Oral History Panel on Hard Disk Drive Transition to Thin Film Media

Participants:
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Abstract: *Syed Iftikar, Francis King, Gil Argentina, Joel Weiss, Jim McCoy and Atef Eltouhky played key roles in the data storage industry's move from particulate to thin film magnetic recording media. Thin film media rapidly accelerated the attainment of small form factor hard drives with very high data storage capacities. Such drives eventually became ubiquitous in engineering work stations, PCs, high performance servers, notebook computers and consumer products. This was a very challenging transition. The earliest film media (1981) were plated and failed to achieve adequate mechanical durability. Use of a sputtered carbon overcoat on the plated media (1982) eliminated this weakness. Adoption of sputtering to also make the magnetic layer (1984) enabled significant extendibility of film media and laid the foundation for today's products. Between 1982 and 2006 bit areal density on film media improved 8,000 fold, from 20 megabits per square inch to 160 gigabits per square inch.*

Originally we planned to include Ed Fleming in this group interview. Ed, who joined Ampex, was one of the most important contributors to the commercialization of one of the industry's earliest plated film disk, the Alar disk. Regrettably, Ed was not able to join us. He passed away recently

Tu Chen was also very influential on this transition. His contributions are summarized in this museum's Oral History of Tu Chen.

Chris Bajorek: Good afternoon. I would like to welcome the audience to this oral interview, on behalf of the Computer History Museum, in which we're going to try to capture the key developments in the transition that occurred in the hard disk drive industry in moving from particulate recording disks to film media. So our focus is trying to capture that transition to film media. We're interviewing a group of pioneers in this industry. I'm extremely honored by having the opportunity to do that. Syed Iftikar, Joel Weiss, Atef Eltouhky, Jim McCoy, Gil Argentina and Francis King. It's a pleasure to have you all here. I'd like to start out, if possible, by just asking each of you to introduce yourselves, share with us your current affiliation, and a little bit of how you each individually got involved in the world of film media. Whether as creators of the innovations, or as recipients of the well-developed or not thoroughly developed—early film disks. So starting with you perhaps, Syed.

Syed Iftikar: My name is Syed Iftikar. My first company I started, I founded was Seagate. And at Seagate, we had to take the size of the disk from 14 inches to five-and-a-quarter inch. That's the first time anybody had made such a drastic change in the disk. And I spent a lot of time at Dysan, looking at oxide coating, lubrication, and then stiction. Our first drives would not spin. The motor did not have enough power to overcome stiction, because what we did was as crazy as we were, we thought the same thickness of lubricant that was on a 14-inch disk would work on a five-and-a-quarter inch disk. And all the motors, the entire production line would come to a stop. We got back to Dysan and we said, "Look, our motors cannot spin a five-and-a-quarter inch disk, because these motors are very small." The brushless DC motors compared to IBM's big, powerful, washing machine motors that would spin anything. So after working a lot of time, and spending a lot of time at Dysan, we would get down to lubrication thicknesses

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that are almost impossible to measure. And we had a person called Al Fishler. He would lose a lot of his hair. And he would tell me, “Syed, there’s not enough lubrication there. It will never work in this environment.” And we went through many iterations finally to get even the oxide media to work. And when I left Seagate, and I started my second company called SyQuest, there I had no choice. Because SyQuest for the first time was a removable disk that used hard drive technology. IBM had done that before in what we called the disk packs. IBM made disk packs very popular, and just about every computer system had a disk pack. But then IBM decided it was not economical to make a disk pack as the densities went higher and reliability wasn’t there. Because the media was interchangeable. And IBM decided to come up with a new class of drives called the fixed drives, where the media was not removed. And at SyQuest, I started something that IBM had given up. Jim Porter told me at that time I was crazy. Al Shugart told me I was crazy in attempting that. And then Norm Dion of Dysan also told me that I was crazy (clears throat) in going into a venture like this. But I guess its crazy people like us who go and create new things, new companies, new technologies. Because if we follow the beaten path, we wouldn’t do the things that happen today. So those are my early recollections of how we started with disks and the media.

Bajorek: Syed, could you pin down the timing for us? When was the problem with Seagate, which year?

Iftikar: The Seagate founded in November of 1979. And Seagate became very successful. And then I found myself doing nothing at Seagate but talking to my secretary most of the time, because we had other people do the work. So I decided I would leave Seagate. I was the first founder to leave Seagate to go start a new company. So I can get involved with technology and not spend most of my time doing administration. So SyQuest was started in February of 1982.

Bajorek: And SyQuest’s first product used an oxide, or a film disk?

Iftikar: The very first product was film disk.

Bajorek: From the outset you were...

Iftikar: From the outset. I did a lot of research and the first person I went and talked to is Francis King, who’s sitting down there. And I talked to Francis because I read his IEEE report on film disk. So I wanted to know if this was possible, and producible, to go into mass production. And Francis showed me his disk at DataPoint. And then after I spent a lot of time with Francis, he gave me some samples. I took it home, had it cut and put on a lathe. We cut it so that it could fit on the motors at SyQuest. Because SyQuest had a non-standard size. It was 3.9 inch. And uh...

Atef Eltouhky: That was a big <inaudible>...

Iftikar: Looking back, in a lot of ways I have to kind of blame Francis for it, again. <laughter> He was not forceful enough! Because I went to Francis, after I talked to him, then we kind of threw the sizes around, and Francis said, “You know, Syed, Sony has a drive. It has 3.5 inch size. And we were the first ones to come with a metal disk to fit into a Sony package. However,…I measured the IBM disk, the floppy disk, it was 3.9 or 100 millimeters. So I had to choose. Between IBM becoming the standard, or there was another standard, a group of people with 3.5 inch Sony, which was 95 millimeters. So Francis had a Sony floppy with him. And I thought, “Well, IBM' is going to be the standard.” So I picked 100 millimeter disk, and it turns out that was the wrong bet. The 95 millimeter became the standard.

Bajorek: So you win some, and you lose some.

Iftikar: You lose some.

Bajorek: Sort of a fascinating way to get started. Let's move on and let the rest of the team introduce themselves. Joel?

Eltouhky: Can I get just a couple of dates from Syed?

Iftikar: Sure.

Eltouhky: When did you Seagate go public?

Iftikar: Seagate went public in November of '98.

Eltouhky: November '98?

Iftikar: '81 (earlier Syed said '79).

Eltouhky: And SyQuest. I forgot now, did it go public?

Iftikar: Yeah, SyQuest went public. And also in December of '91.

Eltouhky: Thank you.

Bajorek: Fascinating.

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Gil Argentina: Good memory.

Joel Weiss: My name is Joel Weiss. I'm vice-president of R&D for Seagate's Recording Media Group. And my first recollection of being involved in thin film media was back in 1974, my first job out of college. Went to work for IBM, and I knew very little about disks or drives at the time. We called them files, of course. And my first job was to create thin films on glass substrates, 18 inches in diameter for the--originally planned for the 3380. Glass substrates made by Corning Glass, and I think, if I remember correctly, the substrates were $5,000 a piece, chemically strengthened, alumino-silicate, very similar to what we use today for, but much smaller, for mobile applications. And my responsibility was to evaporate magnetic films, iron cobalt on chrome, and iron cobalt chrome on chrome. And in a very large, as you can imagine, evaporation tool, e-beam evaporation. And shortly after was troubled by all kind of tribology issues with those media. I switched over doing RF sputtering. Sputtering the same types of materials, chrome and iron cobalt chrome, trying to get to the very, very high coercivities and MRTS that we needed at the time, 400 Oersteds, 4 milliemus per centimeter square. So very different than we were today, but very much better than the particulate media of those days. So that work went on for quite some time, but about two years, three years into that, I was asked to go over to work on the tribology, the mechanical head-disk interface, which was terribly problematic in those days. And continued to be problematic for many, many years, because of the head disk interface and the flying heights of the heads, etcetera, and the fact that we wanted to start-stop in contact, as opposed to mechanically loading. It's something that we do today for mobile applications, small drives. So my first interaction with film disks was characterized by a lot of the same issues that we even suffer today of corrosion, and tribology, and mechanical issues, along with the same ones of signal-to-noise ratio, and overall, the electrical properties of the disk. So I'll stop there, and pass it along to Atef.

Bajorek: Thank you, Joel.

Eltouhky: My name is Atef Eltouhky. I started in the media business through the academia first. I was an assistant professor at the University of Southern California back in 1980. I had a PhD in material science, and I had some friends at IBM. And really found that I liked research more than teaching. I got bored teaching the core course three times in two years, so I couldn't imagine myself doing that forever, so I decided I'm going to come and join IBM. And came to San Jose in 1981, and started working on sputtering. My thesis in college was about sputtering semiconductors, III-IV compounds actually. So when I came to IBM, started working on magnetic alloys, actually sputtering cobalt alloys for magnetic recording. And one of the memories I have of that time is IBM was such a great place to experiment. I found one lab that had something like 25 different elemental targets, different elements that people got over the years, and they just stored in there. So I was working like crazy, just mixing all types of things, trying to figure out, like Joel said, trying to increase coercivity or the orientation ratio, and came up with some combinations of cobalt and gold and ruthenium, and under-layers, and so it was really a great learning experience with IBM. But IBM was a brown disk company, and they just would not really look at anything new. It was very risk averse at that time. So they just would not entertain doing a firm media. So we left IBM in 1983 with a friend of mine, Sabu Sheik, and we started TriMedia in 1983, June 1983.

