

【Samsung Electronics' 2019 Investors Forum】

Ben Suh

Good morning. And welcome to Samsung Electronics' Investors Forum 2019. I'd like to thank all of you for making time in your busy schedule to be with us this morning. My name is Ben Suh and I'm with the Investor Relations team in Samsung Electronics. I've been with Samsung for over 25 years, but I'm relatively new to IR. I joined the IR team in December of last year but I've spent many, many years in, mainly, semiconductor side of electronics. And I'm looking forward to meeting many, many more of you in the near future.

Today, we'd like to talk -- give you several presentations. We are in the age of data, and I believe this data explosion is actually just in the beginning stage. This is because AI is now just starting to emerge and it's going to require much more data. And then we still have this upcoming age of autonomous driving, which will be a lot of servers on wheels that will handle a lot of data. And also, of course, currently, people are watching more and more high-resolution video content. And that's a tremendous driver of data as well.

Fortunately, but not by coincidence, Samsung is involved in many areas to be able to participate in this future data explosion. First of all, more products are going to need more memory that are higher density, higher speed, lower power. And then with all this data for communication, you're going to need more advanced high-speed networks, such as 5G and beyond. And then to interface with the usage of this data, you'll need a lot of personal terminal devices, which -- with much more advanced capabilities. So that's why today, we have invited some key experts in these businesses related to this data explosion, such as from our network, our mobile and semiconductor businesses.

In the first section, we have Mr. Woojune Kim. He is Senior Vice President of Sales and Marketing for the Network division. And he's going to talk about 5G, which is widely considered the fundamental technology behind the Fourth Industrial Revolution. In this session, he will share the status of our network technology development and strategies for the 5G era.

Following Mr. Kim, we will have Mr. Jong Min Lee. He's Vice President of the Strategic Planning group of our Mobile division. And Mr. Lee will walk you through our business direction and strategic priorities for differentiation in this very competitive smartphone market. And he will also include coverage of growth areas, such as 5G and foldable devices.

And last but not least, in the final session, Dr. Kyoung Sub Shin of Samsung Semiconductor R&D Center will address memory process technology. This section will focus on our technology leadership that enables us to drive leading-edge technologies for our memory products, and he will share our current status in developing these technologies and present future process directions.

So without further delay, let's proceed to the first presentation. Please give me a hand in giving a warm welcome to Mr. Woojune Kim from our Network division. Thank you.

Woo-June Kim

Hello. Good morning. Thank you, for making the time here. As Ben is saying right now, I'm Woojune Kim. I've been with Samsung -- well, I joined in '99. But in the middle, I went off somewhere and then I came back. So I'm the prodigal son.

Preparing for this presentation with our marketing team, they made wonderful slides but one thing I did not really look at was the title. And I just saw it right now, it says, For a Better Tomorrow, and some of you might remember but this -- Chow Yun-fat launched his career with the movie, A Better Tomorrow, around 20 years ago. It was one of my favorite movies when I was in high school and college. And in the same manner, I think -- I hope today can be the day when we can launch Samsung 5G in your minds and in the investment community.

So first of all, I'd like to just give you an overview about what 5G is for you because 5G has become this buzzword. And I had to sort of get through to what really -- why I think people are so excited about 5G. Now from a technical point of view, if you talk with engineers -- in fact, we've been talking with a lot

of marketers, if you were to ask them, what does 5G do for you, they'll come up with like these 3 main characteristics. They'll say it's ultra-fast, it's instantaneous and it enables massive connectivity.

And so what does that mean? So if you look at it, 4G was maybe max 1-gig speeds. 5G will allow you to get up to 20 giga-bps of speeds. This is speed that is what fiber connectivity allows you to do. Many of you live in Asia right now, and I know that a lot of you have maybe up to 1-gig speeds of Internet access at home. Today, people who are using 5G say, "Wow, this is faster than the Internet I have at home."

But it's not just that, it's also instantaneous. And this is the other aspect of 5G that it allows you to be instantaneous in that it's as if it's real time. So it's as if you can do -- you no longer have that annoying click and wait problem, even with 4G, even though it was much faster than 3G, you still had that delay. With 5G -- with the changes that 5G bring, you have the potential for things to be instantaneous, to be there. And that will enable a lot of new applications that I'll show you later on.

And then a third characteristic they talk about is massive connectivity, which is connecting everything. And this is not just about connecting people now, it's about connecting devices. And 4G was the start of this, and 4G enabled -- it has IoT, it has -- we're talking over 100,000 devices, but 5G will expand this enormously, 1 million, 1 million-plus going forward. And what that means is that every one of you can be connected, not just with your phone, not just with your watches, your glasses, your shoes, health, everything. And not just you, actually more than that. And I'll talk about that more later.

But that being said, these 3 items are rather dry. And sometimes I wonder, is this why people can be so excited about it? It's really -- I don't think it's really because of these 3 things, it's because what these 3 things mean. And the way I look -- quite like to look at it is, I go back and I look at it a different way, that many of you have probably read the book, Sapiens by Yuval Noah Harari. And what he says there is that -- it's interesting. He says why did the Homo sapiens become the #1 in the food chain? And his ideas were very simple. The key idea he had was it was language. Because people were able to tell stories, build

communities, build culture and that is what differentiated us from the apes and the other animals. And that's how we humans were able to create bigger units of communities, cooperation and we were able to make societies that are 1 million or 50 million strong. And so his key message was always that humans made their leap with language to communicate.

Now why do I bring this up while we're talking about 5G? Well, it's because if you think about it, all communications in -- with phones, we've talked about wireless communication, is about communicating. But 2G was really about human to human. And by that I mean, it basically put a phone in your pocket that previously had already been wired up so that you can talk with people. 3G, 4G, I'd say on many times it put the Internet in your pocket. You could carry around the Internet in your pocket in your smartphone because there's really, in many cases, human to machine, you are talking with servers that Google has or Apple has or somewhere. And it was great because it allowed you a lot of things to do.

But then when we get to 5G, what changes? Well, 5G, I think, unfortunately for us humans, we now become the second-tier citizens. The most important thing in 5G will be machine-to-machine communications. It will be about things talking to things, cars talking to the servers at Audi. It will be about humans -- not humans talking to humans, but it will be our sort of, what is it, the machines at, let's say, at CBS talking with their centers elsewhere saying that we need more products. And we think this is going to be the key driver. Many of you heard about IoT as a buzzword. Well, this is when IoT will become real.

And so why did I just bring up the human discussion was because machines, we think, will be able to make their leap to become really different in 5G when it gets tied with AI and it is used so that the machines can start communicating with each other.

And so you could say that 5G will become the basis for us that will allow humans to bring together all the buzzwords that are going on today, cloud, AI, big data, IoT, et cetera. And 5G is the fabric that will tie it altogether. And that is why I am a real firm believer that 5G will be a fundamental changer in how the world works.

And so 5G, as I said, will be this catalyst for innovation. And it can really change things fundamentally. For example -- so we talk about how 5G can really change many things. It won't be just about phones or anything or machines, it will be about improving your quality of life. It can change your industries and societies. And I think the best way to look at it is we -- our team -- our marketing team has made some -- a great video that can show you very quickly what it's like. So if you take a moment.

Now if you look at what we just saw, you sort of can say that's the 5G vision and many people ask, "Okay, that's the vision. We've seen a lot of that sort of stuff. We've seen marketing stuff. When does it become reality?" And I think today, the message we'd like to get to you is that 5G is real and it is starting and it's here now. And to just give you an example how it's become real and how it's been accelerated, I'll discuss it here now.

