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ORAL HISTORY PROGRAM

Lee Semiatin: Becoming a Journeyman Metallurgist

2020

PREFACE

The following oral history is the result of a recorded interview with Lee Semiatin conducted by Adam Pilchak on February 23rd, 2020. This interview is part of the AIME and Its Member Societies: AIST, SME, SPE, and TMS Oral History Project.

ABSTRACT

Semiatin Lee, aka Doctor Heat, spent his career performing industrial research for the betterment of mankind. Growing up during the height of the Cold War and Sputnik sparked Lee's interest in STEM, and Baltimore Polytechnical High School forged his career in engineering. Early on, Lee caught the research bug and began to study materials at Carnegie Mellon University. Lee worked at the Battelle Memorial Institute and began to build simple models using computational techniques for analysis and prediction in industry. While at Battelle, Lee worked on the processing science project with the Air Force, which was one of the first to integrate computer-based, modeling simulation techniques for prediction of processing behavior and take in economic considerations. Lee began to grow fond of the Air Force and joined, working with the Air Force Materials Laboratory. Lee was inducted into the National Academy of Engineering and spreads his advice to apply yourself, work hard, and if you don't have fun don't do it. Research is 1% Inspiration, 99% Perspiration.

Readers are asked to bear in mind that they are reading a transcript of the spoken word, rather than written prose. The following transcript has been reviewed, edited, and approved by the narrator.

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PART 1

00:53 Growing Up in the 1950s – "I grew up in the best of times and worst of times"

Pilchak:

Today is Sunday, February 23rd, 2020. This is an interview of Lee Semiatin, who is a retired Senior Scientist from the Air Force Research Laboratory. The interviewer is Adam Pilchak, and this interview is being conducted as part of the AIME Oral History Project. We are at the Marriott Marquis Hotel in San Diego, California. And, we're going to talk a bit about Lee's past and his history and what got him interested in engineering and the sciences.

So, let's start with your childhood. Tell me a little bit about where you grew up and what things got you interested in engineering.

Semiatin:

Okay! Well, thank you very much, Adam, for hosting this little discussion. It's always nice for an old geezer, such as myself, to be around the younger folk, especially the millennials and Gen-Xers, and so forth. I guess the best way to describe my childhood is that I was a baby boomer, and, to quote the great Charles Dickens, "I grew up in the best of times and the worst of times." I was born two days before 1950. My father was an accountant, so he wanted to get that tax exemption. I was six weeks premature. So, I guess I hit the ground running. I grew up in Baltimore, Maryland. And, the reason why I said it was good times and bad times, it was the height of the cold war, the 1950s and sixties, so that sure flavored what was happening in people's lives, the threat of thermonuclear war, the government's funding decisions on research, and so forth.

The good part of it was that, after Sputnik, when I was seven years old in 1957, the government started pumping a lot of money into STEM-like education. We think STEM is relatively new. It really was very well-funded in the fifties and sixties. Sputnik essentially was a wake-up call. Sputnik also got a lot of young people, such as myself, interested in the space program. I remember vividly following all the initial suborbital flights by the Mercury Seven astronauts: [I was] sitting in wonder that these machines could lift a person into low earth orbit and then eventually to the moon. So, that piqued my interest in space. I was very fortunate to have teachers in both elementary school and junior high and high school who facilitated that interest.

03:08 Having A Great Affinity for Numbers – Growing My Interest in Mechanical Engineering

Semiatin:

Now, one thing I will say is, my father being an accountant, I had a great affinity for numbers and had teachers who actually pushed me to do things that ordinarily one wouldn't expect a student to do. For instance, I learned how to do arithmetic problems [in] my head, with great facility, and that was very helpful in my later life. I also had great English teachers who taught me grammar and proper English, even though I don't use it all the time! You probably recognize some of that from our interactions, [in] journal papers, perhaps. So, as I got into my teens, I followed the space program. I got interested in mechanical engineering type problems, and I had an affinity for taking things apart. I was not always successful in putting them back together, though.

04:07 Baltimore Polytechnic – How My High School Experience Forged My Engineering Career

Semiatin:

So that was probably the first 12, 13 years of my life. I then had the opportunity to go to a high school, a public high school in Baltimore, called Baltimore Polytechnic Institute. That's really where my engineering career took off, so to speak. This was a high school that specialized in science and engineering, and we had a lot of basic courses in electricity, chemistry, and physics, as well as more application-oriented courses and so-called shop courses. Some of the shop courses included things like foundry and forge. In foundry, every student had his own pile of dirt, so to speak, i.e., molding sand, and we took wood patterns and made molds. Then we had a little electric furnace where we melted aluminum and made small castings. This was a high school, mind you.

Forge shop nearly killed me. Each student was assigned an anvil and a furnace. We were given a rod of steel, and, for three or four weeks in a row, we were told to beat the heck out of the steel to make a center punch. At the end of the forging process, we were taught how to heat treat the material. We also had a pattern-making shop, where we learned to make wooden patterns that were eventually used in the foundry; and we had a surveying course. Last, we had, I think, it was two or three years of mechanical drawing, learning how to make engineering drawings of mechanical parts: gears, valves, etc. The science courses complemented these more application-oriented courses. One thing I will say is all the teachers were really good in their specialties. We had good math teachers. We had a lot of teachers also [that] were former graduates of Baltimore Polytechnic. So, that was very helpful.

One thing which is important for most learning I think, is having a role model. So, all the teachers had a way of "living" their subjects. That even got down to English…we had people who had written a lot in their lifetimes, and they really taught us good expository writing. That background in engineering and science, theory and practice, which was actually part of the motto of Poly, sort of got me on the road to becoming an engineer and understanding the importance of both the theoretical (scientific) aspects, as well as the practical or industrial aspects.

06:53 Undergraduate Studies at Johns Hopkins and the Importance of Fundamental Sciences

Pilchak:

What an amazing high school experience that sounds like! I wish I had shared the same one. So, it makes sense that you continued on the path to be an engineer. So, where did you do your undergraduate studies, and why did you choose that?

Semiatin:

When I graduated from high school, I applied to several universities, and the one I eventually went to was Johns Hopkins University. I was fortunate it was in Baltimore. Johns Hopkins has had a long history of both undergraduate and graduate education. As a matter of fact, Johns Hopkins was the first university in the US to have a graduate school. It was a small school where you could get a lot of attention from the faculty. The subject I took up there, the major, was engineering mechanics. At that time, they did not have an engineering school, it had been disbanded and reconfigured into more fundamental disciplines. So, I was in the engineering mechanics department, and some of the courses I had there were things like solid mechanics, fluid mechanics, [and] experimentation laboratory.

To compliment those courses, I also was interested in some of the more fundamental aspects of physics. So, I got to take courses in the physics department, things like celestial mechanics. Having grown up during the space race and having gone to a lot of air shows in [Washington] DC, I wanted to learn about what makes the planets go around and know what controls the orbits of satellites, and so forth. So, I took celestial mechanics. Also, I was very interested in thermodynamics. I remember Einstein once saying that Thermodynamics was the most fundamental science, so I thought it was very important that I learned a lot about Thermo and thermal physics. I was very fortunate to have a very good teacher in that. I also realized that math, being the language of science, was important, so I took a number of mathematics courses.