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We got funded, and part of the reason for funding was that Syed gave us a P.O. that we took to some of the VCs, and it was a good way to show them that there is a real need for the business. We kept telling them there is an insatiable appetite for memory. We didn't even know what that meant, but that was sale importance.

Bajorek: That was your sales pitch.

Eltouhky: That's the sales pitch. I remember that. <laughter> It was probably true, and I'm sure...

Weiss: Still is.

Argentina: Still is.

Eltouhky: Still is, yeah. So started TriMedia and shipped the first disks in, I believe it was about June or July of 1984, using CPA machines. Horizontal machines. Shipped the first disks to SyQuest. And then soon after it became-- I guess we had 100 different start-ups, thin film different, at least, you know, 50 or 60 at some point, they may have counted 100, and every single one of them wanted to get to the magic number of a million disks. That was the magic business plan. You're right. A million-- we want to ship a million disks. And you get some money for funding. So we got acquired, because the brown disk people, oxide media people like Seagate, like Xidex, which had acquired Dysan, needed new technology. They really felt that sputtering is the up-and-coming technology. So they came and made us an offer and acquired us. So we were actually the first thin film disk company to take the public out. That was in Valentine's Day, 1986. February 15, 1986, was the day they acquired us. And we stayed with them for a few years. They were really focused on way too many things, and we just found it difficult to really make a whole lot of progress at that point. So we got Hitachi Metals to acquire that division. And we worked for Hitachi Metals for a while, under HMT Technology in Fremont, California. And I worked for them for about three or four years, and I left there in 1991. And we started StorMedia Corporation with Bill Almon, and we actually took that public, an IPO in 1995. I was an executive vice-president of research and development in the company. And, you know, like Joel said, kept shrinking everything, you know, spacing, head disk interface, lubrication, thickness. Everything was really coming down, so I decided I'd probably leave that to a younger person, so I left the business in 1997. I retired from technology in 1997. I started a couple of companies in the investment business. Now I am chairman of Aurum Capital Management in San Jose, where we're basically a family office, about a couple billion dollars we manage in assets at this point. So that's the story!

Argentina: Did you ever have any feelings that IBM was wise in not adopting thin film technology back in those days?

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Eltouhky: We really tried so hard to get IBM convinced that this is a viable technology. We went through meeting after meeting, and people would just really come with stories, horror stories about why this wouldn't work, and they would just say, you know, "We did this 20 years ago!" And stuff that we just -- and people would say, "Well, we did this 20 years ago. And it didn't work." They're just really very concerned. And IBM was going through a difficult time. I think the 3380 had a stiction problem. I guess this is what you were sucked into.

Weiss: Yes, that's correct.

Eltouhky: And nobody really wanted to handle anything new. And they didn't have to take risk, I mean, they had the market already.

Weiss: Actually it's very interesting you ask that. I had a little skunk works project at IBM trying to put films on silicon disks. Because disks were getting smaller. Silicon wafers were getting larger, so I figured Chris and I talked about that, I think, Atef, you and I talked about it as well, that if we could make really a small disk -- this was probably in the '77-'78 time frame -- but with all of the right magnetic properties, wouldn't that be wonderful? And I remember going to a Seagate (meant to say IBM) vice president at the time, and talking about it. And his comment to me was, "Oh, my gosh, you know, we can't possibly do that!" Because we had such a huge installed capacity in particulate media and large disk drives. You know, switching over to something small, really didn't make any sense.

Bajorek: And this was that idea at IBM, or was that at Seagate?

Weiss: I'm sorry, at IBM. I'm sorry.

Bajorek: No problem.

Weiss: Yeah, so they said, "There's just no way that we'll enter that business." And then I think that the thin film part of IBM really didn't start until the late '80s.

Argentina: Very late '80s.

Eltouhky: You were doing this in R&D, building 28.

Weiss: Yeah, I remember that. Right, right. Yeah, you were putting some films down.

Eltouhky: I was working for Chris, actually.

Bajorek: I think one of the -- there was this conservatism, but also IBM had an element that no one else had at the time, or very few had at the time, was a film head, which allowed them to extend their technology without pushing the media technology as much as those who didn't have the film head. So that aggravated the ability to introduce new things, because they viewed that as unnecessary risk taking. Now it must have been frustrating for those who were trying to create this new thing, and not be able to have it go into a commercial product. Great work was being done, but it wasn't seeing the light of day.

Eltouhky: Yeah, keep in mind this was 1983 when, you know, the world was exploding with PCs.

Iftikar: PCs just starting, yeah.

Eltouhky: Apple IIs and basically if you knew anything about your computers at the time, you got funding on the spot.

Weiss: Right.

Eltouhky: So you really didn't have to struggle…

Jim McCoy: Not quite…

Eltouhky: Not quite that easy.

McCoy: Not quite, you had to have a team.

Iftikar: No, but Atef, you are right. When somebody dominates the market, there's really no need for them to go look at smaller markets at that time, that are evolving. And that's human nature. We dominated; we had 80 to 90 percent of the market. And we don't have time to look at an emerging market. We are not quite sure how big it's going to be. It's only when that domination starts to dwindle, then they start looking to see what can be done. And in some cases, it's too late.

McCoy: That's how the giants get knocked off.

Iftikar: Right. Nature has its way of leveling the field.

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Eltouhky: Creative destruction, I guess.

Argentina: Yeah, I remember the guy who was chairman of Micropolis.

Bajorek: Stu Mabon?

Argentina: Yeah, he said, "You do wonders when you're going to be hung in a fortnight." When they went from the eight inch disk to the five-and-a-quarter, in some very short period of time. 'Because they basically couldn't sell the eight inch drives anymore. That still today, I think, is meaningful. If you're going to be hung in a fortnight, you do wonders.

Eltouhky: And when you actually sit and analyze, you know, the reason people don't take risks, a lot of them are very rational. They can list everything, and they prove they are right. But it takes a certain mentality, a certain group of people, the need. You know, having no other option, you just take a chance and say "I can only try." And you just go. And if we knew how difficult it would e to get a substrate to work, or the defects-- we had no clue. I mean, I was coming from the magnetic -- I mean, the sputtering technology. And there was no machine where you could do sputtering from both sides. Because the semiconductor industry was all designed for just one side. So the CPA machines were one-sided. And when we started testing disks at SyQuest, we would find one side is good, the other one has, you know, thousands of defects. And we had no clue how to really solve that. And we really had to struggle through cleaning machines, and doing shields. And eventually of course no one really could live with one-sided. We had to go to vertical machines.

Bajorek: So Jim, in the middle of all of this, how did you get connected with film media?

McCoy: Well, it was interesting. I had been a co-founder of Quantum, and had moved on to do smaller drives in a number of different ways. And I was working with Jim Porter doing some consulting for a lot of different folks. And one of the consulting clients was Ampex, Gil Argentina, Ed Badel (must have meant Ed Fleming) and crew. And the mission I had was to go out and assess why the market was not jumping on thin film media, because it was so obvious that it was the right thing to do. Right? Well, it wasn't quite that way. And we ran very much into the inertia that we're just talking about. The oxide media world was well-entrenched. A lot of capacity in place. A lot of engineers comfortable with that technology, and the continuing life of it. And I talked to all of the major disk drive companies at that time. That was '81. Yeah, late '81, I believe. And what I found was engineers that wanted something better than the brown media that they were getting…the oxide media that they were getting at the time. But a general paralysis about making a fundamental step to go away from brown media, and take that big risk to go to thin film media. And Ampex was an outsider supplier to the hard disk drive industry at that time. Okay? So they were having a tough time breaking into the market as a name, if you will, as a known supplier within the hard drive industry. And as I looked around, I saw the media enabled a lot of things that oxide media could not do. And it was one of the key elements that allowed me to start Maxtor. And I started Maxtor in the Spring of ’82, I believe. So I think Sy and I maybe raced to put thin film media into the marketplace. I don’t remember who did it first. But we were able to -- well, we took a lot of risks. Maxtor was a company that was started with eight simultaneous risks, technical risks at a time when the standard wisdom in the industry was, “Never start a new product with more than one risk.” Okay? But I really felt the only way to start a company and really create new value was to take a bunch of big-time risks with technology that I felt was what in those days called through the threshold of viability, but not yet broadly adopted. And thin film media turned out to be very much one of those technologies. We went through some real rough times with thin film media in the early days, and we’ll get into that some more here, I’m sure. But it did allow, I believe, if we were not the first, we were one of the first to go to 1,000 tracks per inch on a five-and-a-quarter inch disk. And we were able to do that with the performance of thin film media that could not be done with oxide media at the time. We had a lot of other problems, but we were able to get the areal density that we needed to really change the marketplace, and indeed create the architecture of all the hard drives that are out there today…was really in that first family of Maxtor products.

