:18 161:5,12 169:22 171:13 182:10 194:18 203:15 205:9
discusses
159:13 174:6,8
discussing
12:24 148:18 153:12
discussion
34:22 90:19 169:19 204:14,24
discussions
36:19
disparaging
172:25
dispersion
63:7
displays
12:12
dispute
13:23 113:5
distance
65:17 66:5,12 68:22
distinguishes
176:21
divided
118:7 145:3 170:23
dividing
141:21
document
6:20,24 7:1,7 14:25 15:1 28:2 103:11,22 104:4,19 146:5 193:7 194:22
documents
5:19,24 6:13 13:3,5 104:2,22 108:17 136:17
dominant
185:15
dots
195:14
Double
193:16
double-gate
15:12
doubt
39:16 45:25 113:19 173:8 179:11
doubts
173:5
Doug
13:8
dramatically
17:11
draw
13:16 117:22 119:18 127:24
drawn
104:15 168:18
drop
83:3,10 160:25
dropped
131:6
dropping
66:20

dt
170:20
due
62:18 116:1,14
120:9
duly
5:5

E

earlier
68:17 128:14 135:19
137:9 182:10,17
187:3 204:24 205:10
earliest
206:20
early
30:6 142:9,10
easily
45:23 95:13
easy
52:13
edge
17:14
EF
122:1
effect
71:23 83:22 85:9,15
86:19 104:24 113:16
117:12 136:9 156:24
179:2,5,7 181:21
183:7 184:5 185:20
187:20 188:5,6
effective
64:7 68:13,19,24
151:18
effectively
123:14
effects
60:14 143:20
efficiently
17:2 129:7
effort
68:16
elastic
66:18
electric
37:10 66:11 83:22
85:14
electrical
21:10 30:14
electrode
33:6 34:16 39:10
65:9,18,21 67:1
68:22,23 69:8,11
101:7,12 105:12,13,
17 111:15,16,18
117:8 121:5,11,20
122:3,6,9 145:11
electrodes
83:23 84:20 85:3
103:15 106:1,14
107:17 111:21
112:15 120:11
135:25 136:6,9
195:25 196:15 197:2
203:13
electron
24:12 37:20 40:14
42:2,22 43:12 46:8,
13 47:19 48:11 50:5,
10 52:25 54:5,22
56:8 57:8 66:14
79:19 80:11,22 81:1
82:17,18 86:4 87:21
88:2,4,18 89:2 90:11
92:20,24 94:1
103:25 126:11,12,
23,24 162:21 164:7,
11,15,16,20,21,24
166:14 168:19,24
169:7,11 173:19,24
178:7 180:18 185:22
186:24 188:3
195:20,24 196:14
197:1,10 198:11
199:2 202:15
206:12,18
electronic
38:4 76:21 77:2
84:19
electrons
61:9,25 62:9,10,24,
25 63:1,2,17 67:10
72:5 85:3 115:17
116:25 117:14
120:12 121:11,24
122:15,20 123:1,11,
13 128:18 129:6,8,9
149:22
element
151:15,25
elements
20:19 115:10
eleven
60:10
else's
139:12
email
12:16
emerge
122:3
emission
85:7,21 86:3,21
87:2,23 88:5,9,12
135:23 175:2,3,14,
21 185:14,17
emitted
157:16 158:2
empirical
192:1
enabled
17:8
encompass
96:7
Encompasses
137:8
end
146:9,18
energy
63:6,7,17 64:6 65:21
66:4,17 69:18,21
72:3 81:17 83:3 85:4
116:24 117:7 122:2
123:2,15 129:10,13,
15
engineer
30:8
engineered
69:7
engineering
19:5 21:10 30:14
enter
122:1
entering
116:25
enterprise
17:17
entire
29:10 173:9 174:20
183:2
entitled
6:24 15:11 193:13
entry
160:25 161:7 166:11
epitaxial
93:19 94:7 98:18
192:12
epitaxially
39:14
equal
118:15 121:19
equally
53:14 54:16,19
72:10
equals
42:22
equation
39:24 41:23,24 43:7,
9 108:10,12 109:6,8,
17,21,22 118:2,14
130:16,18,22,24
131:1,14,18 132:6
136:14,23,25
137:11,14 138:1,2,3,
11 140:18,21
141:12,14,15
142:11,17 164:1
170:12,14,17 172:8
197:6
equations
40:12,13 42:10,12
109:15
escaped
142:24
essentially
66:17 128:25 177:17
178:12
established
62:8 135:19
estimate
28:13 42:2 43:8,9,12
48:3 72:18 127:3,4,
6,12,18 173:18,22
177:3 179:4 185:22
estimated
54:25 62:16 115:24
116:8,9 156:4
173:10,12 176:7
179:15
estimates
43:4 165:24 176:10,
15 180:9 182:2,4
183:9,11 185:19
estimating
39:19 126:21
etch
78:21 79:3
etches
79:3

ev
42:15 43:5 46:16 79:24,25 184:5 187:3
evaluating
162:24
evaluation
23:1
evaluations
22:19
evaporate
91:15 99:6,17 100:17
evaporated
92:3 99:11 101:6
evaporating
91:21 101:10,24
evaporation
93:1 94:4 95:10,13,17,23 96:13,17,21 97:13,24 98:5,24
evenly
151:8,11,23
event
128:24 198:18
evidence
100:23 101:3,9,22,23 103:3 125:18 153:11,12 154:14,15,16 174:21 175:3 182:25
evolved
36:20
exact
8:11 149:12
examination
5:9 11:21 12:4
examined
5:6
excess
14:6,8 62:4
exchange
145:1 193:16
exclude
51:16
excluding
172:17
exhibit
6:18,20 15:1 32:7 38:15,22 43:17 60:1,4 61:18 62:3 67:16 70:12 74:22 83:18 90:16 92:6 107:24 108:13,20 109:2 110:16,24 113:10 120:21 136:21 137:7,17 138:7,10,23 140:14,25 141:3,4,8,15 143:1 148:12 150:4,7 155:6 156:20 159:21 193:2,5,6 197:20 204:1,18
exhibits
6:18 10:6,10 12:24
expand
145:24
expands
169:18
expect
48:18 54:3 55:16,18 56:5 57:15,18 58:2,23 59:6 67:11 70:7,9 80:4,7 82:10 83:2 93:10 117:4 123:17 188:25 201:9 203:24
expectation
49:15 50:17,19,22 51:9 52:22,23 53:2,7,12,15 54:1,14 55:20 57:14 59:10 63:22 64:6,16 82:6 92:17 96:4 102:24 117:12 125:8,12 126:1 153:13,19,22 154:3 155:25 201:9,11 203:7
expected
47:1,14,21 48:12,18,22 50:3,11 54:6,23 56:9,21 57:9 58:6 80:1 81:2 82:5,22 85:20 86:2 87:20 88:3 110:1 122:25 126:13,25 128:7 158:22
expecting
47:25 58:20
experience
22:20 24:25 31:14,17,24 32:1,3 106:22
experiencing
66:16,19
experiment
47:24 59:3 60:20 94:4 97:9 98:7 102:17 156:24 175:15 183:25 184:1,3,14,19 186:12,13 189:24 200:25
experimental
42:15 101:21
experimentation
100:22 102:9 103:5,8,10
experimented
97:21
experiments
30:10 102:20 188:17
expert
7:25 33:15
experts
57:17
explain
20:9 49:12 58:12 68:17 69:16 88:20 120:16 171:9
explained
62:13 115:20 120:7 166:8 204:17
explains
75:11 145:24 162:19
explanation
64:22 68:17
explicit
125:4,22 128:9
explicitly
49:24 96:20,25 115:11 120:14 125:24 126:2 144:15 152:6 157:6
explore
71:24 101:18 192:18
expresses
173:8
expression
121:18
extend
17:9
extent
176:4
extracted
173:6,23
extracts
168:13,14 175:8
extrapolating
182:17 203:7

F

fabricate
30:16 34:3,6 78:20
fabricated
17:1 30:11 32:4 33:20 38:24 156:13 157:10 161:21 170:8 172:20,24
fabricating
31:1,10,17 88:22 92:25 101:25
fabrication
26:20,23,24 27:21 31:11,20 36:9 78:19,23 79:6,12 101:17 158:17
face
199:16,18
facilitated
123:10
facilitates
122:15,19
facilitating
120:11
facilitation
123:10
fact
17:12 18:19 58:17 205:1
factor
20:14,15,17,20,23,25 21:6,7 24:7 94:22 117:2,4,5 131:13 169:14 191:22
factored
75:23
factors
21:6 81:6,9
faculty
21:13,15,18 29:12,17,22 30:8,15 31:4
Fahrenheit
44:13,15,16 45:3,20,24
fair
22:12 31:8 41:19,25 42:14 45:18 65:4 73:20 85:8 95:3 97:4 107:13 112:12