09:07 The Philosophy of Science – Setting Up a Research Laboratory, Research for the Good of Mankind

Semiatin:

In high school, I'd taken introductions to both differential and integral calculus. So, when I got to Johns Hopkins, I went through those fundamental calculus courses very quickly, then took advanced calculus. I really liked partial differential and ordinary differential equations. Having that fundamental knowledge, which Johns Hopkins really was good at providing, not only in math and physics but also in mechanics, I obtained provided a very fundamental education. Also, in my third year at Johns Hopkins, I had the great fortune to meet a professor who was a new assistant professor, Bill Hartman. He hired me to be his lab assistant, essentially his research assistant. That was one of the best experiences I've ever had. I essentially worked to set up his laboratory. I remember setting up a linear air track because he was interested in wave propagation experiments and the fundamentals of high-rate plasticity.

He also had me build, using a Heathkit, a power supply. I did almost everything. I was a jack-of-all-trades as his assistant for two years. Being his only student, I also had a lot of one-on-one attention from Professor Hartman. During that time, not only did I learn about getting your hands dirty in the lab, more so than in an ordinary lab course, but I also learned what can go wrong – and a lot of things can go wrong when you're doing your research, when you're designing your own experiments. In addition to doing the various experiments, I also got to spend a lot of time with the professor talking about the philosophy of science, what it meant to be a researcher, and how important it was that our research have a purpose. That we weren't doing research strictly to satisfy our intellects, but that we were doing research to hopefully, eventually, transition something new for the good of others, so to speak. I remember many times, after working together for a couple of hours, we would just shoot the breeze about new, very philosophical things. That played a really big role in the forming of my approach to science and engineering, in addition to the experience that I had had in high school.

11:43 Catching the Research Bug – Broadening My Graduate Studies in Materials Science

Pilchak:

So, as you were finishing your undergraduate studies, did you ever consider just going right out into industry or working, or was it that you were destined for graduate school and higher education?

Semiatin:

I think after I'd worked in the lab, I had gotten the research bug, and I came to realize that to be able to continually satisfy that addiction, so to speak, I needed to get an advanced degree. Fortunately, the person I was working with, Professor Hartman, recommended several schools to me: Cornell, Brown, Carnegie Mellon. I got brochures from each of those universities, I looked them over, and I said, well, this is very interesting. As I was looking over the brochures, a thought came into my mind; maybe I should broaden myself from something very fundamental like mechanics, engineering mechanics, and do something that's a little broader. I quickly came to a conclusion that it would be good to understand a little bit more about materials, that all solid bodies are not continua. I better learn about what makes up a material and how that affects its properties, both during processing/manufacturing as well as during service. So, I made a major decision – I had seen that Carnegie Mellon also had a very good metallurgy and material science department – to cast my lot with Carnegie Mellon in Pittsburgh [Pennsylvania]. So that was another example of when I was presented with an opportunity, and I think I made the right decision.

Pilchak:

What year was that?

Semiatin:

That was in 1971. I was 21 when I went to Carnegie Mellon. As a graduate student who did not have a metallurgy background or materials science background, I audited a number of the undergraduate courses to come up to speed. The first-year grad students at Carnegie Mellon also take core courses.

I really liked the core courses because they were fundamental in nature, sort of like the materials adjuncts to what I had done at Johns Hopkins. Now, I still remember the core courses of Thermo taught by Professor Lupis. Phase Transformation Kinetics [and] Transport Phenomena taught by Professor Sekerka, and Structure taught by Professor Bauer. So, those three core courses went a long way in my evolution from being a mechanical engineer to a mechanical metallurgist. Having passed through that wicket, I then felt like I had made a good choice. I'd been challenged and survived the ritual of fire, so to speak. That's why I became a blacksmith! It thus set the stage for my future work and the area of manufacturing and processing.

14:51 My Advisor, Henry Piehler , and the Godfathers of Metallurgy

Pilchak:

So, it's often said that you're either like your advisor when you show up or like your advisor when you leave. Can you tell us a little bit about your advisor and the things he was interested in?

Semiatin:

You're right, Adam. I've always thought that the student becomes like the advisor, or the student is attracted to certain types of people like themselves. In my case, there was only probably one or two people doing mechanical metallurgy in the department. The one I picked was Professor Henry Piehler. I liked him because he was very irreverent. He gave you a lot of rope to hang yourself. He would say, this is interesting problem, why don't you go and look into it? He wasn't a micromanager. I liked his sense of humor. He was just a good guy. He wasn't pompous. He himself had studied under Egon Orowan for his master's degree, yes, the famous Orowan.

He also has studied under one of the godfathers of metallurgy in the processing area, Al Backofen, who himself was a student of John Wolfe of the famous Wolfe series. So, when I first met Henry, I said, this is a guy I can work with. Maybe he'll leave me alone, and he did. I saw him a couple of times, maybe once or twice every couple of months. He suggested problems that had a very strong industrial flavor. Another thing about Henry was that he didn't have any preconceived notions that science and engineering were the purview of people in academia. He thought an awful lot of some of the really good researchers in industry. So, that stuck with me that there are good people everywhere you go, not only in academia but also industry and the government labs.

16:48 Coupling Academic Learning with Industrial Needs – My Thesis Topic on Clad Metals

Semiatin:

Henry introduced me to a lot of those industrial folks. That really was my first good introduction to the real world and the need to couple academic type of learning with industrial needs. So, after two years, I picked out a thesis topic at his suggestion. It was the forming of clad metals. We didn't have a contract in that area, but we both thought it was a very useful topic. I was fortunate that we got a small stipend from the Alcoa Foundation. One of the people at Alcoa, the Director of Research, Peter Bridenbaugh, was instrumental in getting us a small amount of funding. I basically did my thesis on this shoestring, very careful about how I spent every penny. Also, the person who invented the method for making clad metals had a company outside of Pittsburgh in Canonsburg, PA. We referred to him as Big John, John Ulam, who had the patents for making clad coins and clad cookware.

John was kind enough to supply the materials for my thesis, and, with those materials, I investigated the formability and workability in various deformation modes, such as sheet rolling and sheet (punch) forming. At the same time, I was fortunate that I was interacting with folks in the mechanical engineering department at Carnegie Mellon who were operating what was called the Processing Research Institute. It was there that I first met George Dieter, who coincidentally moved from Drexel to Carnegie Mellon about the same time I came to Carnegie Mellon. I consider George Dieter, my advisor Henry, and another person, Professor John Low in fracture and fatigue, as really important influences, not only technically but also personally. They really were my friends, and I looked up to them as role models.

19:07 The Importance of Simple Models – Transitioning Research into Society

Semiatin:

But, back to the thesis topic, I learned an awful lot about the importance of coupling our observations, our experimental work, with simple models that were industrially transferable.