Eltouhky: Wasn’t Maxtor, for quite a while, I remember being in meetings where this areal density, as a function of time, of product introduction would be applauded. I think Maxtor was way up there, and almost always had a product that was at the leading edge.

Argentina: They really pushed the ID (inner diameter) of the disk. I mean, they went in much further than you could go with oxide for sure.

McCoy: That gave us total capacity, you’re right. That gave us more capacity. We brought the inner band in, because you IBM guys were all stuck on this new factor, or whatever it was, that would only be this certain ratio of OD to ID...

Argentina: Scaled down from a 14 inch disk.

McCoy: Yeah, exactly. I mean, it was really tremendous group think at that time. And we said, “Why not go in further?” You know, and Gil and Ed said, “Why not go in further?” And so we did. And I think that picked us up, oh, 10 or 15 percent additional capacity per surface, something like that. The OD is a lot more valuable real estate than the ID. But it was still important to use it, and we did, and the industry made that a standard. But the areal density overall, the BPI times TPI, you’re right, for that first 10/12 years that I was at Maxtor, we did push the areal density very hard, and thin film media was a very, very key part of that. The existing players, IBM being dominant in setting the areal density track, was too much driven by marketing. By their internal -- the bundled reality of the IBM world in those days, where there was so little competition for disk drives that went on to IBM big mainframe computers. They controlled their environment so much that the pace of development of disk technology could literally be paced by the marketing side, the computer side. And the OEM marketplace was not that way. We could move as fast as we could to supply other markets. Mini-computer, desktop, personal PC world. And that's where taking the jump into thin film media first really reaped a benefit.

Eltouhky: But, correct me if I'm wrong. Didn't you folks in the drive business, thin film disk drives, the initial ones, did you use thin film heads also or?

Argentina: No.

Eltouhky: That was not developed at that time.

Argentina: We tried.

McCoy: Only IBM. We tried. <laughs>

Eltouhky: So the drive business didn't have a full product at that time?

Weiss: No.

Bajorek: Jim, can you remember -- it would be interesting just to capture, while you were focused on it, the areal density of those early products, 1,000 track per inch, but about 20,000 bits per inch, or 20 megabits per square inch, right?

Weiss: I'll tell you, a 3380 in 1979 was 801 TPI, 15K BPI. So 12 megabits per square inch. So you had to be at least 20/25 percent above that.

Jim McCoy: Yeah. It's tough to remember these numbers 25 years later that we are...

Atef Eltouhky: ...still in the business...

Joel Weiss: Yeah, I'm still there. <laughter>

Bajorek: I just thought it would be interesting to capture it because, although in those days, the exact leverage, right, was debatable, because you firmly believed that the film disk was very important. Today, the film -- we wouldn't be where we are today with film disks. That's clear, right? And today, our latest

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areal densities are 130 gigabits. We'll complete the introductions with you. How did you get into this world of film media?

Francis King: This is Francis King. I left IBM about 1978, and joined DataPoint. DataPoint at that time bought the DataDisc, which had a facility in Sunnyvale, had disk making and head making facilities. So I decided to join that, to utilize that equipment. And they asked me to design a basic subsystem for the DataPoint. Basically a hard drive and the tape drive combined with the subsystem. So I designed both. And at that time since they have the plating disk facility, also the density I wanted to achieve to make a disk drive, either higher track density, comparatively to the brown disk, plus the growth opportunity, a chance to grow. So I designed a disk -- basically that's what it looked like (shows disk sample). It's a five-and-a-quarter inch, but with a one inch ID. I chose the one inch ID because I wanted to use the inner band as much as we can. Actually this kind of turned out a bad decision, because of the one inch ID, the DC motor is hard to make. So anyway, that's hindsight. That turned -- in order to get the recording density at that time, at first let's try 500 TPI, about 20k BPI. And in order to do that, I need to fly the head low. And we tried different disks, thin film disks just not working. 'Because very easy to crash. When flying low, very easy to crash. That design had to…then Lee Dawson came in, and I know probably some of you remember Lee Dawson, he came from IBM, too. And he said, "Francis, there's a DataDisc using a carbon overcoated disk. And they're selling to the military. And it looks good, so why don't you try that?" So I took a look and looks good. The only problem is the carbon overcoat I have has a titanium undercoat, above the magnetics, so made the flying height really high, because titanium about half micron there (meant to say half to five microinches). So really I cannot achieve the recording density. So then DataPoint engaged Duane Secret, formerly at Memorex, the chemist. And so we can try -- at that time we know it's a sputtering process. But how do we put the carbon on there and stay, and also keep it thin? So we tried different processes. Finally Duane Secrest came out and said "Well, I can do sputter etching, with sputter etching I do not need this undercoat." And that way it eliminated the undercoat process. We tried so many undercoat processes when we had to reduce the thickness. So with that sputter etching process, we basically can put a carbon on there and stayed. Now I optimized the thickness of the carbon. Make sure it's thin enough, still have the property we needed. And that's how I got into this carbon disk work.

Weiss: How thick was it at the time? How thick was the carbon?

King: About 6 micro-inches.

McCoy: So the carbon was sputtered, but the magnetics underneath were plated. Is that right?

King: Yeah, correct. Actually we tried Alar disk, too. It looks good, but it doesn't stay, the problem. And the wear resistance, because we were flying so low, even Alar cannot make it, cannot stay long enough. So finally got this process working. I could make it producible, repeatable, controllable. And that's how we basically made it happen at DataPoint. So that's how we evolved this.

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Bajorek: So to just clarify, the basic magnetics were plated.

King: Correct.

Bajorek: Then you sputter etched that surface.

King: Right.

Bajorek: Then sputter on top of that freshly sputter etched surface a carbon film.

King: Right.

Bajorek: Did you sputter etch it in the same tool as you did?

King: Same tool, just same process. Actually the carbon went from 2 micro inches to 6 micro inches depending on the process.

Eltouhky: What kind of machine was that?

King: It's from Materials Science.

Eltouhky: MRC.

King: MRC. We basically leased from them. Doing all the process. Once we verified process, then we bought one.

Eltouhky: It's really important to point out that coming from the sputtering side of the thin film disk that the sputtered disk really stood on the shoulder of the plated disk. The technology that we developed, most of us came either through technology of sputtering itself or some magnetic background, but no one really knew literally anything about the substrates, nickel phos, carbon overcoat. All these things. And of course, lubrication was a whole different discipline. And we just thought, okay, if you get a cobalt alloy that's -- we were looking at the magnetics. This was the focus. But it turned out that this was probably trivial compared to the industrial strength issues that you really had to overcome. You know, the nickel phos, the development of that by the plating people was absolutely part and parcel of how the industry found its footing. We just came and really latched on to what existed. So the work that Francis did and Gil done at Ampex did there was absolutely essential to our taking off as an industry.

Weiss: Was Ampex the creator of the nickel-phos substrate?

Argentina: I don't think so.

McCoy: That goes back to, I believe Bryant, Bryant Computer, which I hope gets tracked by this museum. They did some interesting things in disks way back in the '60s for sure, maybe earlier.

Argentina: Jack McLaughlin worked there.

McCoy: Yes, yeah. And what ever happened to DataDisc?

King: Was basically bought by the DataPoint.

McCoy: And then what happened to DataPoint?

Weiss: They're still in business actually.

King: DataPoint is still in the business, in the systems business. What happened is after making disk drives, and actually we sold quite a few systems, then DataPoint said -- well, and the Seagate came up -- said, "Well, we bought from Seagate, the drive, it's cheaper than we make ourselves." So they don't see themselves as an OEM business to sell drives. So basically they get out of the disk drive business. And that time after that I joined Syed at SyQuest.

Bajorek: Francis, fascinating. But apparently, correct me if I'm wrong, you say that DataDisc was making a carbon over-coated disk for military application which used this titanium...

King: Sub-coat.

Bajorek: Underlayer between the medium, data storage layer and the carbon. Was that a plated disk also?

King: Yes, plated disk, plated magnetics.

Bajorek: And what size of disk was that for the military?

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King: 12 inch.

Bajorek: 12 inch, so it was just a specialized...

King: Military. Yes, a drum they put on airplane.

Bajorek: Drum or disk?

King: Disk they put on airplane.

Bajorek: Interesting. Do you recall by any chance, who did the carbon work, development? Even though it was a laminated structure, right? Did you do it at DataDisc?

King: No, DataDisc at that time -- I forgot the name-- the two people actually. Actually, DataPoint tried to file the patent on that, their process. But I think the poorly written descriptions, so basically other people already had prior art, so it did get rejected. I think Nelson and Vye something -- forgot the name -- the two people did that. But they left. By the time when I joined there, they left already. And actually the military drive was a tripod head, also started with the plated disk first. The time I joined them, probably half months-- half a year before they start to put this carbon disk in there. Looks good. And so with that they start replacing all the plated disks with carbon overcoated disks. But density is so kind of low, and it's a fixed head. And that's where the basic whole thing started. Actually Lee Dawson basically said, "Well, why don't you use that?"