117:25 119:4,8 143:10 155:18 163:1 166:2 180:16 190:15
fall
82:22 126:13,25 127:7,13 199:4
familiar
144:3 147:24 193:24
famous
15:21 17:24 18:4,10 19:4 20:2,4,5 23:20 37:23 38:5
farther
60:9 129:16
favor
22:11
Fe
42:22
feel
81:21 82:2,13 144:13 194:8
feeling
77:21
Fermi
63:25 64:3,20 65:8, 9,20 66:1,7,8,15,25 67:5 68:21 69:10,19 121:11 122:9
ferromagnet
66:8 93:23
ferromagnetic
33:6 34:16 39:10 65:9 66:9,15 67:1 69:8,11 74:18 105:11,13,16 106:6 111:17,21 117:8 120:11 136:3 143:16,17 144:1 145:7
ferromagnets
145:2
Fert
191:16
fewer
89:19 155:15 156:1 158:23 159:2
field
24:9 66:11 203:17, 18
figure
27:8 41:6 62:6 97:25 105:5,15 106:4,17 110:21 111:5,10,11 112:6,10,12,14 120:21,22 121:3 163:5 167:17 168:17,18 170:4,6, 11,14,15 171:7,24, 25 172:3,4,8,9 175:24 176:12 179:19 180:12 184:23,24 185:1,4 195:1,6,14,18 196:4, 5,8,13,25 197:23 198:7,24 199:19,24 200:6 201:21 203:7, 24 204:8 206:3
figures
107:21 175:6
file
6:16 12:19
files
12:23
film
83:24 91:17 112:15 135:20,23 151:25
films
156:16 159:1 161:23 163:10
fin
17:6,8
final
168:16
find
5:22 6:3,19,24 97:10 121:7 128:23 150:9 180:12 189:24 203:1,2
finds
171:4
fine
37:3 38:23
Finfet
15:11 16:24 18:23 23:8 24:13 37:9 38:12
Finfet-base
18:12
Finfets
16:13 17:18 18:15 37:22 38:8
finish
9:9 11:9,14 62:11 81:25 172:13
finishes
10:19
firm
8:1
fit
39:23 43:7 173:3 178:19 184:10,16 185:2
fits
175:2 178:20
fitting
40:23,24
five-minute
36:23 134:19
fixed
131:23
fixes
131:24 171:24
flat
17:5 61:3 151:16 152:8
flip
125:16
flow
84:19 85:4 174:23
FM
60:14
FM-FM
143:13,16 146:17 204:5,15
FM-I
144:24 145:6,16
focus
75:17 143:7
folder
6:6,7,23 10:10 12:19
folks
5:24
follow
9:20 88:21 136:16 171:7 184:22 194:7 199:21
footnote
162:19 166:9
forget
18:11 159:15
form
35:23 41:17 42:4 71:11 75:7 77:15 88:7 89:3 93:3 97:22 103:17 108:22 126:14 127:5,12 171:23 198:13 199:5,14 200:4
forming
102:11 148:14
formula
83:22 130:9 131:12 142:24
formulation
141:18
forward
205:13
found
18:7 19:21 102:8 159:23 165:8 167:12 169:20,23 190:13, 16,17,21
fourth
41:5 162:16
fraction
87:1
frankly
131:8
free
195:24 196:14 197:1,9 202:15 206:11,18
free-electron-like
143:25
frequently
25:2
front
10:9 92:6 146:1
full
40:5 41:4 43:23 60:7 67:21 77:18 113:15 170:2
fully
9:16 51:5 52:7
function
51:1 63:17 65:16 106:10 161:19 163:8 170:16
functional
166:22
fundamental
69:14,17

G

G-22
171:6
G-25
161:13 171:6

gap
122:10 123:3
gas
157:16 158:1 170:8 172:20,24
gate
19:15,22
gave
29:14 31:4 49:24 55:15 91:5 104:10 175:16
general
27:25 63:12 69:23 87:10 96:22 110:1 112:14 138:24
Generalized
83:21
generally
30:16 112:1 121:16 144:4 171:12 199:20
generate
176:23
gist
46:6
give
8:11 13:25 14:10,13, 14,21 20:11 23:9 28:10 35:18 56:6 59:17 60:4 77:18 90:8 92:1 108:17 119:24 132:1 146:2, 5 170:25 172:13 178:22 188:9 190:25 205:14
giving
126:16 129:2 181:13 189:2
goal
53:7
gold
101:7 135:25 136:3, 5,6,9
good
5:11,14 6:8 19:6 59:7 65:1 72:6 84:8 140:6,9 174:2 175:20 181:5,12,14, 24 182:9,11 183:1 185:2,5 188:7,10,11, 15,21,24,25 189:3, 17 192:18 202:25 206:23
Google
15:18
governed
61:24 115:16
graduate
26:2,10 28:16 29:7,8 30:16
graduate/ undergraduate
25:19
grasp
101:16
great
6:11 175:2
greatest
178:17,18
grew
39:6,11,13 93:14
group
63:14
groups
62:2
grow
151:8,22 181:10,11
growing
94:7,25 97:6 181:12
grown
93:7 157:15 158:1, 11,13 160:18 164:25
growth
93:19 98:18
guess
8:17 22:21 108:16 191:18 202:9
guy
139:3

H

half
162:2 163:4
halfway
40:6
halves
131:13
hand-wave
72:22
hands
30:6 31:14
hands-on
31:8,14,23
handy
13:24
happen
63:16 81:22 125:15 139:3 145:22 200:15 202:9 205:10
happened
108:15 179:23
happening
23:7 109:12 174:22 175:5
happy
139:22 146:6
hard
13:15 53:22 63:15 72:21 73:23 128:23 139:14 177:17 181:19,24
head
9:25 28:22 76:12 84:9 86:11,13,14 113:7
header
160:22 162:17 166:5
heard
136:7
hearing
8:20
heavily
19:11 22:17
height
39:19 40:18,21 42:3, 13,15,22 43:5,8,10, 11 46:8,10,12,15 47:18 48:10 49:9,16, 18 50:5,10 51:2 52:24 53:9 54:4,21 55:21 56:7,22 57:8, 12,24 58:21 59:7 60:13,19,24 61:6,10, 13,14 63:23 64:2,8, 17,19 66:19 67:3,4 68:8,11,14,19,20,24 69:4,6,9,14,17,24 71:16,17,23 72:6,11 74:4,6 79:19 80:4,8, 11,22 81:1,3,11,15, 16 82:16,20 83:3,11, 15 85:10,19 86:4,24 87:9,12,17,21 88:2, 10,18 89:2,8 90:11 92:19,24 94:2,6 96:6 101:2 102:4,14 103:1,15,24 104:6, 20 109:24 110:10 112:7 114:9,20,25 115:3 116:4 117:24 119:19,22 120:19,25 121:4,16 122:4,7,25 123:19,22,25 124:2, 24 125:6,20 126:11 128:8 129:14,21 131:19 132:5,9,11 133:2,12 134:1,8,14 143:2 144:23 145:15,19 146:9,11, 20 147:2,4,18 148:1 149:9,16,20 150:17, 24 151:12,18 152:4, 10,14,20 153:3,7 154:3,13,17 155:17 156:3 159:24 160:1 162:11,23 163:10 165:9,16,23,24 166:8 168:5 169:5, 10,15,21,24 170:18 171:8,11 173:6,10, 18,22 175:8,10 176:7,10 177:3 178:7,14 180:9,18, 23 181:13,25 182:8, 18,21,25 183:6,9,11, 13,21 185:19,20 186:23 187:2,5,19, 23,24 188:3 190:2 193:14 195:6,11,20 197:11 198:10,23 199:2,3,13 200:3,8, 22 202:10 203:1 205:3,8,20,23 206:3, 8,15,23
heights
79:16 156:4 164:10 166:12 173:12 179:25 186:7,14 199:9
helium
45:9,14
helpful
121:3
helps
203:23
hesitant
81:6 146:2
hesitate
151:24 202:19,20

hey
74:5 205:7,22 206:7
hiccup
109:11
high
24:7 44:21,22 62:11 79:10 94:10 99:7,15, 17 100:18 101:19 102:5,13 147:20 189:18
high-impact
20:7,10,25 21:4 22:6,10,14 24:1,5
high-performance
16:21
higher
71:9 94:16 95:14 120:9 155:16 156:12 158:5,8,9,12,15,21 159:24,25 161:20 163:7,9 164:25 165:9 182:13,15 188:8,12 189:7 190:24
highly
34:18 151:8,11,16, 22 152:7 183:22 184:3,6 186:15 199:19
hint
74:5,8 205:15
hiring
21:13,21 22:7,22
Hisamoto
15:10
hold
5:22 108:16 172:11 201:18
honest
20:18 72:13
honestly
28:6 138:19
Hong
32:12 36:15
hope
11:1
horizontal
121:5,9,12
hour
11:3 37:6 74:10,15 100:4 134:24 192:24
hourly
10:23
hours
13:15,21
huge
17:12
hundred
6:13 94:23 116:9,17 117:2 147:17,21
Huwasa
29:23
hypothesis
171:14
hypothesizes
170:20 171:8
hypothetical
83:10 194:3 197:23 200:12,13 201:2,6 202:1

I

I(v)
40:7 42:21,25
I-V
166:25 167:12
idea
20:10 36:14 70:4 74:3 75:25 78:14 79:16 158:19,24 159:15 188:21 200:7 201:3
identification
193:3
identified
7:18 19:13 20:17 161:8
identifies
84:22,25
identify
6:18 103:11 104:4 125:17 137:12
IEEE
24:12 32:14 37:19
ignore
184:15
imagine
170:13 200:14
immediately
172:19
impact
17:13 18:25 20:14, 17,20,23 21:6,7 22:8 23:2,12 24:6 79:1,5 191:22,25 206:6
important
18:7 21:23 22:3 68:15 76:1,6 77:4 78:12 79:13
Importantly
68:13
improve
75:18 149:23 182:10,24
improved
120:9
inaccurate
186:2
include
25:12 35:21 152:20 153:2
includes
11:20
including
36:20 57:5,17 122:8
inconsistency
175:16 184:2
incorporated
76:22
incorporating
186:20
increase
17:10 48:13 52:24 53:8 54:7,23 57:24 58:7,20 59:12 65:11 72:10 75:4,11 76:9 80:21 81:2 85:9 88:10,13 91:7,13 95:5 98:3 101:13 102:21 103:13,23 118:18,22 119:10 124:25 125:1,25 126:2 133:17 143:3 146:11,20 149:10 150:1 151:23 152:18,25 153:7,14, 19,23 154:4,13,17 199:10,12 200:2,3,8 206:14
increased
18:13 50:4,12 51:12, 21 57:10 59:8 75:5 87:22 89:13 100:24 102:1 104:7,21 125:21 130:2,3 153:8 154:6 155:21, 24 164:25 169:14 179:12 195:10
increases
44:7 70:21 75:1 118:20 170:22
increasing
57:22 75:17,25 89:17 90:9 91:6 125:11 148:1 170:22 177:24 183:1 195:11
independent
66:5 113:21 150:25 176:15,17
independently
7:9
indication
18:22 205:21
indirectly
151:14,15,18 152:11
indulge
11:2
industry
17:9,13 18:17 23:6, 13
inflection
198:19
influence
74:6 144:23 145:14, 20 146:8 205:3
influenced
192:9
information
27:25 43:4 49:3,4 50:15 89:4 123:6,7 127:3 162:11 189:10
initial
55:6
initially
36:14
inspired
18:8 23:15
instance
34:18
instantly
45:24
instructed
10:18
insulating
83:23 84:20 112:15
insulator
61:2 69:20,23 89:12, 25 111:24 112:2 121:15,19 122:2,11