And so 5G has already been -- 224 operators in 88 countries in the world have already announced that they're either carrying out 5G trials or investing pilots or are going to do planned & actual deployments. And among them, 86 have already committed to launching 5G between 2018 and

2022. And we already have over 10 operators in the world who actually said they have launched. Three of them are in Korea. And I think if you -- I think some of you are already based in Korea and you could already experience 5G speeds with the Samsung Galaxy S10 and the other phones out there.

But how did 5G accelerate so much, because this was not the original plan? The industry had really -- the industry sort of it goes from 2G to 3G to 4G around every 10 years. And so if you follow that schedule, 5G was supposed to arrive around 2020. But for various reasons, it got accelerated. And one of the key things that had to happen at that time was what they call 5G global standards. And this is because from a technical point of view, for people to make 5G work across the world, you have to have standards aligned. And we show here that the first 5G standards occurred -- were made in 2017. The original schedule, as I said, the standards team were working was more 2020.

So this was an acceleration of 3 years. And this happened for multiple reasons, but one of the key things was that, I think, we worked with Verizon and KT in

Korea, multiple countries -- companies in Korea to accelerate this significantly. And this really helped a lot because the industry managed to pull up the standards in 3 years. And so it became more of a stage effort in that initially they just -- we just went for enhanced mobile broadband. What I call this is really simple. It's just wireless fiber; it's fiber-like speeds, fiber-like connectivity but wireless. And this is why the early applications of 5G, for example, in the U.S. have been fixed wireless access and it's been discussed a lot.

But that is not all that it gives you because that's just giving the raw muscle power because the next one after that will be about new vertical services. And this will allow V2X, connectivity to cars, factories and also use of other spectrum, et cetera. And then the others will be there are more expanded services, such as going to public safety, broadcast, multicast, IoT. And basically, the way I look at it is this. In many ways, from a service perspective, the telecommunication industry 30 years ago divided it into 2 streams: it was wireline and wireless. And people said, on phones, I can talk with people. I -- on the -- or if I want to go to Internet or something or get video or something, I would go on my wired service. And there was a dichotomy between wireline and wireless. You still see that everywhere in the world. The U.S. there's the cable industry, there's the wireless phone industry. In Korea and other places, you see people who give you fiber connections and then people who do wireline -- wireless services.

But now with 5G, what's happening is it's converging back. So 30 years ago, they separated, they're coming back. And now that's why in the industry, you'll see a lot of cases where it seems now Verizon is saying they're doing FWA. Basically, they're saying, I'm going back into the wireline business but doing it in a wireless manner. You see -- and that is sort of a trend that's going to happen everywhere. And that is what really what 5G enables in many ways. So from an industry perspective, there's going to be a massive change there.

But another thing is that how could this be rolled out quickly because the industry also has an issue with that because this is such a big infrastructure thing, to roll out new technology is very hard and the industry has had problems before when they did 2G, 3G, 4G migrations because they had to set up a whole new network. So for the early commercial networks, 5G

technologists have become -- technologists have been smart about it. What they created is what's called, from a techy term, non-standalone. And that really means they've built 5G so that it works on 4G networks -- on top of 4G networks. So this allows the rollout of 5G to be accelerated quite a bit and this has really happened already in the world. For example, Korea, we've just launched 5G in, I think, the 5 major cities already in a matter of 3 months or so. This would have been unheard of if you're doing 4G or 3G. You would spend years just building out the towers.

This has been really helpful. But the problem is all good things come with some issues and this is -- 5G built on 4G means that we're sort of tied to 4G so there are some limitations there. Speeds, instantaneous access, et cetera, some problems. So long term, we want to go to what's called a stand-alone architecture where the 5G and 4G networks are separate and you can get completely different services. So the 4G network will run by itself, LTE, which has been a good sort of long-term basis. But 5G will -- when it's run as a separate network is what really allow you to do different innovative stuff.

Now the other part that is important for 5G has been spectrum allocation. So this is again a techy stuff. I'm sorry I go into techy stuff, but the first thing about 5G was for every wireless technology, what you need is new spectrum. So traditionally, it has gone from like 700, 800, 900 megahertz, going up to 2.1. Now we're gearing up to what's called the millimeter spectrum, 24~47 gigahertz. And what this means is that this is really going to spectrum that is -- traditionally, it was viewed as doesn't work for wireless because it's spectrum that has very wide bandwidth, can give you massive bandwidth but really, they say goes only 5 meters and drops dead. And that's one of the key challenges that we have to solve.

But as you can see, the U.S. has been the major leader in allocating millimeter spectrum. Korea, Japan has followed up. Italy has also jumped on the bandwagon for -- I don't know, for strange reasons. Usually, it's the Asian countries that jump ahead. Mid-band, 3.5 is another major spectrum. As you can see, a lot of countries in the world have been starting to allocate 3.5 gigahertz for 5G. And then the last one is low band, which is the 600 and 700 and, again, multiple countries have allocated this spectrum.

But now there -- I know there is a lot of arguments in the industry about which spectrum to use for 5G and which one is true 5G, and I know there are a lot of countries that are saying, 600 is going to be their 5G band. But let's make it clear, if you want to get the benefits that I talked about before about with 5G, which is the massive bandwidth, the ultrafast speeds, the instantaneous communications and the massive connectivity, you need a lot of capacity. The problem with the low bands is that actually, you only have very little spectrum, usually around 20 megahertz or 30 megahertz, which is a very small amount actually.

So if you really want 5G, I think the nation's you have to concentrate on, the technology you have to concentrate on will be the mid band and the millimeter wave. And as you can see here, that is again where the traditional Asian countries, Korea, Japan and probably China are going to take the lead, in that all 3 countries have become very aggressive on allocating a lot of mid-band spectrum, for example, all 3 operators in Korea have gotten anywhere from 80 megahertz to 100 megahertz of 3.5 spectrum, which, if you compare with the LTE spectrum is a huge amount. Because, for example, SK Telecom had only about 120 megahertz or 130 megahertz of LTE spectrum as a whole before they got the 3.5 5G spectrum. So they basically doubled their capacity almost in one go. And so this is going to be a major thing and this is what Korea, Japan, et cetera, are doing with China, and the U.K. have done. And then the other one will be millimeter wave. As I said, millimeter wave, we'll talk about more, but this is the key to allowing you to get to the wireless fiber-like speeds.

Now that being said, so how has this commercial rollout worked out? Well, we've been in a sort of unusual situation this time. Traditionally, whenever new wireless technology is rolled out, Korea, Japan have sort of led the way. This year, it's become an interesting race in that the U.S. has become very aggressive and has rolled out the networks very aggressively. So we have worked with Verizon, for example -- and we at Samsung are the team who have worked with Verizon very closely to launch a 5G service in October 2018, the first fixed wireless access business. But then very closely after that, Korea launched their mobile services. And now in April, we have Korea, U.S. all launching smartphone-based solutions, and then also Swisscom in Europe also

came up. And then afterwards, you can see China, Japan all coming along and the U.S. operators have all been also active, Verizon have been launching.

But there, as I said, the big picture, if you look at it, the amount that's going to be rolled out over the next couple of years, pop-wise, coverage-wise, will be, I think, the major countries, will be -- it has to be -- will be Korea, the U.S., probably China and Japan.

Now this is being driven really by the fact that we have a lot of 5G devices coming out today. So in April of this year, and some of you might have already have it, is the Galaxy S10 5G was launched in Korea and in the U.S. and in other places in the world now. And this is becoming the de facto 5G phone. But not just us, but a lot of other vendors are creating phones -- 5G phones now, Motorola, LG, Xiaomi, Oppo. They've all been announcing 5G devices, and this has really been expand -- this is sort of -- for consumers, this is the key thing. For the consumer 5G to develop, you need the 5G devices out there. And so 2019, as I said, they have -- 39 devices have been announced and probably more will come out.