Bajorek: That's a fascinating detail, because I think, correct me if I'm wrong, it seems to me without that carbon overcoat, film disks would not have made it.

Group: <agrees>

Bajorek: That's the key. The magnetics, right, the substrate -- equally important was, without a carbon overcoat I think we would not be around this table.

Eltouhky: I remember at IBM original -- the natural selection of an overcoat would not have been carbon, because we were trying. We would try titanium carbide, which was a famous overcoat for watches, and tantalum oxide, these types of things were really what one would gravitate to experiment with. So carbon was not apparently obvious choice. And so, obviously, this was a very great thing that we found that technology to inherit.

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King: Right, so that's why I was so happy that worked, and so I made the drive that way.

Argentina: I wonder how many people at the table know that Hoya shipped many millions of 2.5 inch glass disks using a spun-on glass overcoat?

Weiss: Oh, yes.

Argentina: Where we relied on colloidal silica in the coating, to provide the texture. Which at that time texture was only needed for stiction.

Bajorek: Stiction, prevention, yeah.

Argentina: But we shipped many millions of those, mostly to Toshiba.

McCoy: Well, I'll tell a tale relating to the transition from plated media to sputtered media and carbon overcoated media. Having started Maxtor with Ampex Alar plated disks, okay? We had shipped thousands. And the number that comes to mind is something in the range of 10,000 drives, which was oh, a year-and-a-half -- no, no, no. Something in the range of a year after we began shipments. And we -- bottom line, is we realized that the media was not holding up. Start-stop testing in those days was a black art, and we landed on the disks as we were talking about. And Ampex did a fine job of start-stop testing, except the way they start-stop tested was they had one of these washing machine motors that spun up the disk from static to full RPM in about .3 milliseconds. So that head just launched.

Argentina: You didn't use that kind of motor?

McCoy: <laughs> No, we didn't! We used what we could afford.

Bajorek: Minor detail, huh?

McCoy: Yeah, minor detail made a little difference in the drag time of the head on the disk. And make a long story short, Maxtor ended up recalling every single one of those drives, 10,000 drives, okay? And it was done very delicately, very carefully in those days, and I'm not sure how even broadly known that is today.

Eltouhky: This was before the days of Sarbanes-Oxley, I guess.

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McCoy: We were not a public company, okay? We were an OEM supplier only. We were making a superior product. I mean, we were literally supplying three, four, five times the capacity of anybody else that was in the marketplace at that time. So we were enabling the first generation of engineering workstations that without the high capacity, the 140-190 megabytes going on to 380, I think we were still at 190 megabytes at that time. They literally couldn't make these engineering workstations work, period, okay? And it was a very contained marketplace where field engineers supporting product was very normal. So we realized the problem was the durability of the media and the overcoat, which was an organic overcoat at the time that was -- we called it chicken fat, when I've been learning here is...

Argentina: Lead stearate.

McCoy: Lead stearate, but it was very exotic art at that point, I'll tell ya guys! You know, it was very tightly protected intellectual property. And we were scrambling. I mean, Maxtor was dead. We were literally dead in the water, because we didn't have any other media to go with, and Ampex, Ed and Gil, "Gee, we don't know what to do beyond this," and I mean, we were standing there in deep trouble. And I believe it was FCI domain that was the company that was just starting to make sputtered media, sputtered magnetics, with-- I think it was carbon overcoat.

Weiss: Yes, it was carbon, but even before that, at Domain, it was plated media with a sputtered overcoat. We went to that combination -- because of this man (points to Syed) we went to sputtered carbon overcoat, on the plated magnetic media, similar to what was just described.

Argentina: Did Domain ever make sputtered media in production?

Weiss: We did in small quantities, but had tribology issues. Actually,0 we made plated media for the XT8000 (with sputtered carbon overcoat), but I think that was later.

McCoy: Much later.

Weiss: Much later. That was plated, and then carbon overcoated, and then lubricated with the same type of fluids that are used really today. You know, the Fomblin type materials. But the design of the production sputter tool at Domain, which they called the Mint machine, we called it the Mint machine, became the basis for the Conner buy-out after Domain went bankrupt. And it's still in use today, in Milpitas generating over ten million disks a quarter.

McCoy: I think through the course of this story, we went and we got new disks, new technology from Domain, and we brought every drive back in a kind of a conveyor mode, okay? And we exchanged the disks in every drive. And made a step in technology in the coating and got the disks back out into the field, and the rest is history. The company went on to do just fine. But Sy, I don't know if you, what kind of challenges you had with that early lubricant on the Ampex media. Did you ever have that kind of...

Iftikar: No, I was fortunate in the sense. I did not go with the Alar that Ampex had. I insisted on carbon overcoat, and I also insisted on a special lubricant. At that time it was a Fomblin AM2001, it has this futuristic name, at that time, 2001. And it turns out today that ZDol is also one of the Fomblin families. But when we did put carbon overcoat and then the AM2001 lubricant, we never had those problems. And I do recall, Jim, that Maxtor had to recall the disk, because my venture people, investors were really scared. And so they asked me, "You know, Syed, do you have to recall the disks?" And we said, "Thank god, no. Because our disks don't have the same problems that Alar had." But going back to the sputtering process as Atef was saying, when Ampex refused to sputter the carbon, we had to bring the process in-house. And after looking at what Francis had shown me, we went and got a CPA machine, and it wasn't easy. Of course, because when you first sputtered it, the color of the disk started from dark almost dark blue to dark black to brown. At the edges it was brown. And we had to put a lot of shielding. We had to go and talk to people like Atef, and people who could give us advice, and it took us forever. And you gotta realize that we are hard drive people. We didn't know anything about sputtering carbon on disks. We were users. But we were forced to try to figure out a way to do that. Then slowly as time went on with the help of others, we were able to sputter one side. Because the CPA machine that we bought was a horizontal machine, it sputtered one side. So we turned the disk around to sputter the other side; all hell broke loose, and we lost a lot of disks. You know, you wonder how the VCs stayed with us. We would scrap at times 20,000. Jim was talking about shipping 20,000 disks? We would scrap 20,000 disks that after we sputtered, we found they were no good. Okay, it was terrible. It was really terrible. But once the drive went into the field, at least from the problems that other people had with Alar, we did not have them.

Bajorek: Now who were you getting the basic plated disks from before you did? You were not plating your disks.

Iftikar: Yes, as a matter of fact, I hired a chemist from Ampex -- his name was Marvin something.

Argentina: Garrison.

Iftikar: Marvin Garrison. And so we set up our own plating tanks, after we visited that area, and we tried to figure out how to plate the disks. And it's interesting, just moving the person to a different facility did not bring the magic with him. <laughter> Okay?

Argentina: I kept the magic. <laughter>

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Iftikar: So Gil Argentina kept the magic! After trying for a year, and investing a lot of money, we had to close it down, and thank God for us, Ampex did give us the disks, we had to overcoat. Then Domain came in, and then Atef came in, and a lot of people started to come in.

Bajorek: Fascinating.

Argentina: Actually, another little known fact is that Hoya supplied media to Syed. We supplied the 3.9 inch disk with the carbon overcoat and lube.

Iftikar: Yes.

Bajorek: On a glass...

Argentina: No, it was on aluminum. That's how our guys got the experience of making disks for the first time.

Iftikar: Well, actually...

McCoy: That was through the Ampex purchase or we...

Argentina: All we used of the Ampex facility at that point was the Leybold Hereaus ZV1200 sputter machine. Big pass-by machine that Ampex bought for putting carbon, but it was a day late, and dollar short.

Bajorek: Interesting. So this is a very perhaps interesting point to try to just sharpen our thoughts as to where it got started. I think there were maybe 20 announced startups to go do plated media. In my notes, I managed to find maybe only three shipped some volumes, Ampex by far the most.

Argentina: No, I think Domain shipped the most.

Weiss: Domain was the first.

Bajorek: That's right, Domain, Ampex. But then it collapsed, right? And it collapsed partly because there was no carbon? I mean, you went for carbon, right?

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Argentina: We went for carbon, right.

Bajorek: Ampex went for carbon, too late.

Argentina: Said yes, but had other problems with the disks. You know, and exfoliation of the film and stuff like that that were struggling with it. Probably would have been solved with carbon overcoating, but the original team lost control over the engineering direction. And I think in the case of Domain had a corrosion issue with MiniScribe that killed Domain, right?

Weiss: Well, I think the thing that killed Domain was really financial. Mini-Scribe thought they had a huge contract from IBM for drives, and you can go through and read the court case, but...

McCoy: The bricks.