136:10 145:7 158:18
insulators
194:18
integrated
16:22 17:14 19:5
Intel
18:12,14 38:7
intend
142:1 192:5
intended
203:22
intending
139:19
intention
142:22
interacting
123:2
intercept
161:19,20 162:10,25 163:8,11,18 165:10, 17,25 167:16 176:24 177:2,5,9,23 178:3 183:11
interested
14:19 140:4
interesting
15:15 203:2 206:19
interests
25:12
interface
68:23 69:7,12 122:5 144:25 145:7,9,10, 16,21 151:16 152:8
interpretation
129:12 175:1
interrupt
91:25
interrupted
196:11
introduced
90:12 130:8
introducing
90:4
invented
18:18
inverse
165:14,21
invited
28:18,21 29:22,23
invoiced
14:3
invoices
14:2,12
involved
12:8 21:13,15,17 22:18 32:20
involves
88:22 168:12 202:1
involving
13:23
IP
5:12
IPR2024-1494
7:6
Ir-mn
193:16
iron
39:3,11 73:4,5,12,13 98:10,12 101:11 145:11 148:20,21 195:25 196:14 197:2
irrelevant
148:16
issue
59:15 83:14 90:22 127:22,23,25 128:3
IV
176:13

J

Japanese
193:10
JEFFREY
5:4
job
9:14 78:3
joined
30:7
journal
20:7,10,15,21,23,24 21:4 22:6,10,15 24:2,5,13,17,20 191:22 193:10
journals
20:13,15,17 21:8 24:10
Julliere
113:16
Julliere's
84:10,12
July
31:3
jump
203:18
junction
24:17,20,25 25:1,5, 9,15 30:4 35:1 73:14 76:5 107:15 130:9 195:8 197:25 198:9 200:1 201:5 202:4
junctions
193:17 194:13
JUNE
5:1
junk
184:15

K

Kelvin
44:9,19,24 45:7,11, 13 85:22 195:15,16
key
33:15
Khizroev
33:14 34:10 35:5,7, 21
kind
23:11 27:25 33:24 140:23 184:2 185:6 201:22
kinds
22:19
Klaua
62:1,12 115:20
knew
52:18 154:4
knowledge
113:21

L

L1036
194:22
L1038
197:15
lab
30:9,10,17 31:3,5
label
111:15,16 112:5
labeled
157:11,13
labels
112:14
Laboratories
30:9
laboratory
30:25
Labs
31:12
language
204:4
large
70:20 74:25 183:14
large-scale
16:22
largely
62:9 128:18
laser
93:7,9,16
lawyers
11:16
layer
33:9 36:2 39:2,3,6, 11,20 71:2,4 89:1 90:13 91:8 93:15,20 94:7 95:6 98:12,15 100:25 101:19 102:2,4 103:14 124:25 126:23 129:22 143:3 145:12 150:2,13,15,21,23 152:19 153:2 158:20,22 159:2,5, 17 165:16,23 191:2
layers
33:2 35:25 38:25 52:10,11,12 79:3 105:8 106:5,7 194:13
lead
36:9 182:19
leader
36:11
leaders
36:12
leading
17:14 24:10,13,16, 19 62:10 191:13
leap
198:3
learn
33:11
learned
33:16 102:3
leave

144:20
lecture
29:5
lectures
27:7
led
23:5 62:2 173:5
left
87:13 111:6 112:9, 18 131:19,20 156:23 160:10 161:16 162:9 166:17,21 168:15 177:20
left-hand
40:5 41:4 194:25
length
104:8 117:6
lengths
19:15,23
letter
160:22
Letters
191:21
level
9:11,19 63:25 64:4, 20 65:8,9 66:7,8,15, 25 67:5 68:21 69:11, 19 71:8 72:15 94:12, 13 121:11 122:1,9 159:23,25 165:8
levels
65:20
light
103:19 205:12,20 206:25
likelihood
54:18
limit
42:12 179:4
limited
29:8
linear
198:23
lines
107:3 108:14 109:2, 7 137:7,8 170:11,15 171:10 172:7,9,16, 23 184:25
liquid
45:5,6,9,14,15
liquifies
45:6
list
15:25 19:21 25:11, 18 34:23 37:11,13
listed
17:22
literally
130:25
literature
27:19 49:4,14 59:5,9 83:6,7 121:23 132:1, 3 190:15,19
live
9:17
located
8:2
location
122:10 123:3
log
167:18 170:6,24 184:25
long
19:21 64:22 68:17 76:19 129:15 140:5
longer
17:5
looked
27:7 34:1 108:13 137:8 149:12 184:8 194:4 206:11,12
lost
91:4
lot
18:6 22:21 23:9,25 27:19 139:17,18 175:2,19,20 182:16 184:15 185:5 190:15 202:17
lots
20:25 21:1,2 75:8 77:1 140:22 191:23
low
41:14,15,19 83:15 87:16 101:2 102:13 130:10 145:2 147:10,14,20 181:13,25 182:9,20, 21 183:6,21 186:15, 16 187:6 199:9
low-voltage
41:23 42:12
lower
53:9 61:10,15 65:17, 18 66:6 69:3,5,6,7 109:24 116:5 157:7 159:23 160:1 161:20 163:8 165:8 182:18 187:19 188:16
lowered
58:21 69:9
lowering
68:25 86:24 87:9 110:10 114:9,20 115:3 116:4,23 125:8 132:11 133:2, 12 134:1,8,13 143:2 149:20,21 153:7 154:3
lowers
65:8,9
lunch
11:23 29:19 99:23, 24 100:6

M

Mac
5:20
made
16:17 30:3,19 31:2 45:13 49:22 56:11 68:16 73:12 89:11 125:4 135:20 155:22 156:5 167:17 168:10 174:24 179:12 196:14,22 203:17
magazine
19:23 21:1
magnesium
39:7,19 71:5 73:4,12 75:6 89:25 90:13 91:8,16 93:15,20 94:2,8 95:6,18,23 96:14,24 97:2,7 98:14,19,21,24,25 99:3,6 100:18,25 101:6,10,24 102:2, 22 103:14 112:3 124:24 125:20 126:23 145:11 148:15,21 152:19 153:1 155:16 156:14 158:20,22 159:2,5,7, 17,19 165:16,23 177:25 191:1 203:11 204:16
magnet
66:1
magnetic
24:18,20,25 25:1,4, 8,15 27:23 30:3 34:25 62:16,18 63:10 73:14 84:3 106:9,18 115:24 116:1 197:25 198:8 199:25 201:5 202:4
Magnetics
32:14
magnetization
107:16
magneto-resistive
24:17
magnetoresistance
60:19 68:2,3 70:21 74:25 84:6 107:4,8 108:3,6 112:22 113:2,8 135:18 136:9 193:15
magnetoresistive
76:25 143:19
magnons
60:14
main
205:18
major
34:23 79:1 203:14, 15
majority
30:12 61:25 115:17
make
9:14 17:7 20:12 23:12 30:5,17 33:11 47:5 48:3,8,16 49:6 50:1 52:14,16 56:17 60:21 64:10 70:8 71:15 72:18 77:25 79:2 124:12 127:18 131:2 136:5 177:14, 18 182:22 187:7,12, 22 201:25 206:8
makes
21:4 203:12
making
5:13 22:18 45:22 98:6 135:13 199:17
manipulate
5:19
manner