I learned that not everybody can take a complex mathematical formulation or computer simulation and transition it and apply it to an industry. I think this goes back to the way Henry himself was educated by Backofen: getting good experimental data, making good observations, understanding them, and then interpreting them in a relatively-simple manner. That's what I tried to do for the work we did on clad metals, not just specifically for clad metals, but to develop models that would be useful for any sheet forming or bulk metalworking operation. So, it was a good education, not only technically but also it helped set me on the path to do research that was basic in nature but had a strong industrial flavor. I always say that the best engineers use science to solve engineering problems.

Indeed, that kind of mindset came from my training and experiences at Carnegie Mellon. I'd like to thank Henry and George Dieter especially, as well as a lot of colleagues. Newton said that we stand on the shoulders of giants; in my own personal case, I feel that I was boosted up there by Henry, his advisor, and his advisor's advisor. I was fortunate to be following that sequence of evolution, so to speak. Hopefully, I've gone one step beyond, but I owe an awful lot to these role models, these people that I really idolized and thought were good people. I think that it's very important in research to not only look at the technical aspects but also how is your information, how is your knowledge going to be transitioned and used by society.

21:31 Transitioning from Carnegie Mellon Into the Workforce

Pilchak:

Yeah, I've always really admired your ability to make accessible models. I know it's widely appreciated by a lot of our industrial colleagues as well. So, now you're finishing up at Carnegie Mellon, and it's time to enter the workforce, because you can't stay in school forever. So, tell me about that.

Semiatin:

I was one of Henry's few students who finished while he was there. So, I'm proud of that.

Pilchak:

How many years did it take you to complete your PhD?

Semiatin:

It was around four and a half years. I had a short period of one semester, where I was out for some medical challenges. In that regard, after two years, I had to have some medical problems attended to. While I was away from CMU, the dean of the graduate studies and Professor Low sent me a couple of letters to get me to come back. From the personal standpoint, I was very happy to have people who actually cared about me. Nowadays, life seems to be so busy, things are so hectic, but in those days, I was so lucky to have Dean Strehler and a couple other folks who encouraged me to come back. I have something called Crohn's disease, and that required major surgery. I was just happy to be able to come back.

People often talk about sending out “millions” of resumes when they leave school. I didn't do any of that. Basically, a lot of folks visited Carnegie Mellon, and it was actually pretty easy to get a job. I had three or four job offers when I got out. I had an offer from an automotive company, an offer from a [research and development (R&D)] organization, an offer from a government lab, and one or two other offers. Because I had done work in sheet forming, I decided to take, as my first job out, a position at Armco in Middletown, Ohio. That position was in the area of developing new technology for forming of low carbon steel. So, I was in the low carbon steel section of the Armco R&D Lab.

There, not only did I continue to do research in the area of sheet forming, per se, and novel processes for forming of low carbon steel sheets, but I was also introduced to the day-to-day life of how research fits into industrial practice. Even though I was working in the lab environment, every engineer in that lab spent time on the plant floor trying to understand what was happening in the hot rolling operations, the cold rolling operations, continuous annealing lines, and the importance of doing near-term research. So, it was a major difference between academia in that people did not have a lot of time to spend doing basic research. Most of the research was very product oriented.

24:51 Working at Armco – Using Computational Techniques for Analysis and Prediction in Industry

Semiatin:

Another reason why I went to Armco was because I was being mentored and was able to work with a fellow by the name of Rollin Hook, who himself was a student of John Hirth. Rollin, to me, was one of the all-time great physical metallurgists we've ever had. He did his PhD on a crystal plasticity slip problem in a simple binary alloy. He also was one of the co-inventors of the interstitial free steel. So, I went there to work with him from a metallurgical standpoint, get my hands around a real engineering material. Low carbon steel sounds like a simple material, but it's really quite complex. Along the way, I met a fellow by the name of Peter Morris, who was also working in the lab at Armco.

Peter and I developed a working relationship to try to get some more fundamental understanding of what controls sheet formability. We started joint work looking at deformation-texture evolution and the effect of processing on texture. At that time, deformation-texture models were still somewhat in their infancy. Most of them were based on early work that Taylor and Bishop and Hill did starting in the mid-thirties through the mid-fifties. This was the late seventies, and a lot of that work had not been transitioned or widely used because it involved numerical simulations. We just did not have the computers back then to discretize the problems and execute the simulations. Pete and I decided to attack a problem, which coincidentally was also worked on by my thesis advisor, Henry Piehler. Although I did not know it then, it had not been part of my work when I was at Carnegie Mellon.

The specific problem on which Pete and I worked comprised the deformation of BCC crystals by a mechanism known as pencil glide, where the slip direction is defined, but the slip planes are not well-defined. So, Pete and I both realized that the formulation of the problem was not complete. I think we spent one or two months trying to complete a method to take some of the ambiguity out of the problem, looking at both upper bound and lower bound methods for analyzing how body-centered cubic (bcc) crystals deform in a polycrystalline aggregate. That was the essence of it. The problem also involved getting solutions using computational techniques. The computer we had at Armco was a Modcomp computer. To do something that would take maybe a minute or two on a laptop computer nowadays took approximately eight to 12 hours on the Modcomp in 1977.

We both wrote our own versions of the computer program, Pete taking one approach, and I took a parallel approach. We entered our codes using computer punch cards, which you probably have never seen. Then, on alternating days, we put our programs into the computer to be executed overnight. The outputs of these simulations were predictions of texture evolution and R-values, which affect deep drawability. By having two independent people doing basically the same problem, we could check each other. I'm strongly in favor of round-robin type problems in research, especially for complex problems. This was a good example of two people working together, not across the country. We didn't have the internet then, so, having proximity, we could talk to each other and have very rapid development that way.

Unfortunately, this was also a time during which the US steel industry was going through significant economic challenges. There was strong competition from suppliers in the far East. Armco, which is now known as AK steel, a joint venture between Kawasaki and Armco, was not doing too well financially. So, after six or seven months, almost all the newer people were given their marching orders. Unfortunately, I was one of those guys. On the bright side, I had learned a lot about what was industrially feasible. So, despite what happened, it was almost a blessing in disguise, and another door opened very quickly after that experience. Fortunately, as I mentioned before, I had a number of job offers when I left CMU. So, I took up my second job, one of the other offers from when I was a graduate student and went to Battelle. I'd been bitten by the bug of industrial research but still wanted to do some things, which were fairly basic. Thus, the next chapter of my career was spent in an organization in which there was a combination of basic research and industrial research. And, Battelle was indeed that organization, which enabled you to do some of both.

30:13 Battelle Memorial Institute – Industrial Research for the Betterment of Mankind

Pilchak:

So why don't you tell me about some of those clients?

Semiatin:

At Battelle, we had a plethora of different sponsors or clients. Just a little background first: Battelle was set up in 1928, I think. Coincidentally, Battelle was founded, or underwritten, by a fellow by the name of Gordon Battelle. I don't think he had ever gotten married himself, but his family had made a lot of money through investments in the Mesabi Iron Range. So, indirectly, that iron range also supplied a lot of iron for the steel industry. Gordon Battelle believed very strongly in industrial research . When he died, he left a big chunk of money in his will to set up a research organization. The prime thrust of that organization, which became Battelle Memorial Institute (that's the formal corporate name), was to do industrial research for the betterment of mankind.