Weiss: Yeah, they came into Domain, I think it was in ’88, and they said, “You guys are not growing business fast enough. Here’s some money, grow faster.” So we took that money and leveraged it, and got a whole bunch of lease lines, and then they came in, I think, around Christmas time of ’88, and they said, “You know, we messed up. We don’t have that business.” The IBM business vanished. And we were left holding the bag. You know, lease line-- couldn’t pay the lease lines. Lease lines, all the lease money became due, and within 12 months we’re out of business. So in 1987, we were *Inc. Magazine’s* fifth fastest growing company; and in 1989, we closed the doors. <laughs>

Eltouhky: Fastest demise, huh?

Weiss: Probably the fastest shrinking company.

Bajorek: But it’s still not clear to me, because Gil, you’re saying the plated media had exfoliation independent of lubricant or overcoat?

Argentina: No, I think it was related. But I can...

Bajorek: But maybe it wasn’t recognized that the carbon would have fixed the problem? Is that...

Argentina: I think so. I think what happened was the team that knew anything about media was pushed out of the picture, and a whole new team came in, and they were trying to “save the business,” and weren’t really well-equipped to do that experientially.

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Eltouhky: But Gil, it may be instructive to shed some light on the hesitation of the business decision of putting carbon overcoat -- I mean, obviously everybody was demanding carbon. And Ampex just could not really move in that direction. Just excruciating for you, as a marketing man, not to have support inside.

Argentina: It was, but the thing that hurt us the most was Varian's decision to stop selling their sputter machine, because that's the machine we picked. And when we got it approved -- we were going to buy one machine, we got it approved to do, we informed the Varian people, and they told us that based on Akashic's problems using the machine, they were going to stop selling the machine for a while until they could resolve some of the problems. I guess they were threatened by the Akashic investors to do something. So then we had to go back after convincing the management, who knew nothing about sputter machines, that this was the perfect machine. We had to go back and convince them, "Oh, that's the perfect sputter machine. There's ZV1200...," who looks like a boxcar, much bigger than the Varian machine, and not designed for making media, that that was the perfect machine. So it added another, literally 14 or 16 months to that process of converting over.

Eltouhky: That's what business <inaudible>.

Argentina: that's right.

Bajorek: And in your case, Joel, you're saying that at Domain, there was a plated disk with a carbon overcoat, was quite successful, but even that experienced field problems that required...

Weiss: There was constant tribology and corrosion issues with that one as well. I don't know that we ever -- we couldn't possibly pass the corrosion tests that we have today. Don't really recall what the tests were in those days, but obviously, we got through Syed's and Maxtor's and MiniScribe's and everybody else's tests. But the yields were terrible, and control of the interface, and control of the lube were really problematic. The goal actually of Domain was to build -- to be kind of like an Ampex, Alar, a "me too" company, to get us rolling, to pay the light bills, and then immediately switch over to sputtering, like Tri-Media and others. And that conversion over to sputtering took much longer than was anticipated, for some of the reasons that have already been talked about. You know, Varian was our selected machine also, and they had troubles early on. They had VDP1000 was an issue. So it took quite a while before we were able to do anything reasonable with sputtering.

Bajorek: Good, well, I apologize for probing into it, but I thought it was such a march up a hill, right, with plated media. I mean, such an enormous effort. I remember visiting the Ampex Alar disk factory during one of the conferences in San Jose, and that was a very impressive operation, right? And yet, then to see all of that collapse later on was not pleasant, and I was just trying to make sure we understood and had the unanimity on what caused that. And I think what you're all saying is that the plated media per se had weaknesses in terms of tribology, and susceptibility of corrosion. Just carbon itself may not have been sufficient to overcome those. But in trying to react to all of that, the delays in getting carbon mastered and scaled up, were such that by the time you were ready to do that, better media had evolved. Namely, the all-sputtered media. Is that how...

Argentina: I think, too, the market was pretty soft at that point in time, so there was sufficient...

Bajorek: It wasn't quite yet ready,,

Argentina: There wasn't sufficient demand to pull Ampex back into the business. You know, customers, or guys like Jim, helped us a lot. And people just went away and didn't want to help us anymore, because their demand was low.

Bajorek: By the way, some of you mentioned it, but I counted over 60-- at the beginning of our era -- over 60 film disk operations.

Eltouhky: Close to that.

Bajorek: Yeah, roughly 20 went up the plating hill. About 30 independents went up after the sputtered world, and about 10 captives, right? Because you know, Control Data and Digital were -- which is over 60. And today we have less than 10 between the independents and the captives, right? It's extraordinary what sorting out occurred here, and..

Eltouhky: It was very surprising, you know, when it kind of dawned on everybody that we need to go from oxide to thin film. So everybody basically thought, "We've got to get it started." And computer demand was insatiable. And you know, I remember when we got funded. We raised a total of -- grand total of 1.5 million dollars. And we got equipment lease guarantees for another million dollars. So compared to everybody else-- the 60 companies that started -- we were probably, you know, the company not to bet on. 'Because we really had very little. When you really listen to what we're all saying here, and see how each, you know, step of the evolution can lead to, you know, either success or failure, I mean, we're all talking about here about Varian sputtering machines, and how they had a horrible time with one of the great stars, Akashic was a great company, and they had a lot of good people, and they made that bet, and that was the wrong bet at the time. No one knew it in advance, but it just didn't pan out. The machine had stability problems and disks dropping, and so on. We made a bet on CPA. We were actually next door to them, so it was -- and we put a CPA machine and then the one side, up and down, difference was just insurmountable, and we had to go get something else at that point. You got the carbon overcoat and its, you know, mutations, and then the lubricant. And all these things, I mean, every single one of them for the users, you know, in using Alar disks and having to bring them back and change them painstakingly one-on-one, and I'm sure tremendous costs, and if you sit down and say, "I'm going to start a company in that business," you would say, "Are you crazy?" I mean, a rational decision would be...

Bajorek: No.

Eltouhky: "These are really insurmountable problems." You really don't know how to tell anybody honestly that you can put a business together. But all of us, one way or the other, were able to transcend some of these issues and...

Bajorek: And survive.

Eltouhky: And survive and make it happen.

Bajorek: Great story.

Argentina: Until about 1985, sputtering really wasn't appropriate, I mean, because of all the equipment supply issues and the like. I mean, at Tri-Media we bought a machine from a company in Southern California.

Eltouhky: We took a detour, yeah, we made a bet on new technology, and designed our own machine. So we went to a sputter house, and we worked with them on the best ideas we could put together. And we worked with them for nine months or something, and they just couldn't make it. They couldn't make the machine. And we almost lost the company in the process.

Argentina: And when Komag got their first Ulvac machines, they didn't work for like six months. Ulvac was living there. And then CyberDisk down in Southern California, they bought a gigantic Ulvac machine, they could never get it to work. I think Seagate ended up buying it from Kaitek, Kaitek Media on Fortune Drive.

Weiss: Something like that, yeah.

Argentina: So this transition was very painful. And so when Syed came to Ampex in 1981 or '82 and asked for a sputter overcoat, it was like, you know, asking for the impossible.

Bajorek: Amazing. So just come back to this thing's getting born. And so I just want to revisit our consensus, or your consensus for the rationale for introducing film media, instead of continuing to do it the particulate, Jim, you believe that film media were critical to achieve capacities or products that you otherwise couldn't have achieved. Was that generally what everybody was driven by? Or was it that some users wanted film media because it was the latest fashion to have in drives?

McCoy: Fashion never drove it. There was at least one product attempt that tried to put a thin film head on oxide media out of "fashion" rather than "function." And that died an almost instant death. Do you remember "thin is in," at Seagate, when it was still Shugart Technology? Finis tried that one, and it went absolutely nowhere. Nobody cared what the technology was inside the box, it was the megabytes that you got per dollar is what counted. And the simple reality in the early '80s was you could get more areal density with metal media than you could with oxide media.

Iftikar: I think that was the driving factor. You could get higher capacity.

Bajorek: Yeah…

Iftikar: But for us, we had a second reason. We were open to contaminants. So we wanted a cartridge drive that was harder.

Bajorek: More robust.

Iftikar: More robust than an oxide media could provide us. So SyQuest absolutely had to have the metal film disk.

Argentina: And I think in '81-'82 timeframe, IMI, MiniScribe and Seagate, all three were shipping to IBM for the PCXT. And IMI and MiniScribe were using thin film plated disks from Ampex. And Seagate, of course, was using Dysan's oxide media. So from a customer point of view, there was virtually no difference in those drives. And the only one that survived long-term was Seagate. The other guys were all thrown under the bus, and Seagate ended up with all the business.

Bajorek: But in spite of that, overall basically, you all agree that the drive was enablement of better products, higher capacities, more robust products.

Iftikar: More robust.

Argentina: For some guys. I think for Maxtor and SyQuest that was true. I never was really convinced that Vertex, basically, Vertex' drive, did it require thin film media? Could they have used particulate media?

McCoy: It wasn't a competitive drive, because it was an oxide media drive. That's why it was not competitive, because they couldn't get the areal density enough to survive, got absorbed into Priam, and Priam made it a very short time beyond that. Because they didn't make the thin film transition.