And this will lead to enormous exponential subscriber growth, we believe. What this is showing here is that, for example, how long did it take to get to 500 million subscribers? 3G took 10 years. 4G took 5 years, 5G is getting to 3 years. Now this is also -- and I talk about this a lot with my team is that this is also based on people, subscribers. This is not talking about machines as I was saying. Going forward, you'll see 5G cars, 5G streetlamps, et cetera, and those are not counted here. So actually, there's an exponential growth here that we have not really covered. And as I said, that's going to be the fundamental difference. Everything is going to get connected. Every data is all going to go up to the cloud and you're going to have AI picking through it to figure out what's happening in the world.

This will obviously lead, hopefully, for Samsung Networks, which I'm part of, a very large increase in the mobile infrastructure market growth. A lot of it will be focused on 5G. This chart shows significant growth but actually, I think it doesn't do justice to the issue, in that the potential growth is that this is just a mobile infrastructure but as I was saying, going forward, if you think about it,

the wireless, wireline worlds are converging, telecom is converging. And there are new services that are being developed that are going to extend to a lot of other device at the end. And if you start tying that together, the potential for 5G to make changes -- earlier I talked about how 5G is expected to create \$12.3 trillion of business. Well, that's the reason. If you look at just this, you say, "Oh, it's only \$54 billion." Actually, we think it's much more than that.

And so based on this, you can see, like, the U.S., Korea, they've all been announcing major investments. In the U.S., they have said they will invest \$275 billion in 5G. In Korea, \$26 billion. I mean the numbers keep on going up and up and up. And as I said, this is because it won't be just about the mobile infrastructure, it's also about the devices, the services and how it's going to change the whole telecommunications industry.

So as I was saying, U.S. already, last year, if you like the picture on the left, this was -- these are all Samsung devices actually. We were -- the Verizon launched 5G home broadband which was fixed wireless access, a replacement for fiber services in October 2018 in 4 major cities: Sacramento, Houston, Indianapolis and Los Angeles. Samsung was the provider of the network equipment for 2 of those cities. Our competitor provided for 2 others. And then we provide all of the, what we call, the 5G routers and outdoor routers for the all 4 markets. So even at that time, we were viewed by Verizon as the leader for 5G. And if you go to Sacramento, Houston, you might see some of those 5G boxes at the top.

And also in April of 2019, this year, we just launched the 5G smartphones with Verizon, and they've been very successful, I think, and they've been getting -- as I was saying, if you look up in the trade press, there will be a lot of comments about getting gigabit speeds faster than the Internet they have at home.

Now -- but if you want to really see what 5G is doing, I think the best thing to look at is looking at the -- this video, which shows you what 5G is -- how it's being used in Korea right now today. So if we can show the video.

So I think I always tell operator friends who come to Korea, I'd say, Korea is interesting because we're sort of like a nationwide mobile lab. And I think this 5G really shows it. It happened -- 4G -- when 4G happened, the same thing

happened. With 5G, it's really happening a lot because we're -- we've got a nationwide network now. And as I was showing, people are developing all sorts of interesting apps and different applications and services that are being enabled by 5G. Which one will succeed? No one knows. But unless you have the playground where you can play and experiment, you can't make it succeed, and so the -- sort of the tactic or strategy that the Korean operators have taken is the field of dreams strategy, build it and they will come. And so they say, "We'll just roll it out nationwide, start with phones. But then afterwards, we expect a lot more to happen." And so if you go on YouTube and other places, you'll see how SK Telecom is working on factory innovations. KT is working on, I think, AR and VR studios, and you saw a lot -- sport stadiums, you saw that dragon flying around the baseball stadium. A lot of new services are being developed. And I think that is one of the key things about Korea right now is that we're at the forefront of enabling these experiments.

Now that being said, okay, I've talked about vision, I've talked about how things have started up, being sped up. So what about Samsung Networks, how -- and Samsung devices, how are we increasing our 5G leadership? And so this is where I'll talk about that a bit.

First of all, technology milestones. We started 5G research 10 years ago, in 2009. And over the years, we've had a lot of interesting milestones, like 2014, '15, we're showing that -- and this was with millimeter wave technology, which at that time, a lot of people were saying is crazy. It will never work for mobile because millimeter technology at that time basically went like 5 meters and dropped dead. So unless you had a cell station every 5 meters, they said it will never work. But we managed to get it to work. And this was what drove the industry to accelerate 5G. And so as you can see, this is where we ended up at on the long and winding path to getting 5G commercial.

Now that was only enabled because we have such strong research and patent leadership. So we're the leading 5G patent holder, more than 4,000 essential patents indicated by ETSI, and this is their official technology group in -- we'd call European but it's actually the worldwide leader in this. And we've also now initiated 6G research. And the reason is because, as I said, 5G started 10 years ago, our view is that, now that we're starting to 5G deployment, we now have

to start doing 6G research. And this is sort of like an accelerating -- you're like a squirrel on a wheel and you have to run faster and faster. It's an unfortunate thing in some ways, but this is also how we maintain our leadership.

So doing all this research, what did that get us? Well, as I was saying earlier, the key thing it enabled us to do from when we started 10 years ago was millimeter wave 5G systems. And what the key thing is what radio waves are is that when you talk about millimeter wave, it's -- the signal is what sends the data. And it's the amount of times it bounces that dictates how much -- what its frequency is, how much data you can send. The higher the frequency, because it bounces more, the more signal you can send -- the message you can send. And millimeter wave is sort of the ultimate speeds right now. And this is where we have had major gains. Samsung, because we are recognized as -- in the technology world as 5G leader is because we have put so much effort and technology into creating millimeter wave systems. And this has been beneficial because this is what gets you to the 10-gig and 20-gig speeds that we're talking earlier.

But there is a problem with millimeter wave in that conventional networks are built on towers and they have big radios so we call them -- they can have -- you can have a sort of regular pattern. But with 5G, because the propagation speed distance is so low, you need to create a lot of dense networks. So it becomes a much more messy networks than as we show on the left. And as you can see, on the right, you can see you can have one type of network cell site that's sort of built out throughout the nation. With 5G, you need many types, small, big, medium, facing one way, facing another. And what we call them, you need big and small cells, and that's our challenge as an industry.

And to make those, you have to -- basically, you have to make it smaller. And to do that, you have to do, I think, what I -- they call them small cells, and I say they are small for a reason. Why? Because you have to minimize their power, you have to have small power; minimize the amount of back haul they need; and minimize their size. And then you have to maximize the distance that they can cover.

So how do you do that? Well, in electronics, there's only one way you can achieve these sort of things, size and power minimization, better performance. And the answer to that is chips. And that is where we think Samsung's biggest advantage comes into play for 5G. You have -- you'll all be talking about our Memory team division but it is not just about the Memory team or other things, it's that Samsung has built in; its DNA is around chips. We create chips. And that has been the basis for us in that we have created our own 5G modems, our 5G RFICs, for example, and this has led us to be able to create products that are higher performance, lower power consumption, smaller and better performing than others. And this is all due to the fact that we're able to work with our own -- we actually work not just with our own semiconductor brethren in Samsung but also other companies.

But as you probably can know is our Foundry division, our LSI division are industry-leading. So actually, we do probably more work with them than with other customers -- with other partners. And that has become a key advantage. And one of the benefits, as you can see, is that if you integrate with chips, you can get -- for every generation of product, you can get anywhere from 25% or more smaller size, better weight, better power consumption or better performance depending on how you do it. And so this will allow -- the key thing for operator is that it allows quick and easy installation for mass deployments.