For many years, the main strength of Battelle was its materials research, sort of along the lines of Gordon Battelle's background in the materials industry. The main areas of research were not only industrially oriented, some were government-related. Thus, for many years, the average staff member worked on problems that were funded by industrial organizations, as well as projects that were funded by government. Before I came, unfortunately, Battelle had actually made too much money. A lot of it was the money that Battelle had made through its contract research, including its development of the Xerox copier. To commercialize Xerox, Battelle set up what was called the Haloid Corporation, which marketed, manufactured, and marketed Xerox equipment. Four or five years before I came to Battelle, however, a probate judge in Columbus read Gordon Battelle's will and determined that the corporation was not supposed to be making a large profit through its research but instead supposed to be doing research for the good of mankind.

The judge looked at the stock portfolio of Battelle and said, you guys are making money left and right; you better start divesting some of this wealth that you have accumulated. At that point, in ‘73, the corporation started building things in Columbus like Battelle Park, Battelle this, Battelle that. Hence, five years before I came, it became more and more important that the staff go out and find clients. There was less money from the corporate coffers to do high-risk, long-range research, so we really were pushed to get new clients. Although Battelle had always done sponsored research, in the early seventies, it became even more important that the staff members develop new projects, sell them to either industry or government, execute them, and make sure that they did a good job so that they would get other projects.

33:49 First Big Industrial Project – Processing of Nickel Clad Copper Spark Plugs

Semiatin:

As I said, we had both industrial clients and government clients. The industrial projects were typically smaller in dollar value, shorter in duration, and much more focused. Among the early projects I worked on for industry, a lot of them were process development-oriented. I was in the group that was referred to as the metalworking group, which worked hand in hand with the physical metallurgy group. But, being in processing, my bent was more towards heat ’em and beat ’em, that is to say, make something for industry.

I remember my very first project for a company was for Champion Spark Plug Company. They wanted to develop a method to make a nickel-clad copper spark plug, which would give you much better performance. The copper to dissipate heat during the firing of the spark plug and the nickel to provide corrosion resistance. That was probably my first big industrial project, which probably lasted six months. In the laboratory, we made small scale tooling to do small-scale backward extrusion or piercing operation to make a little nickel cup. We put a copper slug in it, and then we co-extruded it to make this electrode for spark plugs. We developed the process variables; we were also working with an equipment manufacturer that made headers. It's a type of machine that actually can do these operations at high speed. We worked out the characteristics of lubricants, forming speeds, and so forth. This was going to be a room-temperature operation. Then, after we developed the process parameters, we had to demonstrate for the industrial client (Champion) that it worked, that we can make more than just 10 or 20 sparkplug electrodes. So, we set up the tooling in an MTS, a servohydraulic testing machine. I think we made something like a hundred of these electrodes within a day. Thus, we demonstrated that you go bang, bang, bang, bang…at a high rate. A year later, my supervisor and I went up to Champion in Toledo, and they were making, I think, millions per year. They were at that production rate, and they installed lines upon lines of heading machines. They're going bang, bang, bang, bang, making our electrodes, which went into the so-called Copper Plus sparkplug, a product that was widely marketed. I'm not sure if they still make it, however.

36:41 Designing a Heat Treatment Line for Bundy Tubing – Solving the Quench Cracking Phenomenon

Semiatin:

Another project I remember involved looking at the manufacturing of appliance and brake line tubing for Bundy Tubing. That project was also a very short duration. I think that it was six months also.

Initially, we paid a visit to Bundy Tubing and saw some of the problems. The brake line tubing was double-wall copper brazed tubing, and we had to figure out a way of doing something that was higher speed, using electric resistance heating. For the appliance tubing this involved roll forming and seam welding of low carbon steel. The problem with that operation was that this tubing, when it would come off the line, would be brittle due to quench cracking; rapid cooling of a low carbon steel leads to difficulty with subsequent forming. For instance, if you have a cooling system in a refrigerator, you've seen the coils of steel tubing in the back. When a secondary manufacturer would take that tubing from Bundy and try to bend it to shape, it would often kink or break.

So, we had to design a heat treatment line, or modify the heat treatment line of Bundy Tubing, to prevent that quench aging/cracking phenomenon. The way we did that was based on testing in a Gleeble machine, a direct resistance heating machine at Battelle. We simulated various thermal cycles, trying to understand the kinetics of carbon aging, so we could tell Bundy how to actually design the temperature versus time profile, or the temperature versus distance profile, since this was a continuous line at Bundy Tubing. That research led to them changing their heat treatment line and getting away from the quench aging problem. That was very exciting.

We also did a lot of work for the forging industry; a lot of the projects at Battelle were funded by multiple clients. One of the biggest ones, led by Dr. Taylan Altan (who at the time was the research leader in the metalworking group), involved 40 forging companies sponsoring generic research that all of them could make use of.

39:23 Responsibilities at Battelle – Characterization of Material Flow Properties

Semiatin:

In this so-called Group Forging program, I was in charge of some of the tasks related to things like the characterization of material flow properties during forging. Because of this, I got to learn about many different material systems. We'd run tests to determine the plastic flow behavior of widely different alloys: aluminum, nickel, Ti [titanium], uranium. You think of it, we've tested it.

I also was heavily involved in looking at die materials and die-wear. In that regard, I got a chance to spend a lot of time on the shop floor looking at different die materials and die treatments, at the Ford forging plant in Canton, OH. They were kind enough to let us into the forging plant to test out some of the die coatings and die treatments, like ion nitriding versus salt bath nitriding. We actually ran the trials under production conditions, taking intermittent forgings over a several day period The selected forgings would indirectly serve as indicators of when you had problems in the forging operation, like thermal cracking, abrasive wear, where the die would wash, etc. We would then take these samples back to the lab and analyze them to see how well our die treatments were doing.

These industrial problems involving modifying a processing line, developing a totally new process, looking at some of the key cost elements of forging were all very useful to get a handle on what's happening in the real world and to understand what some of the limitations are with regard to industrial research. Here, you don't have infinite time. You don't have an infinite budget. You have to be focused. Develop a solution for the client. In fact, I can remember projects that lasted one or two days that would cost perhaps a thousand dollars involving, for example, rolling some material in the lab. Then, you send the sample back, and let the client characterize it. A number of those rolling projects were done for companies who were working on the National Aerospace Plane Program.

41:33 Developing a Process for the Rolling of Gamma Titanium Aluminides

Semiatin:

Some of the rolling projects involved the processing of gamma titanium aluminides, an intermetallic alloy system, which was very difficult to form. We developed a process to roll it, using unheated rolls. Prior to my coming to Battelle, engineers there had developed something called heated roll rolling. It's sort of the rolling equivalent of isothermal or hot die forging but on a rolling mill. We had demonstrated first that you could roll gamma Ti [titanium] aluminides via this heated roll rolling method. At the same time as that, during which we were doing heated roll rolling, we were interacting with universities as well. Jim Williams, a member of my thesis committee, was involved in those interactions, for example. We soon realized that if we're ever going to scale this process up, we're not going to be able to do it using heated roll rolling. It just wasn't feasible. So, we looked into using simple models of the temperature transients during pack rolling, where you put the workpiece inside a protective can or pack.