156:5 164:6
manufacturability
79:7
manufacture
17:3 79:10
manufacturing
18:12
marked
193:2,6
marking
194:22
matching
120:10
material
33:8 34:15 89:22 151:7 156:1 159:6, 18
materials
24:4,16,19 27:11,13 33:5 34:19 36:2,5 65:24 66:3 78:25 100:12
mathematical
49:17
Mathon
62:3,5 116:16 120:8, 17 122:14,17 123:8
matter
38:12 76:17
maximizing
78:14
meaning
80:19 100:19
means
64:2 71:13 89:24 143:16 145:17 147:13 158:15 159:1,16,20 168:2 185:15
meant
159:8
measure
179:8 184:1
measured
42:25 46:16 71:18 166:25 167:6 180:1
measurements
30:17 31:2 44:2,6 45:14 176:13 195:8
mechanism
68:25 116:19 166:24 174:23 185:13,16
meet
13:7 76:7
meetings
36:16
memories
26:16
memory
27:24 34:25 35:22 76:25 106:19
mention
172:17
mentioned
26:15 27:2,23 40:11
mentioning
35:20
met
13:4,6 29:20 36:13
metal
64:1 67:5 69:19 89:11,12 112:2,15 122:1
metals
144:1
method
96:8 101:24,25 102:20 162:20 163:18 164:15,20,24 165:25 173:10,19 179:9 180:4 186:4
methods
101:21 102:10 103:7
metric
78:4
Mgo
61:2,4,11,23 62:5,8, 14,21,23 63:2,5,12, 18,24 64:1,4,20 65:16,17,23 66:4,9, 16,20 67:1,6,8 69:8, 13 91:12,14,17,21 92:3,25 93:4,9 95:8 98:4 99:11 101:19 102:4 111:24 115:15,22 116:14 117:9 120:8,10 122:14,19 123:2 124:7 128:17 129:6, 10,21 148:4 150:1 161:22 181:11,12 187:2 192:12 200:16,17,22 202:10,18 203:14, 18,19,24 205:11 206:5,21
Michelle
13:9
microprocessors
16:21
middle
11:8
milestone
18:16
millibar
94:15
millibars
94:22,23
millivolts
40:25 41:11,18,22 42:16,17
mind
52:9 74:3 75:14,21 76:2 201:24 206:6
mine
22:24
minimum
152:3
minus
14:15 28:11 94:15, 20,22 118:6,12,16 121:20 157:17 158:3,5,6 161:2,4,8, 11
minute
8:15 35:14 60:4 91:20
minutes
37:5 65:4 74:10 99:23 100:3 154:21, 25 192:25
missed
196:10
missing
202:17
mistake
141:25
model
40:18 41:16 143:23 175:9,14,21 178:19 184:10,16 185:8,12 195:25 196:14 197:1,10 198:6 202:15 206:12
modifications
97:16
modified
95:17,22 97:6 110:20
modify
66:2 103:23 203:4
modifying
102:20 150:1 152:18 153:1
modulated
23:10
moment
14:21 28:10 35:18 61:19 90:18 92:1 108:17 119:25 172:13
moments
62:16,18 63:10 115:24 116:1,13
Monica
13:8
Moodera
60:1,6,22 63:23 64:17 65:14 66:13, 21 67:16 68:6,9,10 69:1,25 70:2,6 73:17,21,23,25 74:2 136:19 140:14 142:11,19 143:2,8 146:15 147:25 148:11,19 197:20 204:2,3,13,15 205:1 206:7
morning
5:11,14,16 104:9,10 115:15 116:6 117:6, 20
Mos2
19:14,22
MOSFET
15:12
motivated
59:2 94:3 183:23 184:4,6 205:9
motivates
206:2
motivation
57:22 182:11,13,19, 23 187:1,11 188:25 191:5 205:22
move
66:25 67:5
moving

64:20
MRAM
76:25 140:4
MTG
136:5
MTJ
25:3,7 26:11,15,24 32:9,19 33:4,12,18, 19,22 34:1,6 35:23, 24 38:24 41:10,20 43:1 46:3 47:19 48:11 51:3 52:19 54:5,22 56:8 57:8 65:8 75:12,18 76:17, 21,23 77:3,12,20 78:1,4,8,12,16,20 79:8,20 85:23 86:3, 24 87:1,9 101:25 102:8,11,12 104:20 105:9,20,24 106:12, 22 107:4 109:23 110:11 114:3,6,10, 21 115:4 126:11 132:11 133:2,13 134:2,8,14 136:6 142:10 147:19 148:15 149:1,10 182:22 186:20 187:14,15 188:3 201:12 202:11 206:15
MTJS
26:18 27:2,10,15,23 28:4,14 29:2 31:16, 17,18,25 32:1,3,4,5 73:25 77:1 78:22,24 79:4 84:13 110:6 135:13 191:13 204:16
multiple
129:5 139:19

N

Nagahama
136:20,22,24 137:4 140:14,17 149:25 150:4,9,15 151:5,21 152:12,17,25
Nagahama's
149:10,15 150:12,19 151:2
names
191:11
nanometer
34:24 35:22
nanometers
15:13
narrow
78:15
Nature
23:18 24:1,4,8,16,19 191:23
naught
120:25 121:6,10,13, 19 122:4 167:16,18 176:24
necessarily
124:3
needed
49:7,8 89:7
negative
45:2 170:23
Newport
8:4
nitrogen
45:5,15
nods
9:25
non-volatile
26:16 27:24
nonstoichiometry
156:25
notes
27:6
noteworthy
18:16
notice
7:2,19 121:21
noticed
32:17,18 142:4,7,16
notoriety
18:13
number
6:19,24 7:5,10 8:11 13:24,25 14:24 15:2, 3 17:10 19:14,16 20:13,18,20 22:14 23:16 32:12,13,17 35:9,20 37:11,12,13, 15,16 45:25 78:6 91:10 126:16 130:18 160:11 167:1 170:25 181:3,5 183:15 198:16
numbers
22:13 86:12 168:11 169:23 177:21,23 179:11,14 180:7 181:22 183:14 185:9
numerically
127:4

O

O2
170:8 172:24
oath
5:6
object
10:14 200:12
objection
10:20 41:17 42:4 71:11 75:7 77:15 88:7 89:3 97:22 103:17 108:22 126:14 198:13 199:5,14 200:4
objective
150:12,20 151:2,6 189:22
Objectively
189:20
observed
50:13
obtain
42:2
obtained
38:11 46:10 162:20 164:6,15,19,23 166:13 167:16 169:1,5,10,15 174:22 176:10 178:7 179:8 180:7 183:9
obvious
23:12 97:18 188:23
occasionally
11:2
occurrence
131:20
occurs
131:19
offer
7:24
offices
8:3
ongoing
12:5
open
6:2 7:1 12:10,16,20, 22 14:21 38:15 83:18 105:1 108:16 110:23 111:1 113:10 140:25 150:7 193:7
opened
6:3
operate
110:7
opinion
47:22 50:14 51:22 52:15,20 57:3,12 64:10,14,23 72:1 80:24 97:17 116:20 123:18 124:9 129:2, 16 146:19 152:12 154:12 181:8 183:3 184:7 186:1 189:2
opinions
146:3
opposite
62:10 63:2 90:4 106:7 129:8
optimistic
62:4
option
99:5,6
order
49:6 94:5 101:18 102:17 192:6
ordinary
46:25 47:4,20 48:12, 15,22 49:13,25 50:2, 21 51:7,10,14,19,24 52:14 53:6,11 55:19 56:20,23 58:1,19 59:2,4 63:4,13,19 64:5,9 67:11 69:2 70:3,6 72:2,8,20 73:16,21 75:3,16 79:21 80:19 81:24 82:4,21 85:20 97:5,9 101:14 102:16,19 116:3,12,15,21 117:10,16,18,21 119:17 120:17 121:9,17,21 125:7, 19 126:4 129:11,19 147:23 148:10 152:6 153:16 171:2,11,18 172:1 173:4 188:24

orientation
62:15,18 63:10 115:23,25 116:6,8, 11 144:24 145:15,20 205:4
orientations
147:1
oriented
39:3,7 96:24 151:8, 11,16,22 152:7
Owner's
7:2
oxide
39:7,20 62:13 71:5 73:4,13 74:1 75:6 90:13 91:8 93:15,20 94:2,8 95:6,18,23 96:14,24 97:2,7 98:14,19,21,24,25 99:4,6 100:18,25 101:6,10,24 102:2, 22 103:14 112:3 115:21 124:25 125:20 126:23 145:11 148:6,13,15, 21 152:19 153:1 155:16 156:14,16 158:20 159:1,2,5 161:23 163:10 165:16,23 170:9 172:21 177:25 191:1 194:13,20 198:3 200:25 201:17,19 202:2 203:11 204:16
oxidize
91:16
oxygen
88:23,25 89:14,17, 19,25 90:4,12 91:2, 6,8,13 95:5 100:24 101:3,13 102:1,6,21 103:13,24 155:15, 21,24 156:1,6,14 157:5,6,7,16 158:1, 11,12,15,16,21,22, 23 159:2,7,14,17,19, 23,25 160:19,23,25 161:7,20,22 163:8 165:1,8,15,22 169:14 172:6 177:24 178:14 179:2,5,7,12 185:20
oxygen-dependent
178:25

P

P02
160:22
pack
79:4
packed
78:24
pad
34:1
pages
27:16
paid
14:6
pandemic
9:2
panel
89:13 155:20 173:9
paper
6:24 14:19 15:3,11, 15,16,18,21,22 16:12,15,17 17:19, 24 18:4,6,9,10,14,23 19:12,13,14 20:4,5 23:25 32:10,11,13, 24 33:4 34:1 35:19 36:21 37:10,20 38:2, 3,9,13,18,22 46:21, 23 60:1 62:12 67:17 71:24 72:1,15 83:21 84:10,12 110:16 113:25 114:17 115:20 142:9 144:12 145:23 162:15 175:12 177:16 180:22 181:8,9 184:12 185:4,6,7 187:4 190:6,11 191:8,10,19,24 192:1 193:9,23 194:4,19 197:16,19 199:17 201:7 202:20,21,25 203:16,20,22,23 204:14,17,24,25 205:5,6,14,16,17,18, 19,21 206:6,19
papers
16:15 19:2,4,7,11 20:3,22 21:2,3 37:23 38:5 144:14 190:7, 16 206:21
par-
139:18
paragraph
40:6 41:4 43:23 60:7 61:20,23 62:12 67:22 84:18 92:11, 12 95:25 97:18 107:25 108:1,2,9 109:9 110:3,6,9,14, 15,19 111:11 113:15 114:8,12,16,19,24 115:2,6,7,14,19 116:7 117:3 118:2 119:16 120:1 122:13 126:9 127:20,21 128:4,10,16 130:4, 11,13 132:10,14,18, 21 133:1,5,7,8,11, 15,18,21,25 134:5,7, 12 135:4,8 136:12, 21,22,25 137:16 138:7,11,12 139:18 140:12,19,20,24 141:2,9 142:19 146:16,18 149:3,8, 14,19,24 150:10,19 151:3,5 152:16,24 155:11 156:9,22 157:9 159:22 161:17 162:3,13 163:21 165:4,7 166:17,22 168:16 170:3 172:2 174:20 186:22 195:1,5,22 196:4
paragraphs
149:11 150:5 152:13
parallel
61:25 62:15 63:10 105:21,24 106:2 107:11,16 110:11 114:2,10,21 115:4, 17,23 116:5,8,18 117:13 118:6,7,11, 16,19,22 119:1,6,11, 20 120:12,14 122:15,20,22 123:11 124:8,17 126:7,13 127:8,13 132:12 133:3,13,16 134:2,9, 14 141:22 149:16, 21,22
parameter
76:2,6 77:4 78:8,17
parameters
51:4 52:7,8 75:12 77:6,10,11,19 78:18 91:12 137:12 151:1
part
6:15 15:24 38:12 59:21 115:18 162:9 176:19
participated
34:12 36:8,19
parts
77:2
passage
146:15,19 147:24
passed
62:9,24 63:1,11
passes
128:17 129:6
passing
66:15
past
30:24 37:6 74:14 142:9
paste
131:5
patent
7:2,11,12,16,17,18 13:23 25:5 37:13,16, 18,25 38:1,11 105:1, 3 107:3 108:6,13,19, 23 109:5,7,14,18 137:6,7,10,13 140:15,17
patents
37:11
pathway
17:3
pay
21:7
PDF
14:23 39:23 70:16 84:15 92:11 105:6 107:1,25 108:21 109:3 110:4,25 111:3 113:13 118:2, 3 120:2 130:5,19 132:21 133:23 134:6 137:21 149:4 150:9 155:11 156:19 160:3 163:16 194:12,22