So if you look here, that's the small base station we've created for our millimeter wave technology that was used by Verizon. And I'm not sure if anyone -- have you seen the old cellular base stations, but if you walk around Asian cities or, let's say, Seoul and you look up, you'll see these big antennas and stuff that are hanging all over the place. And installing them is very painful.

But as you can see, that's small enough that 1 person -- you see that little hand at the top, you can just go up in a bucket truck, install it, finish it in 2 hours. This is a huge difference. This is an industry-changing moment right now for us. And this was all due to the fact that we've put -- we made our own chips, around 4 chips that go into that product.

And we need many different types of radios for this for 5G. So as I said, the product we just showed you was the smallest one on the right. We also need

for our existing, the 3.5 mid-band, we also need what are called MMUs, which also need to be -- which are slightly bigger, but they also need to be more lighter, more compact. And then we have the traditional ones for, let's say, the 600 and 700 megahertz. And we need all of these and all of them have to meet various criteria. They have to become -- but the key point is, operators also want smaller, better performing, lower power. And the only way, as I said, you can do that is to meet -- use chips. And by this, we're able to help operators with their CapEx. And CapEx not just from an equipment cost perspective but also installation, services because that's also big item for them on a CapEx line. It's not just the CapEx of the product but also the installation which is also counted as CapEx for them.

That being said, if we can control the cost for operators, then they will love us, but then the other part that they also need is, how do I grow the top line, because if you can't grow the top line just cutting costs will only get you a certain amount. And that's another area that we've been very focused on in that if you think about it, 2G, 3G, 4G is very limited services in many ways. It's about voice and some data. And it's about, as I was just talking about, people to people or people to the Internet or Google. But for operators, for 5G to become the big change for them, it has to be something that enables new services. And that's what 5G is going to do. It's going to allow you to do unlimited services in that it's not just telecom services which is the basis, but it will allow you to do immersive services, things like smart factory, smart city, autonomous driving, drone-based solutions, et cetera. And these are what we think will really enable operators to see revenue growth from 5G.

But what will enable this? Well, if you think about it, the reason they were tied like that was -- multiple things was they were a telco infrastructure. What they need to get to is what's called an Internet infrastructure, i.e., you could say Verizon wants to become like Google. Now to do that, what's holding them back? Well, telecom operators have already had what they'll call dedicated networks for telecom services. Nice big iron boxes specifically made for voice or data or what they are doing. Going forward, what we are developing at Samsung is a completely cloud-based solution. So we're showing we're giving to people like Verizon, SK Telecom, others, the option to renovate their core

and their services so that they become a flexible network for Internet services. They can really now become a company that can be as agile, as efficient as the big Internet companies and create new services. And for example, we've already deployed it in Korea with SKT, KT and LGU+. We have like some 80% of the market and the reason they want to do this is because they want to create new services.

And another part is operations. How do you simplify the operations for them? And so one of the key things we think that is going to be important for simplifying operations and decreasing their OpEx will be the introduction of AI. And again, this is another big area where Samsung is putting a lot of focus because if you listen to what Samsung -- we are putting out is that we're investing a lot in chips, 5G and also AI. And this is not just as a general AI because AI is a tool, people have to use it. And we use it in the Networks division to simplify the operations of networks for operators. We think this is another big point. And as I was saying, we recently said we're investing more than \$22 billion in 5G and AI and future growth engines. And there's a reason why we talk about 5G and AI. As I was saying, 5G plus AI is -- allows machines to communicate but they also allow you to do a lot of things simplified.

So why Samsung 5G? I think there are 4 things that I've talked about here: In-house chipsets. They allow you to make products that are smaller, better performing, lower power, and ultimately, easier -- lowers the CapEx to operators. And this will lead to best-in-class 5G radios. And then the other part is we create cloud-native core, software-based solutions that are services that are -- enable you to increase your revenue. In which for operators, the top line is just as important as the bottom line -- as the cost basis.

And AI-based operations, as I said. AI, we're putting a huge amount of effort to AI. And for operators going forward, I'm showing you how the network went from what I said the cookie-cutter conventional network to the messy 5G network which had a lot of different types of products in there. Well, operating that is going to be hell if you do it the traditional way. What you need will be AI. And that is another part where we at Samsung as a group have huge advantages. And so if you put all of these together, I think that is why Samsung, as a network infrastructure company, is really now coming to the forefront of

5G. We're able to bring all of these to reduce cost for operators but also giving them opportunities to increase revenue.

So this is a leading to major engagements -- 5G engagements. We have more than 20-plus operators engaged in the world. We're slowly developing our other channels across the world. Like, for example, we don't have on places somewhere like the South Americas, we're concentrating more on the advanced nations but we will be going out elsewhere as well. As an early indicator of this already, we -- Dell'Oro already announced that we have 37% of the 5G market in the early -- late 2018 or early 2019. And based on this, our goal is to grow our business. We started in 2000s from 2G, 3G, gone to 4G and with 5G, we really expect and we really hope to grow the business.

So that, I think, brings me to the end of my presentation. Thank you. So if you have any questions, I think -- yes.

Ben Suh

Okay, I guess this is the end of the first session. Woojune, thank you.

Woo-June Kim

Thank you.

Ben Suh

We are having the second session without the break. And after the second one, we will have a 10-minutes break, okay?

Please give a big welcome to Mr. Jong Min Lee from Samsung Mobile.

Jong-Min Lee

Hello, everyone. My name is Jong Min Lee. I'm Head of Product Strategy Planning Group in Samsung Mobile.

So let me just show you our history, the smartphone history in Samsung. Actually, let me explain myself with the Samsung history. Actually, we start from the 1989. It's a very bulky phone. Maybe you already have that or not. But no actually, I joined around here, right, 2001, like when we launched the first camera phone actually, and then we launched in 2010 the Galaxy brand, right? And this year, 2019, is 10th anniversary of the Galaxy brand. As you see, we have many like a historical and remarkable phone so far. So I'm also aligned within Samsung history.

So this year is very important for us. Let me explain. Okay. I will explain mobile market trend and current business status and our strategy this year. Okay. Actually, we had a very -- we have had a very nice performance from 2008. It's like a rocket because it goes up like that. But last year, I think it's other -- well, it's like BTS. You guys take a picture, right? But anyway, like -- but last year is the first year, have a downturn status in the market. So we expect 2019 is also downturn by 5%, right?

So actually, the reasons are, I think, in 4 reasons. And market also think these reasons are right. The first one is the replacement cycle. It's 2 years ago, so we expect it's almost like under 3 years. But nowadays, it's over 3 years. So people doesn't change their phone a lot. They are satisfied with their old phone. So that's why this is one of the issues. And second one is the market. The biggest market like U.S. and China, actually they account for 40% of the total smartphone market. Their markets are already saturated. That means most of the guys have a smartphone.

And third reason is the carrier, they don't -- they doesn't spend money, right? So actually, there is a trend in the subsidy. And final reason is economic headwind and uncertainties, right?