Bajorek: I think that's a very important detail in my mind, at least, an important detail, for us to capture. I think we're about two or three minutes away from ending this tape, we will stay here, and then we'll pick up right after this. <tape change> So the world of sputter media is now rapidly evolving, right? So just revisit exactly your best recollections of how that happened. The plated media ran into trouble. We first started sputtering overcoats. We had done research on sputtered magnetic layers and undercoats and so on. Maybe the question to ask, who came out with it first, the all sputtered disks among us?

Weiss: Hm, good question.

Eltouhky: TriMedia, we shipped, I don't know if we were the first.

Bajorek: But very close to the first.

Eltouhky: Very close to the first. I think we shipped in June/July, '84. Somewhere there. Maybe even some samples.

Iftikar: Yeah, I think you are the first ones.

Eltouhky: March/April '84. So we probably -- I don't know who else was in that. LinData or-- was a bit behind us, I think, maybe two or three months behind us at the time. But they weren't far away. I think Komag was not shipping at that point.

Argentina: LinData was behind TriMedia, right?

Eltouhky: I believe so. Yeah, I believe LinData started shipping maybe three or four months after we did.

Argentina: Komag might have been right after Lin.

Eltouhky: Yeah, might be somewhere in the end of '84, I think, when we started shipping volume.

Weiss: Akashic was in there also. I don't know when Akashic started. I think that might have been later.

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Bajorek:: First note that I have here is that Komag may have shipped the first disks in July of '84, to Vertex and Maxtor.

Eltouhky: We beat them by one month.

Bajorek: Shipped in June.

Eltouhky: Good. We beat them by one month.

Iftikar: I think you're the first ones.

Eltouhky: We had the last laugh <laughter>

Bajorek: Those original sputtered, all-sputtered media were oriented already, or were these still isotropic media? When did we purposefully -- maybe you, Atef -- have a good recollection to start us here. How did oriented media come about? And when they were commercialized first. Do you recall that?

Eltouhky: Yeah, orientation was actually-- at the very beginning was accidental. Was actually detrimental, was not intended. Because the sputter machine had the built-in directional deposition. It was not a round target, and the disk was running longitudinally, so you ended actually with the c-axis of the cobalt being preferentially oriented in different directions. So our first challenge was how to overcome that, how to make it isotropic. Because if you got around the disk, you would actually get an amplitude modulation. You would see a sine wave around the disk. And that was not something these guys could live with. So we ended up actually with a couple of patents on baffles, and various sputter targets to actually attempt to limit the angle of incidence. Because we actually pinned the reason for the angle of incidents for creating that undesired direction. But we also, in the course of doing that research, we realized that, "Well, if orientation is so important, that it can help us, maybe we can make a bet, and actually use it to our advantage." So we found out that texture, which I think Ampex was doing a rose petal or something. So it was not so circumferential, so we discovered, among others, I'm sure at about the same time, that texture, circumferential texture was a really good way to orient the initial cobalt nucleation, so that the c-axis would lie along the circumferential direction, rather than opposed to it. And that gave you higher amplitude and better sign-to-noise. So we were working very hard with a lot of the people. This was technology that was really new to us. We just had this -- again, another black sort of magic, that how do you get the exact texture depth frequency of texture and orientation to give you just the right magnetic orientation. So it came about in a bit-by-bit just like most of the developments. It was very slow in coming. But it was adopted way back in '84. And it's really interesting how this also ties up with some of the peripheral issues in the industry that came about. The patent litigation that came between Hedgecoth, based on Hedgecoth patent of using cobalt chrome. And how they ended up actually taking a lot of money from a lot of companies based on that patent. Which I think was late '84.

And was actually way after sputtered disks with cobalt chrome was shipped already. But the Patent Office gave them the patent, and they had a license to go and collect some money from companies. And I was fortunate enough to actually help some of the defendants in these cases, and I made some money on the side. So <laughs> I didn't get patents for myself, but I made some money defending others. So it was a good development at that time for that.

Bajorek: Just to clarify, do you think the actual, the mastery of circumferential texture where you now put purposefully oriented media, it means it happened at about '84 or after?

Eltouhky: Late '84. The initial disks we really didn't know or care about texture. But you know, we went through it for a month-- by late '84, November/December '84.

Bajorek: Still at TriMedia.

Eltouhky: Yeah, we started texturing the disks.

Bajorek: And now was getting the purposeful orientation then. Systematically. That's very good. I suspected that the genesis of that may have, right, originated. What's your recollection, Joel? When did you...

Weiss: Well, if you go back to film-- just call them film, don't call them sputtered, but film oriented media, you can go all the way back into the '70s, because IBM was doing that with evaporation. Angle of incidence evaporation. Of course, it's much easier to do an angle of incidence evaporation when you've got something that is this big rather than something that's that big. But there was really no way to use that commercially in small disks. But I agree with Atef, I think that it's probably in that same timeframe. You know, IBM and others used to circumferentially buff even the particulate disks. And then even the substrates for metal disks, because you didn't want to have radial scratches left from the polishing marks. Those would lead to missing bits. So there was always this desire to create a circumferential pattern. Didn't really know that it would create an orientation ratio in cobalt alloys until much later. But orientation was something I think the magneticians really understood that was something that was very desirable to get more signal-to-noise.

Bajorek: Yeah, and I was trying to sharpen the, its adoption and how it permeated our whole industry, because even today's disks are all purposefully oriented.

Weiss: Longitudinal.

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Bajorek: Longitudinal. The perpendicular ones are purposefully oriented, but naturally oriented perpendicular. <laughter> They don't need texture, right?

Weiss: They don't need texture.

Bajorek: But so fascinating then, in '84, early on, we recognized that value, and I think it then propagated all these designs throughout the whole industry. Now separate from texture...

Eltouhky: I guess Komag was isotropic for a long time.

Bajorek: Yeah, till the late '90s.

Eltouhky: Yeah.

Bajorek: And I remember IBM was isotropic. You know? 'Cause later on I was involved with their early film disk programs, and they also were isotropic. So for a long time, several paths went isotropic. But orientation in the end was too important to leave off the table. Was about a 3dB difference in signal-to-noise ratio.

McCoy: That's a lot.

Bajorek: And 3dB was a lot to give up cavalierly, right?

Weiss: The reasons was that -- at least the thought process was that radially if you have a lower coercivity, which you would have, or lower MRT, you'd have a -- you'd have to have side-writing, side-fringing so you couldn't get TPI fringing, so you couldn't get TPI. But I think they neglected the linear density benefits.

Weiss: The linear density domain.

Bajorek: Now I thought also it would be good to try to record exactly how did we evolve the various textures? You know, we talked a little bit about texture for orientation here, but I think the initial drive for texture was to avoid stiction, right? And then we went from mechanical texture, to laser texture to zone texture. Can you help recall your early associations with those?

Weiss: Actually, I was at Akashic and we had a team of folks in Japan working in a little R&D center, for Kubota was the parent of Akashic, and the challenge as given to them to come up with a way to make the CSS, the start-stop zone low in friction-stiction, but make the data zone good in terms of flyability, and orientation. So they came up with a team that I helped manage. They came up with a way to do a zone texture. A rougher ID, and a smoother near ID, MD and OD. And it actually worked quite a bit. Actually sold disks to Seagate at the time that were -- had all the benefits, the flyability, the orientation ratio of the data surface, and good properties for good reliability, CSS at the ID. But there was a group actually in Seagate, and IBM working on laser texture. And my earliest recollection of that was that Rajiv Ranjan actually ended up patenting it. And I think it was probably first actually used as a product at IBM later.

Bajorek: And your recollection, I think, is correct. The time at Akashic, can you pinpoint the time you were at Akashic and you saw the evolution of the zone texture?

Weiss: Well, I started there in '91 with just normal texture. I think probably by '93 we had a zone texture process.

Bajorek: Just thought it would be good to capture that. And you're right, I think Seagate, Rajiv invented -- was the author of the patent, right?

Weiss: Yes.

Bajorek: But I think IBM was the first one to commercialize it.

Weiss: Commercialize it, yes.

Bajorek: Then the rest of us followed, I think.

Weiss: Right.

Bajorek: And then we also, I think, however, you talked about a texture, Gil, the glass disks. Hoya introduced a texture on top of the disk. The colloidal silica overcoat, right? But we also then on glass did a sputter texture, right? Gil remembers that, right?

Weiss: There was some Japanese companies -- actually there was a Japanese university -- I don't remember which one, whether it was Tohoku or somebody else, that was doing a sputtered on texture. I think it was a soft metal of antimony something or other that created little bumps to give you texture.

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Bajorek: The Italian glass wasn't quite as easy to texture mechanically as nickel phosphorus on aluminum. So I think part of the glass world ended up dealing with this stiction problem the way you did at Hoya, right? Part of it by sputtering this layer.

McCoy: Sputtering bumps.

Bajorek: That caused it … And then putting the...