You evacuate the can and seal it, so there is no oxygen contamination. And [by] doing an analysis of how much heat is lost just prior to and during rolling, we could determine what temperatures are experienced by the workpiece inside. For gamma titanium aluminides, the working temperature range is very limited. So, we had to design the pack, covers, interlayers, parting agents, etc. to be able to roll these materials, to keep them within a very narrow range of working temperature. We were successful in this endeavor. In the late 1980s, we rolled the biggest known sheets of gamma titanium aluminide on our lab mills up until that time. I think our biggest sheet was 16 inches by around 36 inches. We could have gone further, but that was the limitation of our reheat furnace. At the same time, I want to emphasize that it wasn't enough for us to learn how to do this ourselves. We had to show others. Thus, I remember going on a number of trips to other companies who actually had large scale rolling equipment and showing them how to make the packs, how to roll them. They actually demonstrated some of these techniques on their own equipment. It was very important that we transitioned this technology.

44:06 Director of R&D – Developing Short-time Heat Treatments at the Center for Materials Fabrication

Semiatin:

Another set of industrial-oriented problems, or projects, was sponsored by Electric Power Research Institute (EPRI), who funded Battelle to set up something called the Center for Materials Fabrication. The main objectives of the center were, first, to do research on technologies whose transition benefited electric utility customers, second, to train these utilities and their industrial customers on emerging technologies, and, third, to be available to answer near-term questions of industrial customers.

One of my roles in the center was Director of R & D. I was also in charge of formulating and executing some of the R & D projects. One of the major areas that we got into was the use of induction heating in processing operations. One of the very first things that I looked at specifically was the possibility of doing short-time heat treatments, such as short time tempering of metals. That was driven by an industrial customer, Ajax Magnethermic, and other induction heating companies that made in-line rapid hardening processes and associated induction equipment. But, when they would sell that equipment to customers, they often would harden with induction but temper with furnaces. So, we set out to look at the feasibility and the benefits of short time tempering also using induction methods.

We were successful, and, eventually, some of the parameters we developed (I think this was the mid-eighties) were transferred to industrial use, where they now are doing continuous hardening and tempering. We also looked at methods for heat-treating sheet metal in a continuous fashion, such as annealing and other processes. It was during that time, the mid-late eighties, that we worked with Ajax Magnethermic, under the auspices of EPRI funding, to develop transverse flux induction heating. This was a process that originally got started, I think, in the United Kingdom, mostly for annealing of aluminum. One of the drawbacks was that the inductor that they were using overseas could only treat a fixed width of sheet metal. We worked with Ajax to develop a variable with inductor, so you could vary the width of the feedstock. And, that was very important for you to better handle coils of different widths. This process was demonstrated at a prototype production scale at Allegheny Ludlum in Lockport, New York. It was nice to have that kind of process transitioned also.

47:06 Doctor Heat – Becoming a Cartoon Character to Promote Electric-based Technologies

Semiatin:

With regard to the tech transition activities, I was also asked numerous times to provide courses and give talks at either utility companies or their industrial customers regarding electric-base technologies like induction heating, IR heating, and so forth. It was during this time that I got a nickname from one of my colleagues, Tom Byrer; he started calling me Dr. of Process Heating because of the use of special heating technology for manufacturing. He said the moniker Dr. of Process Heating was too long, and thus, settled on Dr. Heat for short. There were some people in the communications area of the center who said, well, this is really great, we got a guy named Dr. Heat. He travels around the country, giving talks, educating our industrial users, not just in electric based heating but also in the economics of electric versus fossil fuel heating (it was our mission, not only to promote electric heating but to promote energy efficiency and thereby keep the industrial customers healthy and our suppliers healthy). So, they started calling me Dr. Heat, and the communications people said, let's try to make this into something, develop this into something that people will read in a newsletter. Therefore, they made me into a cartoon character, and they'd have cartoons to promote electric-based technologies. They showed Dr. Heat in different situations trying to recommend something. Thus, I felt honored, and I do have a good sense of humor. I'm very irreverent. Hence, that sort of thing fit my personality!

49:01 Research, Industry, and Government Projects – Growing in Technical Breadth

Semiatin:

Working in research as you probably know, Adam, can be a very humbling experience. The more you learn, the more you realize there is to learn. That's why research is such an energizing endeavor. It's wonderful to be able to learn something new every day and to be able to eventually use it; it really drives you. I have given some examples of our industrial work, both for individual sponsors and for a group of clients, such as the forging industry, as well as our work in the Center for Materials Fabrication. All during that time, we were doing snippets of basic research. We were doing the things that were very industrially oriented. It was a nice combination.

At the same time that we worked on industrial projects, we also had government funding. The government projects typically were longer in duration. They involved usually larger budgets, and the technical breadth was wider.

In the 1980s or late 70s, when I was working at Battelle, we were very fortunate that digital computers started getting faster, and Moore's law started helping us out quite a bit. The old Modcomp computer from my Armco days, could do one problem overnight. When I went to Battelle, we started buying PDP computers, with which we would now have the opportunity to start thinking about doing more complex forming problems. In this regard, we were very fortunate that the Air Force recognized the need for computational simulations in the processing industry. This was recognized by both the basic arm of the Air Force, AFOSR, and the more applied people at the Air Force Materials Lab. This was in the late 70s and early 1980s.

51:34 The Processing Science Project – Computer-based Simulations for Processing Behavior and Economics

Semiatin:

During this time, Battelle bid on something that was referred to as the AF Processing Science project. That was probably the first, if not among the first, program to integrate modeling and simulation techniques that are computer-based for both processing and service behavior predictions and economic considerations. The genesis of the methodology thus started with the Air Force. There had been some previous efforts, small parts of what we now refer to as ICME, integrated computational materials engineering. For example, there was the project Themis at the University of Kentucky. But, the AF Processing Science program was the first real attempt to integrate mechanics people, materials people, industrial research organizations, and academia. I think the project started eight months after I got to Battelle and went on for four or five years.

We put together a team, with the Air Force doing the program management, as well as executing some technical work, of course, at what is now called the Air Force Research Lab. Anyhow, we assembled a team involving researchers at Battelle itself. We also had a number of university partners, as well as industrial partners. The university partners included Shiro Kobayashi at UC Berkeley, Howard Kuhn at the University of Pittsburgh, Jay Thomas and Parviz Dadras at Wright State, John Jonas at McGill University, Rishi Raj at Cornell, John Hockett at Los Alamos National Lab (who had a cam plastometer, a very unusual piece of equipment for measuring the flow behavior of metals), a couple of others. Then industrially, we worked with Wyman-Gordon Company in Worcester, Massachusetts, to do actual forging demonstrations.

What was nice about the project was that, in addition to doing the basic research, such as understanding material behavior during processing, be it in microstructure control or defects, we also chose a demonstration problem, which in this case was the development of a process and the fundamental understanding to make a graded/dual microstructure, dual property compressor disk of the titanium alloy Ti-6242. That was the foundation for all of our research. It led me to believe that it's always good to have a good demo that you can base your research on.