So that's why, as you see, the market is going down. So maybe you can say like this, wow, mobile industry has completely fallen, right? But I want to say, no,

it's not like that, okay? There are very distinct reasons here. Maybe you can see these kinds of pictures in your family or in your -- okay? Like they are immersed in the smartphone like this, right? So in my family, I want to have a dinner with conversation, but they just look at their smartphone. And when they come back home, they're like, oh, father, give me your phone, or something like that. This is almost like the same situation in every family. So that's why -- and the other one is, I thought this one, do you know the market capitalization of Uber? Do you know? Or Lyft? 20, right. Lyft, 20. Uber is currently like 70 something, and maybe evaluation -- the expectation of their evaluation was 120 or something like that before IPO. So actually, that amount, they don't any driver. They don't have any car. They just have a very nice system, who make that kind of new industry? I think in the mobile, without mobile, they can't. Without LTE, they can't make that kind of like such a big kingdom now. So that is the power of mobile, right? So actually in the coming future, we have tons of opportunity to bring up our mobile business again.

The first one is, as you know, Woojune already told you, like the 5G era, okay? So we already started 5G April of this year. Actually, it was very good start, right? And surely in 5G era, surely the equipment, that's important. But actually smartphone is very, very important, and the smartphone is located in the center, right?

So 5G have 2 meanings in smartphone. First one is, they -- 5G stimulate the demand for replacement, okay? Like 2 weeks ago, my father bought new phone, that's 5G phone, right? And I asked, "Oh, do you know what is good in 5G?" And he said, "Oh, just -- it is affordable." And they don't -- he doesn't know anything about 5G. He just know like, oh, it's fast. But actually, he's replaced because they have a better feature, big screen, big display, big camera and with affordable price. So that stimulates the demand for replacement.

Second, the ASP of a 5G device is higher than the normal devices, so currently like ASP of most of the devices, like around 200 or 300, something like that. So even in 2022, we expect ASP will be over \$500. That is a big -- a very nice signal to us.

And the reason -- the second reason is foldable or -- so I can say like a new form factor, okay? So you guys are our normal customers, find a way to use just a plate-type smartphone. All smartphones look the same, and they can't find any distinct features on the smartphone. But in a foldable or new form factor phone, it's totally different, okay? I'm beta tester of a foldable phone. So I'm using Galaxy Fold. That's a totally different experience. So when I come here, usually I bring my -- the briefcase with the tablet. Well, with a foldable phone, I just bring just my phone, right?

So I have a foldable phone here. So then I can just do this, and I can see my e-mail or whatever, watch a video or whatever, okay? So maybe you're still in the Unpacked event. So I think that you guys have many questions about the foldable. Let me answer later on. But please remember, foldable is very useful. It's different from the normal smartphone. So once I use this one, I can't back to a normal plate phone, yes? Actually, you look old. You look like a 20 or 30 like that. I can't see exactly what I saw because my eyes is getting worse. Foldable is the best for that really, yes. So we think that foldable demand will rise in the market, right? That's the second reason.

And third reason is you guys -- all companies have said, AI, AR, robot or whatever. But now under a 5G circumstance, we can make a VR, AI, AR, robot industry, okay? Maybe the -- Woojune, the -- already told we have 3 aspects. The 3, what is the strengths of 5G is low latency, high speed and multi-device connections, okay? Actually, these areas, AI, AR, robot, they need that kind of features, right? So that's why I'm absolutely sure this kind of technology will be flourishing in 5G era, right?

So there's just a funny story. Actually, in my family, with my wife, all the time issue is who turn off the light before going to bed. Do you understand? Usually, we just go to bed and lay down and turn off the light. Who the last person or "You, you're close to the light." But these days, no, we just use Bixby, like "Hi, Bixby, turn off the light." That's it. But actually, my wife doesn't know anything about technology. She just use that kind of IoT features, and she's thinking, wow, this is really useful. And the other neighborhood coming to my home, and wow, this is fascinating, something like that. And then they already use IoT

or AI already. So that means that would be a part of your life in the coming future.

And the other -- the good thing about 5G is that will make a totally different experience. The one of the big areas is game. So let me show one video.

You don't know what they are doing. It's like crazy guys. But it's like this. In off-line, with 100 guys, we shoot each other, right? And there is a monster. We kill this monster with the collaboration of the 100 guys. So this is just under a 5G era.

First one, low latency. If there is long latency, you can't, right? And second one, multi-connection. 100 guys simultaneously, right? And they will download tons of data, okay? That's why it will work. So actually, do you know the company Niantic? It's the company to make Pokémon GO, right? Actually, they have a very good technology in AR. And they ask like, okay, we made -- we want to make these kinds of fascinating games. But under 4G, they can't because the latency, is too long, right? That's why we are working with Niantic, right?

So let me briefly go over current business status. So fortunately -- actually, we had a constant really 5G devices working fine in sales. But in Korea, we already sold 1 million devices in Korea. So in Korea, totally 1.3 million devices are registered, almost Samsung account for 80% of 5G device. And initially, there is some issue in the quality or whatever. We all fixed with -- working with our carriers or the equipment company or other devices. So actually -- so as I said, 5G will stimulate the demand for replacement. It's working like this, right?

So as you know, we are the company for -- which have all from chipset, devices and access and the core and software tools. We are the company. And we have worked with the many carriers already in Korea in the U.S. That's why we have experience, right? That's why -- so we have many -- the carriers, they work with -- they want to work with Samsung because we have a very strong experience in Samsung. We launched in the -- first in the 2 big countries, right?

And flagship, as you know, we have launched 4 kinds of S10 series, S10e, S10 and S10+ and S10 5G model. The good news over here is surely the S10+ is the most expensive model. Sales of S10+ is almost major, majority of our whole

sales. That means our profit is good, and market response is very nice. And they think S10 shows you some innovative features, and they show innovation. And so we are happy to have that kind of positive feedback, right?

And for mass device. Last year, we realized Samsung mass device. Mass device means midrange price or like a low-price device. They don't have a competitiveness compared to the other brands. So that's why we changed our strategy now. We put new, innovative features, mass device first, right? So that's why, if you remember, last year, we launched an A9 and A8s, A80, like that. And the quad camera and the punch hole first and the rotating camera this year, okay? That means usually we put new features in flagship device first, and then we just download to the mass device. That was usually our steps, but we changed our direction. That's why the market thought, oh, what is this? What is the direction of Samsung? They are a little bit crazy or something like that.

But actually, our strategy was right. I will show the sales performance. And we realized, in India, the online market is very important. So that's why we have worked within free cart and Amazon and we launched online-focused model, it's M Series, right? After launching M Series, we have almost 10x sales, all sold out, okay? And we found out, oh, with the competitiveness of our performance and a reasonable price, customers still like Samsung, right? So that's why we are the -- as leaders, we guys have almost 1.6x than our predecessor models, okay? So we called this as a new Galaxy A Series, right?

So I'm not sure -- you haven't seen this, guys, A80 models. If you haven't, kindly please look at your YouTube video, that's to make the full screen experience. We have a camera up there, and it's rotating like that, okay? So it will launch, coming soon, right?

And we also launched a new Galaxy Watch and Galaxy Buds, right? Actually, the many people thought, okay, Galaxy Watch is a super hit, that's for man, something like that. And we're targeting female, right? And the response from female was very nice. Actually, the market share of Galaxy Watch was almost 15%. And the Galaxy Buds -- actually, the wearable market is a very rapidly growing market. It's almost over 10%, right? So that's why the Galaxy Buds also

have a more-than-double record. Surely, I can say like this is the nice result for Samsung. We -- our goal is more than this, but I'm very happy to have a very positive and promising result from this, right?

So this is 2019 business strategy. Okay. We have 3 strategies. Surely, our -- the Samsung Mobile is a mobile company, so we have to strengthen our smartphone line-up for secure shipment and profitability, right? That's the number one. And second, so we have to launch successfully commercialize 5G and foldable smartphones, right? And third, we want to be a -- we want to pioneer new business like 5G-related service and wearable or normal services, okay? So we have 3 pillars.