197:16
peak
9:1
penetration
85:14
people
18:4,7,20 20:25 21:2,7 22:23 34:11 36:24 63:14 91:15, 16 140:22 191:24 192:20 203:17
percent
44:6,7 46:3 48:14 50:12 54:24 57:10 62:5 70:11 119:6 125:12 147:17,21 181:17 188:14 189:4,6,8,19
percentage
195:19
perform
102:20
performance
77:5 78:1,4
Period
103:2
periods
31:7
permit
85:14
permitted
11:15,24
person
46:25 47:3,20 48:12, 15,21 49:13,24 50:2, 20 51:7,10,14,19,23 52:14 53:6,10 55:19 56:19,22 58:1,19 59:1,4 61:12 63:4, 13,19 64:4,9 67:11 69:2 70:3,6 72:2,8, 20 73:16,20 75:3,16 79:20,25 80:19 81:24 82:4,21 85:20 87:24 97:5,8 101:14 102:3,15,18 116:15, 20 117:10,16,18,21 119:17 120:17 121:8 125:7,18,24 126:4 129:19 147:23 148:10 153:16 171:2 172:1 182:11 183:3 188:24 203:5
personal
23:1
personally
22:16 192:20
persons
121:17
perspective
153:25
PH.D.
5:4
phi
40:17,20 120:25 121:6,10,13,18 122:4 131:19 164:4 166:5 168:5,12 170:16,20,21,23 172:4 173:6 179:2
phone
17:15
photographically
131:1
physics
25:20 26:3,11 27:21 28:5 67:8 81:14 191:21 193:10 202:17
pick
138:17
picked
138:22
picture
121:2
pieces
50:8
pinning
33:2
place
66:10 128:15,24 159:12 187:16
places
42:21
plane
17:5 96:24
planer
17:1
play
21:20,22,25 79:8 81:6,9
plot
166:16 167:15,19, 21,22,25 168:2,4 170:6,10 172:4,7,16, 22 173:1,13,23 176:11 177:10 178:16,22 179:15,20 180:8 182:2,3 183:9 184:25 185:21 195:18 198:24 199:23
plots
161:19 162:10,25 163:12 166:14 168:10 169:6,11,16 170:17,24 176:23 179:18 180:9 184:16
plotting
173:1 176:23
plural
18:2
point
21:9 27:19 32:8 45:15 69:15 103:22 106:7 128:16,25 131:11 140:23 159:13 174:10 194:11 198:19 199:6 200:16 205:16,18 206:1
pointed
127:20 202:12,18 205:5
pointing
67:9 105:17 108:18 109:19 171:5 196:21
points
128:9 196:18
polar
62:25
polarization
144:25 147:3,5
polarized
62:25 63:1 124:6
poly
152:2
popularity
23:3
portion
85:22
POSA
47:20,22,23 48:2 49:7 50:10,14 52:22 54:5,17,22 55:1,3 56:9,15,17 57:9 58:6 59:10 60:17 61:12 64:13,15,24 72:24 74:3 75:14,21,24 77:7,12,19 79:9,25 80:6 81:1 82:9,10,14 83:2,9 86:2,22,23 87:3,7,14,18,20,24 88:2,8,17 89:1 90:12 91:7 92:23 93:10,25 94:3 95:22 97:19,21 98:2,6,22 99:2 100:22 101:22 102:3,7 103:4,7,12, 23 104:5,14,19 123:7 126:12,19,24 127:2,5,11,16,17 128:6 147:6 148:25 154:2,4,9,12,16 174:13,15,25 175:12,25 177:15, 19,22 180:13,20 181:6,8,22 182:6,11, 19,21,24 183:3,16, 19,22 184:3,8,12,17 185:4 186:10 188:4, 6 189:14,16 190:23 198:5,9 199:23,24 200:1,7,13 201:3,7, 8,10 202:3,7,20 203:1,5 204:25 205:7,9,21 206:2,7, 10,16
POSA's
79:8
position
63:25 64:3 66:8,12 67:6 68:20 69:12
positive
22:8 170:21
possibility
51:16 180:24
possibly
186:15 191:6
potential
85:4
potentially
187:21
PP
32:14
pre-electron
204:7
precisely
150:20
precision
56:2

predict
55:22 70:20 74:25 81:22 82:10 123:6,9 147:7 151:24
predicting
63:15 71:7 82:3 126:20
prediction
125:5 147:18 206:11
predictions
148:14 192:2,7,14, 19
predicts
144:23 146:8
predominantly
121:25
prefer
74:11
preference
124:7
preparation
13:14,20
prepare
13:1,4
prepared
13:17 85:24 90:21
preparing
86:15
prescription
90:8 91:5
presence
157:16 158:1
present
156:14 158:16 161:21,22 170:8 172:6,20,24 174:23
presentation
125:3 126:6
pressure
89:14,17 94:14,19 155:21,25 156:6 157:8,17,20 158:2,6, 11,12,15,21 160:23 161:1,8,20 163:8 165:1 169:14
pressures
160:19
pretty
16:24 19:6,10 59:17 72:14 75:19 128:23 178:20 183:14 184:16 189:17 192:17
previous
41:1 161:15 163:3 172:18
previously
145:3 147:11,15
primarily
13:9
principles
73:7 148:20
priori
126:20
private
30:25
probability
55:23 56:3 182:1
probe
34:25
problem
144:20 175:23 177:8,10 178:11 180:11 182:5
process
17:1 34:6 79:12 93:13 95:7 170:6 172:4
produced
95:13
product
76:13,17 77:11 78:7 79:9
professional
16:1 138:24
professors
30:13
progress
36:18
progressed
36:18
project
32:8 36:10,12,14,16, 20 103:6 123:9 202:9
projecting
82:14
Projects
16:8
prominent
191:22
promising
186:17
promotion
21:17 22:1,11,23
promotions
22:22
pronounce
193:21
properties
62:22 102:12,13 116:22 150:1 152:18 153:1 200:18
property
61:24 115:16
proportion
124:4,11
proportional
170:18
proportionately
119:2,12 123:20
proposed
143:14 204:5
proposition
177:24 178:3 205:2
protocol
9:20
protruding
17:6
provide
47:21 59:15 110:19 130:12 140:18 148:19
publication
20:16 21:20 35:8,9, 11,13 47:5 49:23 174:20
publications
18:6 20:22 21:25 23:3 24:10
publish
16:14
published
16:12 21:3 22:5 32:13 37:19 49:4,21 70:5 84:1 112:25 113:24 135:15 148:7 191:14,21
publishing
140:6
pull
6:1 61:17 92:9 137:21 155:6
pure
192:22
purporting
203:10
push
139:14
put
22:25 81:10 112:19 126:6 142:11 185:24 193:5 200:23 205:13
puts
74:2
PY-G-
173:2
PY-G-11
172:17,21 173:15
PY-G-11(1)
168:23 170:9 171:22,23 173:1
PY-G-22
171:25
PY-G-22(2)
157:11,15 158:13 160:14 161:1 164:14 169:5
PY-G-25
171:25
PY-G-25(3)
157:13,25 158:10 160:14 161:9 164:19 169:9

Q

quantify
126:8,15 127:2 181:15,16
quantitative
70:8
quantitatively
57:1,2,3,4 129:23
quantity
118:6,16 127:4
question
9:9,22 10:3,15,19 11:8 35:16 42:11,18 46:19,22 47:14,24 55:6,8,11 59:25 72:16 75:19 81:7,8, 24,25 83:6 84:8 85:24 86:5,7 87:25 90:23,24 91:23,25 92:4 95:20 96:11 124:20,22 128:1,6 132:15 133:9 139:10

141:13 152:22 156:13 174:2 176:5 182:7 191:7
questions
9:6 11:16,25 64:25 65:2 67:15 73:1 90:25 146:6 194:3,5,8
quibble
139:13
quickly
89:10
quote
162:1 163:4
quoting
162:5