McCoy: So the universities did it first. And then Fuji, Fuji Denki actually adopted it, and they actually made media for a while with sputtered on texture.

Argentina: I think in Hoya's case, we benefited by IBM's introduction of two-and-a-half inch drives with a ramp load. So that took, basically, there was no texture on two-and-a-half inch disks up to 30 gigabytes per platter. Beyond that required a texture just to get the signal performance needed for the higher areal density. But to this day, most all mobile drives use ramp load.

Bajorek: I heard your first mobile drives didn't. They used start-stop.

Argentina: IBM's first mobile drives?

Bajorek: Yes. And I think then they -- that's why they needed the texture and then they went away -- once ramp load was introduced, the textured glass was no longer necessary. In all of these trials and tribulations, who supplied the substrates to you guys? Was getting substrates a cakewalk?

McCoy: Never been a cakewalk. <laughter>

Weiss: Still the most expensive part of the disk.

Eltouhky: Even 20 years later, you can't look back and forget all the horrors. I mean, Stolle Industries was doing that aluminum.

McCoy: Stolle in Ohio.

Argentina: I think TriMedia was the beta site for Toyo Kohan, who's one of the biggest substrate makers in the world today, and they started shipping substrates to us. In fact, there's a funny story about they were using a mechanical micrometer for measuring the thickness, was putting a little dent on specific

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locations. <laughs> So they didn't know anything about the business, basically, they just saw an opportunity. But today, they're an A-1 company, they're just a great aluminum substrate manufacturer. But also I remember at TriMedia we had I don't know how many vendors. I mean, just to get what needed, as many as four or five substrate vendors.

Eltouhky: You really had to encourage everybody to get in the substrate business, and get them Pos, like Syed said, you know, a million disks a month. That was the magic number.

Bajorek: Now were you buying just aluminum blanks, or were you buying ground substrates, or were there already coated with nickel phosphorus and polished? How were...

Eltouhky: At the beginning we were buying finished nickel.

Argentina: Ready to texture.

Eltouhky: Ready to texture.

Bajorek: So they were polished, they were an aluminum core, plated with nickel phosphorus, polished. That's what you purchased, and you just textured.

Eltouhky: And then for a while we also did polishing of nickel phosphorus, because some vendors didn't have a lot of capacity, so we had machines and we were actually polishing it in house for a while. I remember one of the episodes in early '85, we were actually going to be acquired in a few months. I guess late '85. And at Fremont, the local government came by and said, "Your polluting the Bay. Do you have a license to polish nickel?" And we had no idea! We just, "You mean we need a license for this?" We weren't really in the business of actually doing plating. We were just polishing.

Bajorek: Polishing, yes.

Eltouhky: And they analyzed something, and they found some heavy metal, and they said, "You need a license, so they shut us down." And we were actually going to lose our contracts, and it was just a-- we had to get <laughs> tanks outside to...

Bajorek: To collect the slurry.

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Eltouhky: Yeah, the slurry. And tanks would actually be shipped to a dump site legally. And we were in business. We were down for 24 -- 48 hours or something like that. But it was another potential end to the company. Just how long would it take to get a license from Fremont.

Bajorek: Amazing.

Eltouhky: So it was very scary.

Weiss: And Domain was buying aluminum blanks and turning them and grinding them, and etching them, and plating, of course. But I mean, there's been, like you said, if you could buy them at just the stamped out blank level, you know, many different steps the way that -- there was almost as many start-up substrate companies probably over those years, the '80s and even into the early '90s, looking for replacements for aluminum as there were media startups. There was probably at least 30 substrate companies, if you include glass and aluminum. And then there was all the other exotics from silicon carbide to boron carbide to polymers...

Argentina: Ultem.

Weiss: Several composites.

McCoy: Remember the Ultem plastics.

Weiss: ...plastics, and I mean, you name it, there's a substrate company that made it. Even today, probably once every few months somebody has a bright new idea. It's like, "Oh, my god, we tried that in 1984. It's not going to work." <laughter>

Bajorek: But I gather, Atef, you made this point earlier, I think, as you guys were talking about it, that the nickel phosphorus as an under-layer really was created for the plated disks? How did we pick nickel phosphorus?

Iftikar: We knew on oxide disks, right, we put the coating directly on aluminum.

Eltouhky: On aluminum. That's what we assumed when we started sputtering. We thought we would use aluminum. And don't know how the plated media chose nickel phos, but I doubt it was developed specifically for that. Nickel phos was used for a number of different things.

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Argentina: It's a way. You know, there's a couple of ways you can plate directly on aluminum. You can put a zincate on the surface, because it's easily oxidizes. You can do that, plus you can put nickel phosphorus on. So I think aluminum plating in general was relying on nickel phosphorus before anybody thought to make a disk that way. And I recall Ampex hired a guy from IBM-- some of you may know him, Iggy Tsu?

Someone: Oh, yeah.

Argentina: That name sound familiar? Yes? And he was -- and they opened a facility in Burlingame, and he was doing nickel phosphorus plating on 24-inch disks for a product called Video File that was the company was interested in. And that was probably in 1964 or '65. So he brought the technology with him from IBM.

McCoy: A good point to interject, one of the early film disk products was an Ampex, well before computers used them. An Ampex instant replay large disk that got an Emmy in what year?

Bajorek: 1964, I think.

McCoy: You said it was Olympics.

Argentina: '64 Olympics, yeah.

McCoy: And you've still got the Emmy!

Argentina: No, I don't. <laughter> The Emmy corroded, I think.

McCoy: Oh, okay.

Argentina: They mounted it in plastic and it corroded.

Bajorek: But that disk probably used a nickel phosphorus, right?

Argentina: It did. And a cobalt phosphorus cobalt.

Bajorek: And it was plated, and the data layer was then plated, right?

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Argentina: Yeah, it was electroless cobalt. Just like the Alar disk was.

Eltouhky: But that technology had to be developed with a whole string of very different specifications for the disk industry. I mean, the nickel phosphorous, nickel that's used in other industries has probably no similarity to what this -- because I mean, you're looking at defects, you're looking at uniformity. You're looking at so many different things that have to come together for the head disk interface, and for the magnetic integrity of the disk. So that's really an unsung hero of the business that no one really -- we just inherited it and we used it. So.

Bajorek: Yeah, and I think in a similar vein, I'm sure

-- and you must know the details much better than I do, the aluminum itself evolved as an alloy, right? Became modified to be able to keep up with the defect requirements, right? You could not tolerate crystallites, nucleation or growth after you ground this aluminum, you wanted it to be very stable, right? So I think the aluminum manufacturers had to develop multi-generations of alloys, which were then coupled to multi-generation refinements of nickel phosphorus plating, right? The electroless plating, and then...

Weiss: Particularly after we went to sputtering, which was a relatively high temperature process, so that you had temperature now, so you have any kind of grain growth or whatever happening that -- or distortions, you know, the heat treatment, the thermal history, and the alloy composition in its purity all played a role in that evolving substrate.

Bajorek: Refinement of that substrate technology. And correct me if I'm wrong. When I last looked at it, which was about two years ago, I think the disk surface finishes on the substrate that we either texture or sputter off, are probably the finest surfaces in mass production. They're even finer than the surfaces of silicon wafers for semiconductor chips. Isn't that correct, in terms of microwaviness, in terms of roughness measuring Ra units, right? Isn't the disk substrate the most advanced substrate made?

Iftikar: Has to be because of the flying height.

Argentina: I don't know about the...

Eltouhky: When you look at -- I think you're trying to get at something that's very significant. When you look at the number of technologies and sciences that have to come together to make that it's just a miracle that it's magnetic, you know, head disk interface, work, it's really mind-boggling. I mean, if somebody would say, I mean, this is equivalent -- somebody said it's equivalent to a 747 flying at, you know...

Weiss: Never liked that analogy. <laughter>

McCoy: Yeah, the inches, yeah.

Weiss: 'Cause I didn't want to be in it.

Eltouhky: It's just a miracle how you could get a disk that smooth, and you don't have the luxury of picking components like a silicon wafer and say, "Okay, I'm gonna get X-number of the chips working." The whole disk has to work. In very tight situations as far as, you know, and the head has to fly a distance, and the stiction factors, the magnetic undercoating, the channel work. I mean, it's just, to me, and obviously, I can be more objective now, because I'm not in the business, but it's really a lot tougher than the semi-conductor industry. The environments just beyond reasonable. But it's really a miracle how we all made it work, and we keep challenging ourselves to tougher and tougher and tougher. I mean, when you look at the improvement that we were talking about in terms of the price per megabyte, or whatever, that price curve, nothing compares to it in my mind. I mean, computers, semiconductors, just over 20/25 years where basically storage is free. It's really very much clear right now. And the industry has really done that. Year in and year out.

Bajorek: And for the last decade roughly, it's been running faster, progressing faster than Moore's Law, which is the law that we sort of followed in the semiconductor world, and indication of how we put this together. Gil, you were not only lucky to be with Ampex at the beginning, but now with Hoya. Could you just summarize for us your view of the evolution of glass substrates, and the significance? Because you were in it with glass from the early beginnings, right? I even learned that Hoya shipped some aluminum disks! I didn't know that.