So, we had this whole team working toward a goal doing fundamental research under the Air Force sponsored program, at the same time knowing that we'd have to demonstrate the utility of this basic knowledge to make a part that eventually could be used in service. And, we were doing this with an integrated product team. There were the people I mentioned, working on fundamental material models. There were guys looking at service behavior, fatigue, and fracture. At the same time, there were some of us at Battelle working on the development of advanced mathematical modeling techniques for simulating metal forming problems. When the processing science program first got started, we were thinking, let's use the upper bound method for analyzing metal flow. Soon into the project, however, we realized the upper bound method wasn't going to work.

55:22 Developing ALPID - An FEM Program to Analyze Forging Problems

Semiatin:

At that point, we decided to shift gears regarding the simulation approach; I think we were maybe six months into the project. We said, okay, we're going to put our money, not on the upper bound method for simulating the forging process, but rather, with the new faster computers, we were going to develop a finite element method program, i.e., FEM program. That was probably the best decision we made with regard to the computation aspects of the project. Fortunately, at the same time we got a new staff member, who came I think probably a year after me. I came in January of ‘78. Soo-Ik Oh had just finished his PhD with Professor Shiro Kobayashi at the University of California, Berkeley, which was also one of the team members on the program. He came to Battelle and started working immediately on developing an FEM computer program to analyze forging problems.

That computer program was eventually called Analysis of Large Plastic Incremental Deformation, or ALPID. I remember after a year; we actually had an FEM engine that was workable for which we could do both isothermal compression simulations as well as non-isothermal compression simulations. We were at the annual review meeting, I think it was 1980 or ‘81, at which we demonstrated the capabilities of the ALPID code, and everybody's mouth just dropped. With the detail that could be simulated with this computer code, it was quite amazing. So, that was the genesis of the joint work between Battelle and UC Berkeley. Incidentally, Dr Taylan Altan, who was the Battelle PI, had also been a student of Shiro Kobayashi, who had been instrumental in developing new FEM codes for metal forming.

My main role in the AF Processing Science program involves more metallurgical aspects, making sure we developed useful models for plastic flow behavior, microstructure/defect evolution, etc. For example, I worked very closely with John Jonas at McGill. We both had a great interest in plastic flow and flow-localization problems that limited workability. At the same time, I had another grant from the Air Force Office of Scientific Research to understand shear band formation. McGill looked at problems involving tensile instability, the kind of thing you're interested in during sheet forming, drawing of polymers, and so forth. So, we naturally had a very good relationship, working on those two types of related problems. Furthermore, Rishi Raj worked on fracture modes during hot working such as wedge cracking. It was just a great team. It was a very active time. And, I think we all worked together well, and it was well managed. It was well funded, and we had a lot of support from our government program managers, who themselves were doing great work as well. So, it was an exciting time, it really was, being there, so to speak, on the ground floor of a new technology.

PART 2

00:22 Air Force Processing Science Program – Projects with Titanium to Uranium-Based Materials

Pilchak:

You've told us a lot about the Air Force Processing Science program. Were there any other important or influential government programs that you worked on during your time at Battelle?

Semiatin:

Being at Battelle and having a great laboratory capability helped us get other government projects that involved a number of things that I can't talk about but helped me broaden myself with regard to materials systems. We did a lot of work for the Department of Energy, [such as] looking at uranium-based materials and uranium metallurgy. We worked on shape fabrication. We worked on extrusion operations. Those rolling mills that we had for intermetallic alloys, like gamma titanium aluminides, were also useful for making sheets of other materials. I remember developing pack rolling processes for AlBeMet, an aluminum beryllium mechanical composite.

We also did extrusion of round rods of various materials. The approach we took for titanium or for any material system was very similar. It emphasized the importance of understanding physical metallurgy, phase equilibria, and kinetics, because everything in processing comes back to what are the stable phases? Is it single-phase or two-phase? What limits the workability? How do you control the microstructure? And, how does that microstructure control the properties? So, it's very classical metallurgy with an emphasis on the processing end of things, because if you can't make it and you can't make it well, you can't put in service, and you can't assess its life, its behavior, and lifetime. So, in conjunction with working [with] some of these exotic materials, I also had the chance to work with some of the best people in the characterization area that I've ever known.

Our characterization equipment was nothing like what we have today, we were working with a Bausch and Lomb Research II optical metallograph. Even with the B and L, getting good polarized-light micrographs of uranium, for instance, was really difficult. A lot of the photographs that we made ended up in handbooks. Also, with regard to some of the other government work, we did a lot of work on assessing technology. Much of this work also involved developing new technology as well as knowing what other people were doing to prevent us from being leapfrogged. So, I had the opportunity to work quite extensively assessing what other people were doing around the world. Once in a while, we would get something that we could look at, a product that we could look at it to see how others were doing things similar to what we were doing. It was very interesting to understand how people think and how people approach development of new materials and processes.

03:39 Growing Fond of the Air Force and the Wright-Patterson Air Force Base Materials Laboratory

Semiatin:

About the same time that I was working on the Air Force projects, I got to know the people at the Air Force quite well, not surprisingly. We had projects through the Air Force Office of Scientific Research in the early ‘80s. Then we had the Processing Science program in the late ‘70s, early ‘80s. After those projects were over, I started spending more time as an Adjunct Professor at The Ohio State University. Coincidentally, one of the master's students I worked with was the son of the chief scientist of the Air Force Materials Lab. The son's name is Paul Burte. His father was Harris Burte. He was the Chief Scientist of our lab for a number of years.

I was working with Paul, his son, on his master's thesis in a topic related to interface heat transfer during forging. That provided the opportunity for me to get to know his father, Harris, much better. Harris, as a matter of fact, had been a big champion along with Alan Rosenstein at AFOSR of the Processing Science program. I knew Harris through some of our annual meetings for the Processing Science program. So, it was sort of coincidental that I would be his son's thesis advisor in the late ‘80s. Alan Rosenstein was also a mentor to me. I think it was the beginning of 1987 or 1988 that they started saying, “Lee, why don't you consider coming to work for the Air Force?”

I think it was 1989 or 1990, they convinced me to spend a part-time (visiting scientist) sabbatical, where I'd go two days a week to the lab at Wright-Patterson Air Force Base outside of Dayton just to get the lay of the land, so to speak. I had the opportunity to work on gamma titanium aluminides, which was still a pretty hot topic with regard to the National Aerospace Plane Program. I thought this was a pretty nice laboratory. Of course, I'd been there before while we were working on the Processing Science program, but I actually had a lot more time, through this visiting scientist effort, to see how it worked. After a couple of years, Harris came by to chat and my predecessor as a research leader, Jim Malas, who himself had succeeded Hal Gegel, who was one of the guys involved in the early Processing Science program days, said, “Why don't you come give us a talk?”

I didn't realize that the talk was actually a job interview. I think it was 1990. After the talk, they said, “We'd like to make you an offer.” After thinking about it for a few months, I accepted it. Even though there was a hiring freeze, they managed to get my application through. Eight or nine months later, I was there at Wright-Patterson Air Force Base in the, what was then called, the Materials Laboratory of Wright Research and Development Center. There's been numerous name changes over the years, but it's always been part of the Air Force Material Command.