So first, flagship, I already explained many things about flagship. So we will launch in August new Note 10 series, okay? So I can say Note 10 is the most powerful device ever, and that will provide the highest productivity with S Pen, okay? You will see how S Pen is changing, right?

And second, for mass device, the mass device, we have 2 things that's important: how quick responds to rapidly changing market, okay? So our product planning, they are very working hard to catch the user trend, and once they think, oh, user trend is -- goes in different direction, they just give up, okay? Let's do the other model. Like we just do the -- so that's why we have no rule like just a lifetime of 1 model is 1 year. But it could be just 6 months, okay? So we are -- respond very quickly and we change our organization to response to the mass model.

The second one is secure profitability. So that's why we are focusing on including effective marketing campaigns and second one is component standardization as that's very important for us.

For foldable, Galaxy Fold was launched in Samsung Unpacked event. That's the first model, and we are preparing various kinds of foldable models, okay? So you will see many kinds of our foldable models in coming future. So this is a tablet type, and we are testing, we are preparing different kinds of -- but we think that our approach infolding way is very -- it's working, really. Think of then, if I do, I'll fold it like this, how can I put it here or something like that? This

is an expensive device, okay? So that's why we are sure this will be driving force of Samsung Mobile industry.

And let me explain some core parts, like a camera or display chipset or whatever. So maybe you know that we have Infinity-O Display. Actually, our goal is to make a perfect full display experience. So that's why we are trying Infinity-O like this, and with a fingerprint scanner, with ultrasonic technology. And as I said, like in A80, we have a full screen with rotating camera, okay? So unfortunately, I can't open here, but we will show a new full screen experience without that kind of barriers, yes? But I'm pretty okay. I also use that kind of S10 5G models, even though there's 2 holes, I don't care. There's nothing that bother me to enjoy my contents.

Okay, this is a kind of quiz. Actually, this picture is from the YouTube. Actually, we didn't take these pictures. Please guess which one is by Galaxy and which is by DSLR, okay? Gentlemen? So could you guess which one, left or right? By Galaxy, right side? Okay. How about ladies? Left side? Okay. One more pictures, okay? How about this? Lady first, which one? Still the same? Wow. How about you? You don't know. Okay.

There is one more picture. Yes, one more. Yes. Actually, I download this one from the YouTube and the one YouTube compared Galaxy and DSLR, actually Canon model, yes. Left side is Galaxy -- all left side is Galaxy. So that means in normal condition, we cannot distinguish which one is which one, right? That's why -- actually, I'm a camera mania, so I have several cameras, a DSLR or a small camera or whatever. These days, I don't bring my camera, surely even though they have a better picture quality. But it's difficult to send to the other guy like using Messenger or WhatsApp or whatever. So that's why. So I'm pretty okay with these kinds of pictures with S10. So actually, this kind of technology - - the picture is based on our technology like three cameras, like they provide ultra-wide, wider angle and telephoto. Actually, this is very useful, okay?

And next one is we have a dual aperture, so that's why we can have a very nice image from even a low light condition, right? So look at this. This is a video. We have a very nice super-steady mode. Please see which one is better.

Actually, they're just like this, okay? Yes. Okay. I don't want to show -- okay. So actually, the other model is our competitor, and the other one is the Galaxy 10, in video, our super-steady mode. And we are -- we are improving those features more and more. So in Note 10 and in S11, you're going to see a better quality of camera functions. For the other chipset, as you know, we have Exynos chip, so -- which one have the NPU functions. So maybe you heard from the news, and they were getting stronger and stronger or something like that. And then we first launched biometric authentication. That's getting better, and it's very easier to see and very secure, right? And third one is Wireless PowerShare. I'm not sure you guys are familiar with these features. Currently, just the S10 is supporting their features. But in my company, there are many guys using the S10 so we just, when in the get-together at the dinner time, when I doesn't have enough in the battery life, give me your phone, I can rent your battery, okay?

So you guys have 60% in your phone, or my watch or ear buds. It's very convenient, right? So I think that this kind of distinguished and new feature will help the people, wow, Galaxy is really nice in life, okay? So we will keep showing these kinds of new features, right?

So as I said, this is the 10th anniversary of Galaxy. We have many consideration of how we have to go, okay? But I think our competitor goes to very closed way, right? They make their own Netflix, right? But we don't make our own Netflix. That means we are working together within our eco. That's very important, okay? So that's why we have tons of CE devices. The first one is experience to connect to those devices. So that's why we spend time and effort to make it. And so as you know, we have a very secure element called Knox. So as you know, security is very important these days. So that's why we are -- keep focusing on the Knox.

And the other one is Android. We have a very close partnership with Google. So for example, like in Galaxy Fold, there's a continuity features like that when I see the -- like this or this, a good example. Okay. When I see more men like this, and then, oh, I can see men like this but I can open, they show bigger pictures, bigger maps, something like that, okay? So usually, I'm using like this. In the subway, I'm looking, oh, okay, okay. And then out of the subway, I just opened

my window. I can see the bigger one, like that. Actually, to make these kinds of features, you have to make a very strong partnership with Google, okay? That's why they're supporting the continuity features.

So Samsung, we are -- internally, we have these kinds of devices, and we have a communication, health&wellness, and the entertainment thing with Knox and Android. And maybe you guys remember, we acquired HARMAN, Joyent, ViV and SmartThings. In 5G area, they will brighten, very shining, okay? They have the capability to make a better service in 5G era. And if we don't have capability, we will work with Google or Spotify or Instagram or Netflix, those guys, very closely. Okay?

So as I said, we are a mobile company. We are just a mobile company. So we think the most important in mobile is experience. So in next 5 years, we're going to have a new mobile experience. So please think of Samsung Mobile as an innovator of new mobile experience. That's what we're trying to do. And if you think Samsung is innovator, we are very happy. And thanks to you, right?

Thank you.

Ben Suh

Okay, everyone. Before we start, I'd like to make a quick comment. For the Q&A session, please ask a question that is only related to the contents that presented today, okay? For example, like memory price outlook, CapEx plan, those kind of things he cannot answer that question, okay?

Okay, let's start the last session of today. Please give a big welcome to Dr. Shin from Samsung Semiconductor R&D center.

Kyoung-Sub Shin

Thank you. Hi, everyone. I'm Kyoung Sub Shin from Samsung Semiconductor R&D center. As the Head of the Process Development team, I'm responsible for the development of fabrication process, almost for all kinds of semiconductors in Samsung Electronics. First of all, it's a great honor for me to be here and give you a presentation in front of such a distinguished audience from all over the world. And thank you so much being here together with us today.

The title of my presentation is Samsung Memory Technology Leadership. As a fabrication process expert, I'll especially focus on the innovative fabrication process, which I believe is the key factor of Samsung memory technology leadership.

My presentation consists of 3 parts. In the first part, I'll talk about the position of Samsung in Memory business and review the history of our DRAM and NAND flash memory briefly. Secondly, I will introduce Samsung memory fabrication process, especially, the leading-edge technology and innovative approaches. Finally, I'd like to talk about consistent leadership in future Memory business based on synergetic and collaborative ecological systems inside Samsung.

All right. Now I'll go into my first part. The position of Samsung in Memory business. Let me start with the history of Industrial Revolution. As you can see, now we live in the era of fourth Industrial Revolution. In this era, thanks to the smart devices and wireless communication technology, people are connected quite well almost all the time. Under this hyper-connected society, we create a lot of information and share it with many people every day. As a result, we need to handle and store a lot of data, which is very crucial for Memory business. In addition, our history tells us that the speed of changes will be so fast.