Argentina: Hoya started in 1986 in San Jose, acquired the Ampex facility, and started developing the glass disk at that time. And it was a real struggle. I mean, there was no real demand for it. Actually, Maxtor had encouraged Hoya to get into the disk business, and encouraged a lot of people, but Hoya took it to heart. And because Hoya makes photo-mask blanks which use very flat glass surfaces with a lot of layers on them, they thought, you know this is gotta be similar technology. So it's something that we can do. But it wasn't until the former co-worker of Jim McCoy's, Jack Schwartz, started a company called Areal Technology, and he decided to use a glass disk for 2.5 inch drive, that Hoya really got the nudge that it needed to turn this disk into a product. And Areal didn't do well as a company, but they did inspire Toshiba to adopt a glass disk. So Toshiba became a big customer, particularly for us who were in San Jose making media. They were our biggest customer for two or three years. And then IBM decided that with the magneto resistive head, which is not velocity dependent as far as signal amplitude from the disk, they could use a small disk, and really get some advantage in the marketplace. So IBM jumped into the mobile storage business, became a huge customer for Hoya, not for media, but for substrates. So the substrate business got a shot in the arm from that IBM introduction of the mobile products. And then from there, it's just been a growth story. I mean, today the company is shipping 11 million media pieces per quarter. Almost 45 million substrates per quarter. Just an unbelievable growth story.

Bajorek: And I think if I'm not mistaken, without a single exception, all drives used in mobile applications, whether its notebook computers, or Apple iPods, are all glass-based.

Argentina: That's correct.

Bajorek: The glass brings to those drives a far superior shock resistance than it's possible to achieve with aluminum.

Argentina: The very fact that a glass surface is elastic, which a lot of people don't understand that...

Bajorek: It's counterintuitive.

Argentina: They can't understand that, right. But you cannot deform the surfa -- you might break the disk if you hit it hard enough, but you won't deform the surface. So it is still, I mean, within the last six months there've been a few attempts to try to use an aluminum disk in a mobile application. First of all, the disk is very thin; it's 25 mils thick. And aluminum is like foil, you can't get it that thin. But they, certainly aluminum disks and longitudinal recording have, perhaps a performance advantage over a glass disk, depending on who makes it. And because of the ability to texture and get the high orientation ratio. With the PMR technology right here and now, that advantage is going to go away as the mechanical superiority.

Bajorek: Thank you very much. Well, Gil also introduced the word du jour, PMR, perpendicular magnetic recording. Joel, you're at the leading edge of this. I think, end products, we're shipping out 130 gigabits, but it's still longitudinal recording, but I think now people have announced and shipped...

Bajorek: Perpendicular recording product. Could you give us a little summary or where we're headed to, and we'll end our discussion there -- as a technology, as an industry.

Weiss: Well, as I mentioned before, every time we at the industry have kind of jumped an S curve from one technology to another, it's enabled broader product lines, you know, continued growth in storage densities, and likewise with perpendicular, going from longitudinal, we've been able to see a path to maintain a growth rate in storage densities. You know, above 30 percent compounded annual growth rate. So question is how long will perpendicular survive as a technology? Right now it's enabling at least in laboratory demos, over 300 gigabits per square inch. End products, as you mentioned, 130 gigabits

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per square inch. There's typically a couple of years lag time between the demo and actual product coming out. But I see that perpendicular has given us a kind of boost with what we saw with oriented media, that boost that's enabling for us perpendicular is the signal and noise ratio that you get with it. You know, it's very interesting, because longitudinal was kind of running out of steam, running into the laws of physics. You know, was there a limit? Well, of course there's going to be a limit. But what really happens is that when you jump that S-curve, and you start taking engineers off of longitudinal development and put them into perpendicular development, just by its own nature, the curve will roll over, and probably roll over faster. So I think our last demo at Seagate for longitudinal was about 130 or 140 gigabits per square inch. And that's just because we're not doing it anymore. And it's all shifted over several years ago to perpendicular. And that's just continued to climb. And I see that continuing to climb until we reach the next physics limit, which is, of course, forecasted by all the modelers and the physicists to be somewhere in the terabit per square inch range, when you have to do something significantly different. And those significant differences span quite a wide range of things, but all of those are huge changes in technology as we know them today. Things like heat assisted magnetic recording, where you go to very high coercivities, and you heat it, drop the coercivity, write it, and then cool it. That's one that we've been talking about in our research division in Pittsburgh for some time now.

Bajorek: Goes by the acronym of HAMR, right?

Weiss: Heat assisted magnetic recording, HAMR. Then we have-- we in the industry have talked about bit patterned media, where you put little islands on the surface, similar to what we were talking about before with glass. You know, sputtering on little islands, you can create islands lithographically. Or you can create it other ways. And creating little islands also creates topography. And the last thing that we can live with today is topography. So when that would come in, maybe 2015, I hope we're all retired by then. <laughter>

Bajorek: You don't want to do that... <inaudible> <laughter>

Weiss: But those would be real challenges. But I see perpendicular carrying us, you know, 500 gigabits per square inch easily. 1000 gigabits, or a terabit per square inch probably starts to get challenging again.

Bajorek: Thank you. What's significant from the benchmarks you described this where a terabyte drive for a consumer is just around the corner, right?

Weiss: Yes, we're shipping 500 gig now.

Bajorek: 500, half a terabyte is in production. And any moment now, in the coming years...

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Argentina: It's time to get back in it, Jim. <laughs>

Bajorek: A terabyte on a desktop, right?

Weiss: Uhm hm.

McCoy: I'll tell you a story on the IPO road show for Maxtor in '85, something? Yeah. I think we were at 380 megabytes, and I think we were talking to -- well, certainly New York, the toughest audience for a financial audience. And I made the statement that your kids will have gigabyte drives in their hands in their pockets. And it just sucked the air out of the room. And nobody believed it. Totally impossible! It was never gonna happen! One gigabyte! One gigabyte. Today a terabyte is more the one to be saying, yeah.

Bajorek: It's gonna happen. Well, having been part of the industry and having been tutored by all of you, this discussion I think clearly demonstrates to me at least that the progress we've achieved wouldn't have happened without the risks that a lot of you took, without the trials and failures, right, that a lot of you engaged in introducing film media. Because it was an extraordinarily brutal and difficult process. And had it stayed in the, what I'll call monasteries, <laughter> it wouldn't have made the progress that...

Eltouhky: That's a good name.

McCoy: Yes.

Bajorek: And IBM was a monastery, but not the only one, right, because you were frustrated, you couldn't make it happen, right? You were frustrated. I suspect the environment and the Hitachi, Fujitsu, right, Control Data, Digital Equipment monasteries was very similar, right? And I don't think we would have made the progress we did.

Argentina: That's right.

Eltouhky: There's another aspect of this brutality that that is alluded to, I think, should not really go unnoticed, and that's the difficult -- the financial difficulties of all these companies, the media companies specifically. I know that the drive companies also had a very tough time, but being in the media business from 1983 through the end of the century -- I can't vouch for anything beyond that, I'm sure -- Joel and Gil and others can describe the changes. You really had a very tough time. There were so many suppliers. You had very little reality in terms of being a supplier or a vendor to a drive. The customers were bringing four or five media people in for any design. You don't know if you're going to win the next design or not.

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And add to that, the drive makers were actually being your competitors. So you had in-house media people that always had the first, you know, order. In other words, if the times are good, you may get an order. If the times are bad, guess who is going to be cut?

Argentina: The outsider.

Eltouhky: So that dynamic was just really brutal. I know in my case, I can really tell you that the business on the media side had only two bull markets. There was one right around ’85/’86/’87 where, you know, where TriMedia was bought. You know, Maxtor went public, Komag went public in ’87. Domain went public. This was a golden -- didn’t last very long -- it was like two or three years. And then a long, long bear market. I had to wait all the way to like 1990-something -- ’95/’96/’97 for the IPO to be done. They’re the new bull market, they had to take the drive. You know, stock’s up, and we could breathe some sigh of relief. And lucky for me, and for a lot of people, we actually took my second company, public, StorMedia went public in 1995, so I was fortunate to actually benefit from two bull markets. And the first wave and then the second wave, but between these two, was a long, long miserable existence for the media guy. And I mean now it’s mature-- I mean, the business has matured now.

Bajorek: Well, I think there was a third period after you left, of the drought.

Weiss: Oh, yes.

Bajorek: And it’s back to a healthier posture now, so you’re right. Probably over the history of the film disk, there were three periods of better moments, brighter than others. And but I think right now we’re back to a reasonably healthy one. But after the fallout of over 60, right, pioneers attempted to do this and didn’t make it, congratulations to all of you! Because you’re among the few who did make it. But more importantly, you were among the few who made the big breakthroughs possible.

END OF INTERVIEW

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