06:52 Joining the Air Force – The Responsibility of Lab Construction and Equipment Manufacturing

Pilchak:

When you joined the Air Force, tell us a little bit about some of your principal research activities when you first arrived.

Semiatin:

When I first arrived, I was actually hired to be the research leader of the metals processing group, or rather the materials processing group, because we did more than just metals. We did MMCs [metal-matrix composites], CMC [ceramic-matrix composites] processing, nonmetallic polymer processing but with a heavy emphasis on metallic materials, of course. I was hired as a senior scientist, near the top of the research ladder in those days; it was. We hadn't transitioned into the so-called lab demo personnel system yet. But, I was given somewhat of a carte blanche to organize the program, which was nice. Also, it turned out that the building that we were in was only three or four years old. Our lab, during 1991, had started transitioning from an old building, which was eventually demolished, to the building that we're in now. So, I was put in charge of overseeing the moving of equipment and setting up of the processing labs.

That was very nice, not only to have the responsibility and some of the authority for the research itself but also to oversee how the lab was constructed, how the layout was to be done in conjunction with some of the other government folks, of course. It turns out that, even when I was at Battelle, one of our government projects had been to make recommendations for the purchase of a new forging press. So, I knew its characteristics exactly, since Taylan Altan and I had actually written the spec for the press that was eventually bought by the Air Force. It was coincidental that the five or six years between spec-ing the press and my joining the Air Force was the same length of time it took to buy the press. And, I think six months after I got to the Air Force, we had a hole on the ground, and the press was delivered and placed into it.

In addition, some of the equipment that initially was going to be thrown out during the move from the old to the new building, I managed to save. We were able to get extra space for the lab, which is in a high bay area. Aside from the high bay area, we also started building new capabilities, especially in the area of hot workability. For example, we undertook to build an advanced hot compression system, a new torsion testing system, as well as looking at new characterization tools. I think we were some of the earliest users of, at least for aerospace alloys, electron backscatter diffraction methods to titanium.

10:04 The Four Core Thrusts of the Air Force Materials Laboratory Processing Program

Semiatin:

The overall processing program itself was basically broken into four major areas. First, the bread and butter comprised developing material behavior models for processing of aerospace materials, mostly titanium and nickel, i.e., conventional alloys. A lot of it also had to do with intermetallic alloys because this was still during the time when NASP [National AeroSpace Plane] program was a high visibility, highly important program. So, we were developing models of microstructure evolution, defects, and texture evolution, not only for the intermetallic hard-to-work alloys but also for the conventional alloys. We wanted to make sure we were strong in this area because the Air Force has its own, sometimes niche, materials. There's not a big economic driver for many of our materials, nor a big commercial tonnage production-base to support research.

That was half our program. The other parts of the program consisted of developing and characterizing novel processes. Third, complimenting the material behavior models, we develop advanced computational techniques for simulating microstructure evolution. And last, we developed our own advanced characterization techniques. So, those were the four major areas, and those four areas probably summarize the work we've done since 1991 to the present. It's evolved over time, but that's been the basic thrusts.

12:03 Materials and Manufacturing Directorate – Integrated Work with Industry

Pilchak:

So, during your earlier years, you talked a lot about interactions with industry and transitioning practical, pragmatic models to industry. Can you describe how that continued in the Air Force?

Semiatin:

That's a good question, Adam. One of the nicest things and one of the most attractive aspects about working in our lab is that the laboratory handles more than its own in-house research, and we're very well equipped for that, both equipment-wise and staffing-wise. We have a wonderful technical staff, a number of PhDs and master's students and great technicians. In addition, we manage the extramural program. In other words, some of our funding, especially our advanced development or 6-2 funding, goes to companies. Sometimes universities have to do research that parallels our research but we also take the next step in material/process development. We've had a number of contracts to develop processing know-how, to take some of our basic knowledge, and actually try and do it on industrial scale.

One of the biggest contracts we've ever had has been the so-called Metals Affordability Initiative, or MAI. I think it got started in 1997 or 1998, and the objective of that contract was/is to develop and demonstrate new processes and new alloys. It has been a very successful program over the years. Having our own in-house research, we want to transition new ideas, but, at the same time, it's a two-way street. When industry tries to do something, not only for MAI but for anything that they're doing for the government, oftentimes, there's a challenge. We learn what the technical challenges are, and that helps us. There's a feedback loop; it goes both ways. We learn what things may need basic research. At the same time, we're motivated to try to do the early development work that will help make the eventual industrial project more efficient. That's probably one of the nicest things about working at the materials lab, in general. Right now, its official name is the Materials and Manufacturing Directorate, because we try to do this stuff jointly with our manufacturing team members at making better products for the Air Force.

An example of these interactions is the work we did on developing models of the behavior of titanium during forging. That was a project that we did with a forging company, a titanium company, and an academic partner, among others. It was a project that ran three or four years. We developed some of the basic understanding of plastic flow of two-phase structures, microstructure evolution during forging and heat treatment, and developing models to describe all this stuff. There've been numerous instances where we do integrated work with industry or where we do some initial work, and it's transitioned to industry. And, I can tell you, there have probably been, in my lifetime and before and at the Air Force, I would guess a good 20 or 30 times where something we do has been spurred by something we've seen in industry, or a need expressed by industry, or something that we knew could be done jointly with industry.

Semiatin:

One of the nicest things about our lab, related to our prototype production scale equipment, is that we can do something a lot more simply on our equipment than you could do in a real production environment, where they can't take equipment offline. A lot of our equipment also has very special sensors and control technologies to enable us to do things that are sort of novel. Good examples include things like developing novel forging processes. Also, we'd done work on severe plastic deformation processes, equal channel angler extrusion being an example, where we built our own tooling, and we demonstrated some of the pros and cons of the process for refining microstructures. We have done a lot of work on thermomechanical processing in general. We've also done a fair amount of work on other states of matter, including vapor processing and solidification processing. Regarding vapor processing, for instance, we did work on looking at the deposition of coatings by plasma spray, or electron beam, physical vapor deposition for engine blades, for instance. In the area of solidification processes, I think we were among the early groups to look at additive manufacturing techniques.

17:20 Addressing All Three States of Matter – Solidification Processing and Additive Manufacturing

Pilchak:

You've described a lot of your work in thermomechanical processing, forging, heat treatment, rolling, extrusion, et cetera. Are there any other processing methods that you've worked on?

Semiatin:

Yes, as I have just mentioned we've looked at what I think are some key problems in both solidification processing and vapor processing. So, we've addressed all three states of matter. For instance, in solidification processing, we've looked at novel techniques to melt material, such as electron-beam (EB) cold-hearth melting, looking at alloying element losses, and developing models, for instance, of the loss of aluminum during hearth melting of Ti-64, associated with melting in a vacuum. We also looked at the effect of process variables on surface finish in EB hearth melted and cast ingots. One of the things that I'm most proud of is our early work on additive manufacturing, basically a micro-melting and solidification process.