Actually, it is happening now. As you can see in the graph, annually created data as of today is above 60 zettabyte and it is expected to surpass 160 zettabyte in 2025. The 1 zettabyte is equivalent to 1 billion SSDs with 1 terabyte capacity. So if we line these SSDs up then it is long enough to go around the

earth twice. This huge amount of data is created and utilized mainly by Internet, automotive, AR/VR and data centers as you can see.

Now I will review the history of our DRAM and NAND flash memory briefly. I'll start with DRAM first. So far, we have successfully developed each generation to maintain the world's #1 position since 1992. The third generation of 10 nanometer plus DRAM product, D1z will be released this year as planned. There are a lot of factors for the success of DRAM scaling, but I think that the excellent Samsung fabrication process technology is a key factor. Actually, we have developed a lot of innovative fabrication processes for cell capacitors and cell transistors, which are the most critical components in DRAM. I'll explain the detail later in my talk.

In NAND flash memory history, the most significant achievement, I can say is, V-NAND. As you know, Samsung developed and produced V-NAND for the first time in the world in 2013, and we are still maintaining the world's #1 position. Thanks to this innovation, we could overcome the scaling limit over the previous 2D planar NAND flash memory and we open a new paradigm of 3D vertical user. The fifth generation of V-NAND, V5, has already been in production since last year. And we will also start V6 production as scheduled this year. Again, our excellent fabrication process technology played an important role for the success.

As you can see from the history of Samsung memory scaling, although it was so challenging, we have been successfully overcoming the limitation and maintaining the world's largest memory market share for more than 25 years. We believe that our excellent fabrication process enabled this achievement.

In addition, Samsung will maintain the world's best position as long as we keep developing the leading-edge process technologies and introducing new innovative approaches.

Okay. Now I'll move on to the second part of my presentation. It might be a little bit difficult for you, but I think I'll try my best to let you understand. Okay. First, I'll briefly explain the semiconductor fabrication process for those who might not be familiar with it. The picture looks so complex, but I think I'll try my best. Okay. Simply to say, it is -- the fabrication process is just repetition of

sequential processes called unit processes. Each unit process has its own function. For example, the CVD, chemical vaporized deposition, process deposits a thin film, very thin film, and drying process makes a permanent structure by chemical and physical reactions using plasma. And -- yes, we have other processes, but I think we can divide their functions mainly into just 2 parts, as you can see, in the green ladder and blue ladder, the material process and patterning process. CVD and deposition implantation and metallization, they're kind of same processes, unit processes can be categorized as material process, for example. And then CMP and cleaning is not that easy to be inside patterning, but we put those unit process into the patterning and that put into the photo lithography and etching process can be categorized patterning processes.

Okay. So on the silicon wafer. On the silicon wafer, we form thin films by material process and then make them into a certain structure designed by designer, by patterning process. We also insert specific ions sometimes, by ion implementation process and apply heat to make them -- to make the structure as a really working electronic device. Now this is just overall fabrication process, okay. On the basis of this, now I'll go into Samsung's core fabrication process more deeply.

First, let me start with Samsung's material process technology. To help your understanding, I brought specific application of ultrathin layer deposition process, especially for DRAM capacitor fabrication. To make DRAM capacitors, we need to deposit very thin film of already patterned structure, we call the structure capacitor hole. However, since the patterned structures are so tiny, it's about nanometer scale right now, the more film is formed on the top as you can see in the left figure. Especially as the dimension scales down more, this issue becomes even worse. So we made a fundamental solution from 10 nanometer class DRAM. I'll not cover the technical details here, but by developing a specific surface-activation process before the thin-film deposition, we could successfully form ultrathin and uniform film as shown in the right figure.

For the material process, we also need high performance material to meet the required electrical property. For example, we have to continuously develop

new materials with higher dielectric constant for manufacturing required electrical performance of transistors and capacitors, especially as their size scales down. So far, we have successfully developed high-k dielectric materials, such as aluminum oxide, hafnium oxide and zirconium oxide with Samsung's unique fabrication process.

RC delay is another critical issue. It becomes higher as the dimension of device shrinks. To reduce it, we have developed ultra-low-K inter-metal dielectric and introduced metals with low resistivity such as copper. As air gap and new metal materials is also under development for the future RC delay reduction.

In fact, material development, especially new material development, it requires huge resources because we need almost boundless material sensing and screening activities to meet the targeting specification. So it's not that simple. Therefore, Samsung is closely collaborating with a lot of external partners from academia, consortium, equipment companies and material suppliers.

We are also extensively utilizing internal facilities and recently, we organized Samsung Material Exploring Project, we called -- we call it SMEP, in Samsung Advanced Institute of Technology. Fast and rigorous screening of new material is being performed actually there. So we are expecting that our material process will become even better in near future.

Now I'll talk about patterning process technology. I'll introduce 2 main patterning processes, closely related to lateral and vertical scaling, respectively. First, let me introduce EUV technology. As you know, EUV is a key patterning technology for lateral scaling. When there is no EUV technology, we introduce multiple patterning technology, MPT, to extend the resolution of the previous laser technology, which was ArF. MPT requires high complexity in process steps, but it can enhance the resolution by sometimes double or even quadruple. So we call the double, the DPT and quadruple, QPT technology, respectively.

Anyway, as you can see in the graph, the number of additional manufacturing steps due to this kind of QPT or DPT processes in DRAM has continuously increased. That is kind of real data in our DRAM history.

So if we still use MPT technologies with ArF for D1A, the process steps complexity is too much. So -- but if we introduce EUV in D1A, then we can dramatically reduce the number of additional manufacturing steps almost by 50%, as you can see. Actually, we will apply EUV as many layers possible from D1A production. In addition, EUV allows fine patterning, as you can see in the small picture in the graph comparing MPT, due to it has extremely high resolution. Therefore, I think it is the right time to move on to the new era of EUV.

Let me talk a little bit more about EUV technology. As you know, the resolution of patterning or minimum feature size is proportional to the wavelength of the light source we use. Since EUV has a very small wavelength, it's 13.5-nanometer, currently, we can pattern the minimum feature size of around 18-nanometer with EUV. With half of new material and process development, we are expecting to reduce the minimum feature size further down to 14-nanometer and MPT will extend the resolution even more. So sub-5 nanometer patterning technically might be possible.

In return, as you can see in the right picture, EUV becomes extremely complex system. First of all, the laser-based light source is changed to the plasma-based source because in order to generate EUV light, we have to make plasma, very special plasma with tiny tin droplets by precisely heating the tiny tin droplets with CO2 laser 50,000 times per second. Surprisingly, the precision of the heating is almost the same as that of heating a coin on the moon way far from the Earth by shooting a gun, and 5,000 times per second. Conventional lens-based optical system is replaced -- will be replaced by mirrors because EUV light, because of its high energy, is absorbed by most of the materials, so we cannot use conventional lens-based system. As a result, as you can see, the size of the equipment and number of parts inside the tools increase almost above 3x.

Yes. It's very complex. However, to utilize this kind of complex EUV system, especially for production, we have prepared a lot. We have prepared Samsung's unique ecosystem for a long time. Samsung EUV ecosystem covers almost everything related with EUV technology, such as mask, photo resistant materials, metrology and analysis and EUV-specific processes, such as dry

etching and photo lithography. We are also studying even vacuum and plasma deeply. Thanks to the strong EUV ecosystem inside Samsung, as you may see, we could start the world-leading EUV mass production for logic devices from last April. It is all successful for now. And I'm sure that we will continue to dominate the patterning technology in EUV era as well.