R

RA
76:2,13,16
radical
16:24 23:15
random
76:25 106:18
range
81:16 82:20 83:4,11,12 92:19 96:6 103:1 130:10 164:6,10
Rap
107:11,14 122:23 123:19 124:3,9 129:9
rate
20:21 117:13 123:21
ratio
62:4 68:2,3 89:25 90:1 107:4 108:7 118:5,11,15,18,21 122:21,23,24 124:1 129:9,13 159:7,18 193:15 195:7,10,19 205:19,23
ration
108:6
reached
94:19
reaction
101:11 155:22 157:5
read
18:7 20:25 27:19 28:2 42:6,9 55:9 72:20 74:7 91:21 133:8 144:6 145:25 153:8,17 170:13 180:25 187:4 190:11 191:24 194:6 202:19
reading
72:2,9 73:21 80:7 102:3 117:11,21 123:8 129:11 147:6 167:23 171:2 172:2 173:4 174:14,16,25 175:12 177:15 181:8 184:12 196:3
readout
35:1
reads
154:10
ready
96:1,2
reason
18:10 39:16 58:22 59:6 70:9 79:21 86:20,21 87:8 113:19 122:17 125:15 137:3 138:6 140:16 141:11 142:18 144:16 153:18 178:9,10 183:16 188:25 189:4,14,17 203:9 206:24
reasonable
28:13 48:18 50:22 52:21,22 53:1,7,11,15,25 54:2 55:2,4,16,18,20 56:5 57:13,15,18,19,23 58:6,22 63:22 64:5,16 66:22 67:10 92:17 96:4 99:16 100:16 102:24 103:6 117:4,12 123:16 125:6,8,11,13 126:1 129:12 153:13,22 154:2 163:20 183:4,5 191:22 201:9,10 203:6
reasoning
117:17
reasons
17:21 75:9 82:12
recall
26:17 27:3,9 28:20 29:1 32:25 33:1,3,7,10 34:17 35:22 36:2,5 47:15 138:19,21 148:2 190:9
received
37:12
recent
23:25 140:7,8
recently
8:19 142:3,4,7 194:4
recess
37:7 74:19 100:6 135:2 155:2 193:1
recite
108:9 136:13
recognize
191:10
recollection
26:13 29:3,18,24 128:13
record
37:5,8 55:9 74:14,20 100:3,8 135:1,3 154:25 155:4 192:25 193:4,25
records
21:20
recruiting
21:15
rectangular
143:24
reduce
109:25 110:11 114:10,21 115:4 123:21 132:12 133:3,13,16 134:2,9,14 149:16,17 177:25 187:24 199:13 200:7
reduced
61:6,7 117:3,7 119:23 126:10,22 129:21 148:1 198:11
reduces
110:12 114:11,22 115:5 125:6 132:13 133:4,14 134:3,9,15
reducing
57:24 104:5,20 119:9 124:24 146:10 149:9,15 152:13,20 153:2 154:13,17 198:10 199:3
reduction
126:21 128:7
refer
7:17 10:6,11 25:1 38:21 116:7 138:13 156:8
reference
18:9 132:1 138:17 139:25 140:1,9 168:17 196:19,22 197:2,3,12,16
referenced
124:15
references
151:20
Referencing
136:22
referred
7:15 52:6 67:19 81:23 89:10 117:2 135:7
referring
25:4,8 34:9 35:7,9,13 38:22 120:22 144:22 152:5 163:3,10 204:23
refers
145:6 158:25 166:22
regard
31:16 62:22 118:10
regarded
24:10 174:13 202:3
region
84:20
regular
10:22 28:16
reject
201:2,3,6
related
16:11,14 35:4 37:18,21 100:13 101:3 122:18
relationship
115:8 124:5
relative
64:1,4,20 65:10 66:9 67:1,6,7 68:21 69:12 116:25
relevance
204:15,20 205:13
relevant
77:4 139:22 148:14,25 197:24 201:4

202:3
reliability
179:5
reliable
47:10 169:24 175:11 179:3,9 180:5 182:6
reliably
48:3,8
relied
177:23
relies
60:20 176:19
reluctant
81:4
rely
176:1 177:21 178:6 180:15,17 185:18,21 186:23 202:8
relying
138:10 165:4,10,17, 24 178:2
remarkable
185:2
remember
14:10 28:6,24 29:20 32:22 36:13 38:6 128:21 131:8 135:12 190:14,17,22
Remind
111:1
remote
5:1 8:23
remotely
5:6
removed
131:14 157:4
removing
90:5 91:3
rendered
97:17
repeat
42:18 50:6 55:6,8 87:25 90:22 95:20 182:12 184:3,4 190:1
repeated
129:5
repeating
186:17
reported
163:12 176:11
reporter
5:6 9:12 37:3 193:3
reports
166:12
represent
5:12 40:20
representation
40:17 142:1
representative
199:25
represents
105:20 106:9 121:13 196:9,25
reproduce
183:23
requested
55:10
require
78:23 85:25
research
16:8 25:12 34:23 62:2,8
researchers
142:14
resistance
41:10 62:15 76:3,4, 5,13,23 77:3,11 78:7 84:4 105:25 106:2, 13,23 107:11,12,15 109:25 110:11,12 114:3,6,10,11,21,22 115:4,5,23 116:5,9, 16 118:6,7,11,12,15, 16,19,21,22,25 119:1,6,11,13,21,22 123:25 126:13,25 127:7,8,13,14 132:12,13 133:3,4, 13,14,16 134:2,3,9, 10,15,16 141:22 149:16,18,21
resistances
119:10 124:17 126:8
resolve
182:7
resources
127:17
responding
91:1
response
176:4
responsible
60:15 127:18 190:18
rest
59:5
restate
24:18 37:14
result
95:5 103:8 156:3 159:24 165:3,9,10, 17 167:19 191:13 197:1,9
resulted
86:25 101:12 155:16
resulting
103:15 195:24
results
101:1 177:19 183:17 184:9
retained
7:24
retired
31:4
return
79:15
review
13:4 14:1,11 27:16 90:14,18,20
reviewed
13:3 83:7
revisit
183:2
rewrite
118:14
right-hand
43:22 60:7 67:21 84:18 146:16 163:17,24 204:3
rightmost
160:21
rise
175:16
role
21:20,22,23,25 22:3 36:10
roll
21:6 176:2
room
8:5,6 30:22,23,25 31:1 44:19,20 46:2, 9,13 48:13 50:13 54:24 57:10 81:17 85:21 97:25 98:10, 24 99:4,12,13 101:6
rose
98:25
rough
28:13 151:25
roughly
10:23 58:11 197:9
roughness
151:17 152:1,8
routine
101:18,21 102:9 103:7
row
173:16
Rp
107:10,14 109:18 122:23 123:19 124:2,9 129:9
rule
11:20 29:25 30:12

S

S-A-I-T-O
193:20
Saito
193:20,21 195:5 204:8 205:17 206:13
Saito's
204:17 205:25
sandwiches
73:5
sat
33:25
saturates
41:11
scalable
15:12 17:4
scale
16:20
scaling
17:10
scanned
34:25
scattered
184:22 199:19
scattering
62:19 116:2
scenario
71:25 79:23 81:20 82:9,15 83:2,16 85:12
scenarios
84:25

Scholar
15:18
Schottky
161:19 162:10,25 163:12 166:23 170:6 172:4 175:1,3,13,21 185:8,12,13,16
Science
19:23 20:6,24 21:3 191:23
Sciences
21:11
scientific
18:6 20:16 21:2,8
scientifically
127:18
scientist
183:25
scientist's
23:3
screens
12:10,14,23
searching
190:16,19
second-to-last
161:17
section
120:7 173:5
sections
139:18
selectively
62:24 63:1,11 79:2
self-aligned
15:12
Self-assembled
35:21
selling
18:15
semiconductor
17:9 25:19 26:2,3, 10,20,22 27:21 28:4
seminar
29:7,9,15,17,19
seminars
28:16
senior
11:1
sense
29:13 37:21 54:19 128:22
sensed
76:24
sentence
40:6 41:1,5 43:3 44:2 67:22 70:20 71:13 74:23,24 120:6 136:13 143:12 144:21 146:8,12,17, 22 149:25 153:5 156:11 161:17 162:1,5 163:4 166:21 168:16 172:18,19 174:21 175:17 177:16 196:6
sentences
146:24,25
separate
45:22 176:19
separated
83:23 136:10
separating
143:25
September
138:21
series
29:12 73:3 194:3
services
16:1
set
5:20
setup
5:16,17 12:12 109:11
shape
61:1
shared
82:11
Shinji
28:20
short
20:11 129:15
show
44:3,6 141:11 142:23 198:14
showed
5:23 17:2,3,7
showing
196:24
shown
41:6 76:19 103:4 195:6 198:7
shows
60:8 105:15 106:5, 18 164:23 169:18 195:6 198:25
sic
95:25 108:20
side
65:8,22,24 66:1 69:19,21 122:3
sign
57:5 129:25 130:1
significance
18:22 23:2
significant
16:2,18,19 17:20,25 18:1,17 85:22 86:3, 25 87:18 88:13 187:20 188:7 203:17
significantly
18:13
silicon
17:6,11
Silvas
9:13,23 55:7
similar
47:13 83:23 94:24 95:1 120:5 128:20 144:11 206:7
Simmons
39:24 40:18 41:15, 23 42:10,12 43:7,9 64:3 83:20,21 84:14 110:16,24 111:1,11, 15,20,23 112:1,2,5, 12,14,21,24 113:24 114:2,5 120:21,25 121:7,22 124:15,16 130:6,9,15,19,21,24 131:1,14,18,19,20
Simmons'
40:12,13 110:20 112:10 114:17
simple
20:12 23:11 68:25 148:5 206:23
simplest
6:22
simplicity
65:25
simplified
121:2 206:17
simplify
6:14
simply
11:4 70:2 123:6 124:3 200:23 205:1, 5
single
27:20 39:6 96:23 101:20 192:12,13,15 193:16 195:8 203:13,14,18
single-crystal
93:14,20,23 98:18, 21
single-digit
35:22
sir
7:8
sit
26:17 27:9 32:23 81:21 83:1,5,16 85:25 86:16 192:10
situ
98:11
situation
66:23 68:6 80:9,10, 18 149:13
size
78:16
sketch
34:1
sketched
33:25
skill
46:25 47:4,20 48:12, 15,22 49:13,25 50:2, 21 51:8,10,14,19,24 52:15 53:6,11 55:19 56:20,23 58:1,19 59:2,4 63:4,13,19,20 64:5,9,13 67:11 69:2 70:3,7 72:2,8,20 73:16,21 75:4,16 79:21 80:19 81:24 82:4,21 85:20 97:5,9 101:14 102:16,19 116:3,13,15,21 117:10,16,18,21 119:17 120:18 121:9,17,21 125:19 126:5 129:11,19 147:23 148:10 152:6 153:6,16 171:2,11, 18 172:1 173:4 188:24
skilled
92:16 96:3 102:23

186:25
slightly
121:2
Slonczewski
143:14,22 144:3,8 145:22,24,25 146:3, 4 148:3,9,12,19 197:19 202:13 204:5,7
Slonczewski's
144:22 197:16 204:11 205:25
slope
61:5 166:13,16 168:3,9,11,12,17 169:2,6,10,15 170:17,24 173:12,23 176:11 178:15,21 180:8
small
78:24 79:1 81:4,5
smaller
62:17 81:15 115:25 116:10,17 170:25
so-called
17:1
solely
190:18
solid
29:9,15 31:9,10 195:23 196:8,13,25 197:3 198:7,14
solidly
129:3
sooner
11:3
sophisticated
124:4
sort
139:20
sought
149:25 152:17,25
Soukup
88:22 89:10,11 90:3, 15,16,18 91:2,4,5, 18,20,21 92:2,22,25 93:12 94:6,17,18 95:2,10 96:7,10,16, 23,25 97:1,3,7,11,23 98:23 99:9,11 100:17 101:1,2,3,5, 15 102:3,10 103:19, 21 135:7,12,15,20, 25 155:15,20 156:8, 12,18,23 157:3 158:25 159:22 160:3 161:16 162:24 163:2,6,16,22 164:5, 13,18 165:8,11,13, 18,21 166:3 167:3 169:4,18 171:3,8,17 173:8 174:6,8,14,16, 18 175:16,24 177:13,17 178:6 179:10 180:11 182:5 183:5 184:9 186:23 187:21 190:17
Soukup's
92:18 93:3 94:19 96:5,7,22 97:19 101:24 102:25 155:5 162:15 165:24 182:12 187:1 190:6, 11 191:1
sounds
41:25 44:20,22
soups
187:11
source
140:1 162:11
space
20:16
speak
9:15 100:10 126:7
speaker
28:21
speakers
28:18 29:22
speaking
29:1 68:4
spec-
171:15
special
61:24 62:21 115:16 124:7 200:18 203:12
specific
5:18 16:15,16 29:3, 18,24 52:3 73:3 97:20 181:22
specifically
34:17 125:17,25 143:6
specs
76:7
spectrum
82:17
speculate
81:4 202:8
speculating
163:7
speculation
192:22
speculative
171:16
speed
79:17
spend
13:13
spent
13:22 200:15
spin
61:25 62:10 63:2 115:17 129:8 143:24 144:25 147:3,5 149:22 197:11
spins
116:24 124:6 144:24 145:16,21 147:1 205:4
spintronics
25:13,16,23,25 26:1, 4,6,9
spoke
15:6 104:8
sponsor
29:5,14,16
sponsored
15:23
sponsors
29:12,17,23
sputter
34:21 91:17
sputtering
93:7,9,11,16 95:8
squared
167:18 170:7,24 172:5
squares
195:15
standard
45:5,10 72:23 157:22
star
163:23 164:4 173:6
start
9:9 18:15 26:7 41:2 74:3 81:12 90:7 100:22 115:14 136:20
started
18:12 28:14 140:5
starting
40:7 170:3 172:2 199:2
starts
41:5 43:23 60:8 113:15 133:23
state
29:9,15 31:9,10 48:1 51:15 56:14 80:20 84:11 105:21,24 106:10,13 109:24 110:6 146:10,19 149:9 165:7,13,20 177:22
statement
120:5 125:2,22 148:5 202:5
states
60:14 143:2 151:5 161:18 196:12
stay
126:9 135:4
step
157:4 166:19
stepped
30:21
steps
34:6
stick
77:16
STJS
197:12
stoichiometric
89:21,24 156:15 159:1,16 161:23 163:9
stop
79:3 80:3
story
183:2
straight
167:19 168:18 170:11,15,19 171:7, 10,23,24 172:7,9,16, 23 173:2 184:25 185:3
strictly

89:5
strike
25:2 26:8 47:17 75:23 77:8 84:24 86:20,22 102:17 128:1 138:2 176:9
strong
57:22 144:23 145:14,20 146:8 187:18 205:3
stronger
147:1,3
strongly
129:7 200:12,20
structure
51:3 52:11,19 62:23 63:6 64:1,4,21 66:10 67:2,7 102:8 116:14 117:1 122:19 151:17 152:1 192:13
structures
30:11 52:12 93:6
student
28:1
students
29:8 30:16 32:4
studied
199:16
study
193:25
subject
38:12
subscribe
21:1
subscribers
20:14,20
subscript
131:21 160:22
subsequent
18:5,21 70:6 205:17
subsequently
33:20 66:3
substrate
97:12,24 98:4 99:7, 15,17 100:18
subtleties
148:17
success
92:17 96:4 102:24 125:8,10 183:4 188:25 203:7
succinctly
76:20
sufficient
49:3,4 50:15 74:11 99:24 100:1
sufficiently
34:3 48:7 56:16
suggest
34:15 70:2 185:9 186:14 205:19
suggested
69:2 100:21 156:12 159:25 200:20 205:6
suggesting
200:13
suggestion
60:21 187:18 206:17
suggests
180:23 197:8 206:13
suitable
97:11 151:6
sum
165:13,20
summarize
163:6 185:18
Summary
160:7
supervise
31:20
Supervising
32:4
suppose
13:18
surface
17:6,7
surmount
85:4
surprise
20:1
surprised
15:19 19:24 120:4
suspicious
171:17
symmetry
120:10
system
93:8 157:8,17 158:2
systems
106:15

T

table
160:4,7,21 162:16 163:13 164:9,13,18 166:3 168:8,21 169:4,13,17 171:5 176:8,12
take-away
204:25
takes
61:1,4
taking
201:24
talk
28:23 29:14 30:13 84:12 111:5,20 114:5 155:5 194:25 195:4 197:22
talked
26:4,5 34:19 38:4 74:23 91:18 112:24 117:5 171:13 182:16 201:8,19 204:1
talking
9:18 28:14 38:6 60:23 65:14 66:13, 18,22 68:19 69:25 82:23 83:8 112:1,3 117:15 119:9 122:23 130:21 143:19 163:24 200:16 204:21
talks
112:21 114:2 159:9 194:19
tantalizing
183:22
targets
34:20 91:17
taught
25:24 26:1,5,9,11, 14,19,23 27:1 92:25 98:1 103:12,23 104:5,19 120:8 122:14 125:18 139:4 155:15 165:14,21
teach
25:22 27:11,13 28:3 122:17 135:13
teaches
96:9 99:9 181:9 183:5
teaching
25:18 26:7 61:13 93:3 96:5 116:7 120:16 187:21
teachings
88:21 92:18,22 96:7, 10,12,13,15,16,22 97:10,20 100:17 102:11,25 187:1
technical
16:2 24:9
technique
151:7,10,21 182:12
technologies
101:17
technology
16:20,24 18:18 29:10,15
telling
46:2 60:17 164:14 169:13 171:18
tells
46:23 164:18 195:14,23
temperature
40:7 42:20 44:19,20, 24 45:10,21,23 46:9, 14 47:8 48:13 50:13 54:24 57:11 81:17 85:21 93:12 94:5 95:4 97:12,25 98:4, 10,25 99:4,7,12,13, 16,17 100:19,20 101:6 166:24 167:13 170:5,16,21,22 171:9,12 175:7 176:20 178:24 179:21 195:7
temperatures
43:1 46:3 96:18 167:1,10 176:25
ten
29:17 60:10 74:10, 12,13 158:8,9,12
tens
19:2
terms
52:21 54:10 82:2 126:7 152:10 175:5
test
187:25 192:1,5,6,18 203:20,22 206:21