Okay. Right. Now let me introduce another very complicated and difficult process, HARC dry etch process. HARC stands for high aspect ratio contact and aspect ratio is defined by height divided by width. DRAM capacitors and V-NAND channel holes, those are very critical components in 2 devices, are typical HARC structures and their aspect ratio becomes higher when next generation comes up.

To help you understand the difficulties in HARC patterning, I would like to compare this concept with other well-known things to you. For example, can you see the hair? We can integrate more than millions of capacitor holes into the diameter of human hair. Also, the largest channel hole in production -- the latest channel hole in production will be 7 times higher than Burj Khalifa, one of the tallest buildings in the world under the same normalized scale.

Actually, the real process of HARC patterning, dry etching, is very difficult and complicated. Okay. Generally, dry etching process is a process -- is a procedure to figure out the relationship between adjustable input and visible output, which can be final profile. And by using plasma, we connect the input and the output. And then we have to figure out what's going to be the optimal input for the best output.

The problem is inside the plasma because plasma is so difficult. So let me talk about plasma more. Plasma is ionized gas, you might hear, so-called the fourth state of material. Solid, liquid, gas and then fourth one is plasma. If we keep adding the energy, eventually, the gas will become plasma. Anyway, we use gas particles, such as ions, radicals and polymers, these kind of gaseous particles, inside plasma for dry etching. A very small atomic level, sometimes molecular level particles.

Unfortunately, precise control of etched gas species is so difficult because we use not just 1 source of species, there are a bunch of gaseous particles and

species and some of them are not used and some are not -- some are very critical. So to control every species precisely is not that easy. And they -- I mean, the species influences each other and respond to the input I put differently. That's why it's not that easy.

In addition, it becomes more difficult to supply enough gas particles for etching into the deep bottom hole of the HARC because it's too narrow and too deep. Especially as the aspect ratio increases, it becomes even more difficult. So it's not that simple to design the optimal input recipe for the best output profile. That's why experts are so important in this area.

Anyway, we have been successfully developing as a real, the channel hole etching process for V-NAND and maintaining the world's #1 position since the beginning. We are very proud of that as a process engineer inside Samsung. And I believe that we will keep our leadership in V-NAND based on the strong HARC etching technologies together with a lot of experienced experts inside Samsung.

Okay. Finally, I'll introduce the futuristic innovative and disruptive technologies to overcome the limitation of current fabrication process technology. We are also preparing a high NA EUV system, NA stands for numerical aperture. With bigger mirrors, we can extend the resolution limit of current EUV further, theoretically. As I told you, we can enhance the resolution not only with smaller wavelengths, lasers, but also with higher NA, we can also enhance the resolution because we can focus more light -- with more light. So we're expecting we can extend more EUV lithography technology. I told you 5-nanometer feature size theoretically possible if we introduce multi-patterning technology with EUV, but with this high NA, even the smaller feature size, like 2-nanometer, even just less than 1-nanometer resolution might be possible.

We are also developing free-electron laser based on high-energy accelerator to provide high powers, which is expected to improve productivity. Yes, you might hear EUV productivity is not that high, but by introducing this kind of technology, we can improve productivity hugely. That way, we expect to make the EUV technology much stronger.

As a different approach, we are studying e-beam, electron-beam lithography. Since the wavelength of electron beam is really very small, it's just -- as you can see, it's less than 1 angstrom. 1 nanometer is 10 angstrom. Considering that, it's really small. So using that e-beam, we can draw very small -- we can draw custom patterns with a high-resolution even without mask. It's very good point. However, since we have to draw all patterns directly, throughput is very low. We have to overcome that.

Okay. As a disruptive idea, bottom-up technologies, bottom-up -- kind of bottom-up patterning technologies, such as selective ALD and DSA processes have been also being investigated. As you can see in the left figure, selective ALD, I mean, atomic layer deposition, ALD process consists of 3 main steps. First, we change the substrate -- surface property so-called by self-assembled monolayer, in short SAM. Secondly, we do ALD, atomic layer deposition on it. ALD will be only deposit on the specially treated surface. Finally, we remove SAM by strip. That way, we can deposit material only on the desired area selectively.

However, it is essential to find out and develop the right materials that meet the selective characteristics for the mass production. That is also the homework we have to solve.

DSA, direct self-assembly. DSA can be also explained with 3 steps. First, we put a bunch of block copolymers on the guide patterns. Second, we anneal for self-assembly with heat. Since block copolymers consist of 2 different types of polymers with hydrophilic and hydrophobic characteristics, they are self-assembled by attractive and repulsive forces between the polymers and the guide patterns. Finally, we remove 1 type of polymers by develop process. That way, as you can see, we can form the smaller patterns and nice patterns, smaller than the original guide patterns. So we can improve the resolution in this way. However, in this technology, defect is a major concern, so we have to solve that as well.

Okay. Finally, I'll go into the last part of presentation. So far, I have talked about memory leadership of Samsung and excellent fabrication process, I told it was the key factor for the leadership. Then how about the future? So now let me

talk about how to keep consistent leadership even in the future Memory business.

Of course, the fabrication -- the excellent fabrication processes that already we have developed and made is our #1 asset, #1 weapon. So I'll just add 2 more things on it for our future. First one is synergy. I'm going to talk about synergy. It's a great advantage for us to develop many products, as you can see, at the same time. Logic, DRAM, flash, and CMOS image sensor, new memories, such as PRAM and MRAM. We are doing a lot of semiconductor products at the same time. That way, we can share the technologies between products and lessons learned from each product. I think it's a very strong point of us. For example, EUV was initially applied to logic devices. However, now, as I told you, we are seriously considering to apply EUV technology into DRAM as well. And we are already -- it is already migrating to DRAM. As you can see, HARC, I told you, and HART is a little bit different, but high aspect ratio trench instead of contact, anyway, a similar process. HARC, HART and new materials are also example of synergetic technologies using more than 2 different products. So I'm very confident that these synergetic process technologies among products would guarantee our future leadership, not only in the Memory business but also in the general semiconductor businesses as well.

Another one I want to add as our weapon is strong Samsung R&D ecosystem. Samsung Semiconductor R&D center, where I'm working, is playing an important role as the core of all these collaborative activities. It looks very complicated, but anyway, if I explain. We are currently very closely working with world-class external research institutes, such as IBM, ISDA, IMEC and SRC. In addition, we are jointly developing equipment and materials with partner companies. Industrial collaboration with various projects is also being performed actively. We also have a lot of business test and packaging center and LED and system LSI foundry and memory surrounding us. As long as we maintain this strong semiconductor R&D ecosystem, the future of Samsung Semiconductor will be bright.

Okay. Today, I have talked about Samsung's outstanding fabrication technology, which I believe is the key factor of our Memory business leadership. In addition to fabrication technology, Samsung will continue to show consistent leadership

with synergetic activities and a collaborative ecosystem, as I told just a second ago. As a process expert, I will continue to develop these innovative and disruptive fabrication processes to guarantee you the successful growth of Samsung Semiconductor business.

Thank you for your attention.

Ben Suh

Okay. So that concludes all of our presentations for the Investors Forum this year. Once again, I'd like to thank you for your participation, and I can see many of you are eager to leave the room already.

Anyways, I hope today's presentations helped you better understand Samsung's efforts to remain leaders in this new data world, and we'll do that through technology leadership as well as the relentless efforts to achieve sustained growth. Also maybe you can better understand why we have the highest R&D budget of any electronics company in the world.

Anyways, I know many of you have spent -- it's now your third day here. So I hope you can enjoy some of the weather outside before the rains come in. And for those of you who have traveled from overseas, I wish you safe travels. Thank you very much.