tested
33:20
testified
5:7 8:19 103:19 116:6 159:22 190:23
testify
149:15
testifying
154:19
testimony
7:25 51:23 53:10 56:19 58:10,13,16 59:15,23 90:10 95:11 97:4 100:15 102:15,18 104:10 119:15 129:19 140:16 153:15 154:1,7,8,11 155:14 172:10 180:19 185:22 186:1 189:3 202:2 206:10
text
137:11 140:7
textbook
27:17 28:2 62:7 138:14,17 139:2,5,7, 13,16,21 140:15,17
textbooks
121:23
theoretical
57:17 144:12 145:23 195:23 198:20
theorists
49:21
theorized
89:18
theory
47:9,10,25 48:1,6,8 56:14,16 71:22 72:16,17 143:13 144:22 146:17 173:3 199:1,9,21 200:25 202:12 203:20 204:4,8,12,14 205:12,25 206:18
thermal
85:3
thermionic
85:7,21 86:2 87:2, 13,22 88:4,9,12
thermotic
86:10,21
thicker
71:8
thickness
40:15 70:22 71:1 75:1,6 77:17 150:13, 16,21,23
thicknesses
52:11 79:1
thin
62:8 77:1 83:23 85:13 135:20,23
thing
127:9 181:20 182:9 185:1
things
6:14 30:18 75:10,24 81:5,17 111:14 112:9,11 123:3 184:1 188:18
thinking
64:16 74:3 79:8 133:6 181:9 192:21 203:4
thinks
183:3
thought
51:25 55:3 72:9 73:17 82:11 148:25 153:15 198:6 201:4
thousand
22:10
thousands
19:2
three-layer
32:20
throw
184:14
tilt
66:21
tilting
63:24
time
5:13 8:13 9:3 13:13, 22 14:3,7 16:25 29:10 30:21 32:8 36:24 47:4,11 48:2, 9,16,20,25 49:13,21 50:6,21 54:17 55:20 56:15 57:21 59:5,14, 18 63:15 64:14,24 65:1 70:4 72:21 86:18 91:15 99:22 101:21 106:5 117:19 120:16 133:10 134:20,23 140:5 190:10 194:6 201:20,25
times
8:10,12 9:17 15:16, 20 19:8,25 22:10 62:17 94:14,20,21 115:24 116:9,17 125:23 129:5 158:8, 9,12 200:20
title
193:18
titled
160:7
TMR
44:6 46:3,9,14,17 47:1,14,19 48:13,19, 22 49:9,15,18 50:3, 11,12,16,18,22 51:1, 11,15,16,20,25 52:17,23 53:8,12,16 54:6,23,24 55:4,16, 17,21,24 56:1,9,21, 24,25 57:9,14,15,18, 22,24 58:7,9,18,20, 23 59:1,8,11,12 62:4 67:12 68:1,4 69:4 71:9,16,23 72:10 75:4,11,17,25 78:4, 14 79:22 80:21 81:2 82:22 104:7,15,21 107:8 108:3,10 109:8,17 113:8,15, 22 117:23 118:2,5, 10,14,18 119:2,6,10, 19 124:25 125:1,5, 11,21 128:7 129:20, 24 133:17 136:14,25 137:14 138:2,3,11 140:18 141:19 142:24 143:3 146:11,20 147:8,25 148:14 149:10,23 150:1 152:18,25 153:8,14,17,19 154:4,6,13,18 181:21 182:10,13, 15,20,24 183:1 184:6 187:20 188:5, 7,8,9,12,16 189:5, 11,17 190:24 195:7, 10,19 198:11,15,22 199:3,10 200:2,8,19, 21 202:10,25 205:7 206:4,14,22
TMRS
62:11 120:9
today
5:13 7:5,11,16 8:2 10:11 13:2 17:13,17 78:22 82:3 120:16 129:2,17 148:18 182:17 200:20
told
57:25 117:20
top
23:17 28:22 39:10 43:17 76:12 84:9,17, 18 86:11 105:13,16 106:6 111:6 113:7 121:12,25 134:24 143:7,11 146:16 166:17,21 168:23 173:16
topics
154:22
torr
94:20,23 157:18,20 158:3,5,6 161:4,11
trade-offs
77:13
tradeoffs
77:25
transactions
24:12 32:14 37:10, 19 38:3
transcribe
9:23
transistor
17:4,5,8
transistors
16:20,25 17:11,18 19:15,22
transmission
143:23 197:10
transport
44:2,5 66:18 81:13 116:13 185:13
transverse
78:17
treated
25:2
treatise

77:18 139:20
trend
199:20
tri-layer
39:13
triangular
61:1
trouble
175:25 180:13
trough
198:19
true
30:15 32:2 123:20 148:2 173:14 174:4 178:4
tunnel
24:17,20,25 25:1,4,8,15 30:3 35:1 68:1,3 73:14 83:22 85:14 89:12 92:19,24 96:5 103:1 105:12 106:1,10 107:8,15 108:2 112:7 113:8 114:25 117:3,7 121:24 122:2 123:24 124:6 130:9 144:23 145:15 146:9 147:2 193:16 194:12 195:8 197:25 198:9 200:1,17 201:5 202:4,18 205:3 206:5
tunneling
39:24 61:9,24 62:15 66:20 81:13 84:3,6 85:17 86:10 87:13 110:7 113:2 115:16,22 116:5,16,22 117:13 120:11,13 121:23 122:15,16,19,21,22 123:1,20 124:5,8,18 129:10 135:17 136:8 143:13,17 144:24 145:16,21 146:17 153:7 196:7 197:5 204:15
tunnels
66:14 143:16 204:5
turn
154:21 156:19 194:21
turned
17:12
twelve
60:10
type
23:6 174:23
typically
22:22 78:23
typo
32:16,18

U

Uh-huh
31:22 40:4 95:9 174:9 186:5 188:20 191:9 198:21 204:22
ultimately
17:9 98:20
unable
127:5
uncertain
48:24 89:6
uncertainty
174:17 178:17
unchanged
119:7
undergoes
81:14
underlayer
152:2
underneath
195:2
understand
7:4,17 9:5,16,19,21 10:3,5,13,17 11:12,19 22:24 25:3,8 42:1,24 47:11 57:25 63:5 72:3 97:14,16 116:3,15,22 117:11 120:18 121:9 126:5 139:24 147:14 152:7 171:3 201:21
understanding
7:8 27:18 39:12,21 40:19 43:2 48:1 56:14 58:13,15 63:15,20,21 80:6 104:25 116:21 148:8 188:22,23
understands
121:22
understood
10:21 11:18 12:2 51:1,5 52:8 56:15 62:21 63:9 117:19 121:17 147:7 153:6 171:13
unfair
194:8
uniform
159:6
uniformity
159:9,14,15
unique
200:18
unit
106:18 157:20
university
30:12
unknowable
190:5
unlike
62:13 115:21 171:25
unreliable
171:20
unsure
177:13,20

V

vacancies
88:24 89:7 90:13 91:8 95:5 100:24 101:13 102:1,6,21 103:14,24 155:15 156:1 158:23 159:2 177:24 178:14 185:20
vacancy
88:23,25 89:19 90:4 91:13 101:4,19 159:23,25 165:8,15,22 179:2,5,7
vacuum
94:10,12,13,16,25 157:8,17
vague
93:6
vaguely
193:24
values
145:3 147:10,14,20 168:8 176:7,8
variable
152:4
variation
61:3 99:1 176:20
varied
69:24 178:14
varies
150:15
variety
51:4 52:7 91:14 101:16 122:7
vary
63:8,22 66:12 67:2 70:4 71:18 120:18 122:25 123:18,25 129:14 147:18 187:19 200:21 206:4
varying
60:23,24 64:3 68:22 77:17 94:4 97:12 129:14 150:13 156:6
vast
30:12
verbally
9:22
verge
35:17
version
110:20 131:24,25
versus
123:11 124:8 167:18 170:7,24 172:5
view
101:15
VII.E.3
120:7
volt
81:1 90:11 94:1 168:13 180:18
voltage
41:15,19 65:20 130:10 167:3 193:14
voltages
76:22
volts
40:14 42:2,22 43:12 46:8,13 47:19 48:11 50:5,10 52:25 54:5,22 56:8 57:8 79:20 80:12,23 82:18 86:4 87:21 88:2,4,18 89:2 92:20,24 103:25 126:11,12,23,24 162:21 164:7,11,16,20,21,24 166:14 168:19,24 169:7,11

173:19,24 178:7 185:22 186:24 188:3 195:20 198:11 199:2
volume
32:14,17 79:10 193:10

W

wafer
17:6
wait
9:8 35:14 47:2 91:20 141:13
walked
107:20
wanted
14:16,18 15:3 75:4 77:12 88:17 91:1 190:24
ways
91:10,14 97:10 122:7
weaker
147:2,3
week
31:6
weekly
29:7,9
weigh
22:11,16
weight
22:25 23:9
well-cited
15:18
well-known
19:10 139:2
Western
7:22 10:14 11:16,25 12:6
Wichman
5:10,12 6:10 36:22 37:2,4,8 41:21 42:8 55:13 71:14 74:9,13, 17,20 75:7,15 77:23 88:16 89:9 98:8 99:21 100:2,7 103:20 109:1 126:17 134:18,22 135:1,3 154:20,24 155:3 192:23 193:4 198:17 199:8,22 200:9
widely
132:4
Width
193:14
Wilson
6:5 8:1,3 13:8 41:17 42:4 71:11 77:15 88:7 89:3 97:22 99:25 100:5 103:17 108:22 126:14 134:21,25 154:23 155:1 198:13 199:5, 14 200:4
window
5:23 6:1 12:16 108:16
windows
12:13 92:10
wires
77:1
wondering
142:8
word
44:17,22 45:4 113:4
words
115:12 147:9 191:1 195:4
work
6:15 13:16,18 14:18 15:22 16:12,16,18 18:8,20,21,22 22:23 23:5,14 31:9,23 32:20 34:10 35:4,12, 24 37:1,18 73:19 101:18 138:23,24 155:6 186:6 188:18
workable
56:17
worked
31:11
working
13:22 34:9,12
worth
53:8 183:7 188:19
wow
187:5
writes
40:13
writing
36:21
written
100:12 139:19
wrong
175:15,18,22 178:23 180:10 184:17 185:7 186:14
wrote
111:23 142:24

Y

year
8:17 13:25 28:3 193:11
years
8:22 27:1 30:24 113:24
yield
40:12,13
Yuasa
28:20 29:1,6

Z

zero-field
161:18 162:10,24 163:11,18 165:10,17 167:16 176:23 177:2,5,9,23 178:2 183:11
zero-intercept
162:20 164:15,20,24 173:10,19 176:13 179:9 180:4,8 182:3 185:19 186:3
Zoom
6:3 12:19 193:6