I think we were among the first to develop processing maps or processing know-how for additive manufacturing of titanium alloys. This was in the 1998 to 2002 timeframe. We were working with mostly powder injection methods where you have an energy source, such as a laser, and you inject powder particles which are melted incrementally, layer by layer. We did work with a small equipment manufacturer, Optomec, on the LENS™ [Laser Engineered Net Shaping] system. We also worked with a larger scaled-up system using a CO_2 laser to do what was referred to as laser additive manufacturing (LAM).

19:10 The Key to Understanding the Transition from a Liquid to a Solid

Semiatin:

The person who worked on that program was Pam Kobryn. It was fortuitous because she had done her PhD on permanent mold casting of titanium. So, she understood the important process variables. That was key to understanding what happens when you do micro-melting and micro-solidification in the LENS vs. the LAM process. It's also applicable to the newer or the more recently used processes that are based on powder beds. It was very nice that Pam was able to take some of the knowledge she had gleaned from her work on permanent mold casting of titanium, in which you cast into a metal mold rather than more conventional ceramic investment casting process, and show why, in some of these additive manufacturing processes, you almost invariably get a columnar grain structure. Taking a more generic approach, as in this case, is, I think, a hallmark of our work. We're not necessarily studying additive processes or casting processes per se. We're trying to get a unified vision or understanding of what happens when you go liquid to solid. What happens when you put work in the solid-state for a thermomechanical process, or, in the case of a vapor process, what controls the structure and the defects?

The vapor processes are very important for coatings. We've looked at plasma deposition of coatings, but we also spent a good deal of time looking at electron beam physical vapor deposition (EBPVD). An example of that is both single layer as well as multi-layer coatings on nickel substrates for thermal barrier coatings.

We've also looked at EBPVD with partners in Ukraine to make thin foil products. Thin foil is a very important aspect of making thin structural components, such as thermal protection systems. So, we worked with them to demonstrate that we could make foil products. We demonstrated the technical feasibility and showed that, economically, it's a lot better to do that than to take a big ingot and work it down to a sheet and then to a foil. So, those are a couple of examples of vapor processing. We wanted to show that we could make the product, but also what were the important process variables, and how can we take this generic knowledge to obtain a unified understanding of vapor or solid-state or liquid to solid-state transformations?

22:17 Fundamental Knowledge Desire – Making Products and Understanding Limitations

Semiatin:

So, there has always been this desire to get fundamental knowledge, but the end has been, can we then take this knowledge and make a product from it? So, rather than trying to just do something via an Edisonian approach to make a product, we have wanted to understand what limits our ability to control microstructure, defects, crystallographic texture, and so forth, and that permeates everything we do. With that basic understanding, we're also able to get a better handle on development of material sensitive models. A couple of examples of those models, as I mentioned before, include basic material behavior modeling techniques like Monte Carlo modeling of recrystallization and grain growth. Another example would be cellular automaton type techniques. In our case, we used the latter to look at recrystallization problems. A third category would be crystal plasticity FEM [finite element method] (CPFEM) [crystal-plasticity FEM] techniques, where we want to be able to simulate not only the evolution of deformation texture but also understand how deformation may bias a transformation that occurs following high-temperature heat treatment. For, the Monte Carlo technique, we've tried to apply that mostly to titanium and nickel alloys. One of the limiting factors that we've always known is the dearth of good input data, grain-boundary energy and mobility. I say that's one thing that we really could do a better job on. A number of our staff members have taken on the grain-boundary energy problem for high-temperature commercial alloys but fallen on their swords trying to get the needed input data, unfortunately. Regarding cellular automaton, I think we demonstrated very well why you get different types of flow curves during recrystallization problems. CPFEM modeling, I think, has been one of the most successful approaches, for deformation textures as well as for transformation textures and some of the annealing/recrystallization problems. We're very interested in the long-term in getting a code that will work not only on a research scale but also be transitioned to industry for titanium alloys. Again, we're talking about codes that will give us a 10 or 20% error at most, because we fully realize that a code that just gives qualitative guidance is not going to go anywhere. Overall, then, developing these modeling techniques, such as crystal plasticity or some other technique, requires very careful calibration and validation to get them to be transitioned to industry. If I've learned one thing over the years, it's that we have to make sure our models are so-called industrial-strength, that they work within reason, and give you an answer to a problem that is too hard to measure. You need modeling techniques to avoid excessive trial and error experiments. Over the years, our efforts have naturally evolved to integrate all this basic and applied understanding.

25:54 Our Impressive Career – Working with Incredible Coworkers and the Help of Family and Friends

Pilchak:

Yeah. So, you've just described an incredibly impressive career. If you had to summarize some of your key accomplishments throughout that career, what would they be?

Semiatin:

Well, that's like saying who was my favorite child. Again, when you say my career, it's been our career, our team, our group's career, our colleagues' career. I've been fortunate to work with so many wonderful people, not only wonderful technical people but people who are friends. I think that we look at what's happened in the area of processing over the years, the evolution of what we now refer to as integrated computational materials engineering, or integrated computational materials science and engineering. It has not happened overnight. It's been evolving for almost the 40 years that I've been in the area of processing. So, I consider that part an evolutionary thing. We're now constructing an edifice to help industry by incorporating and integrating tools.

I would say the microstructure, defect, and texture tools that we've worked on are among the major things, as well as the introduction of new processes. The tech transition teaching industrial partners what can and can't be done has also been a major accomplishment of our team. I think just developing a mindset to get people interested in processing and understanding the need to couple processing knowledge with behavior and life prediction, I would say that was very important; I was very happy to make a contribution to that. I've been very lucky. Although I've been known to be somewhat of a taskmaster at times, especially when it comes to writing and communication, it's been fun. Without those friendships, though, and the help of family and friends during the hard times, all of this would have been impossible. I've just been very lucky.

28:30 A Society is as Good as its Members – Working with TMS, ASM, and AIME

Semiatin:

I must say I've also been very fortunate to have had the opportunity to work with technical societies. TMS, ASM, they've all been very helpful in developing these contexts that we've talked about. A couple of examples… I remember coordinating my first symposium, which dealt with shear bands in forged products in 1980. It was held in Chicago, I think, or Rosemount, whatever that little suburb of Chicago is. Having the opportunity to develop symposia and work within the committee structure has been very helpful, not only to develop me as a technical person but also to meet other people. TMS and, in some respects, some of the other constituent societies of AIME, has been very, very useful to me.

With regard to other societies, such as ASM, I've had the opportunity to work on a number of handbooks for ASM, a number of topical symposium proceedings for both ASM and TMS. All these things, networking with people, organizing information for use by others has been a very enjoyable experience. I would highly encourage our young members, be they TMS, AIME, or some or any other society, to take advantage of the opportunity that we have to work on a committee, to work as a conference organizer, or a topical symposium. In other words, to start something new because the society is only as good as its members. We're helped out quite a bit by the administrative staff, but we are the society, and it's up to us to continue the tradition. When I think about TMS, I remember my days at Carnegie Mellon, going down into the basement and finding these dark purple lavender volumes of Proceedings TMS-AIME, oftentimes blowing the dust off of them for volumes from 1910, 1920, and so forth. That was classic research.

30:51 Growing from a High School Engineer into an Inductee in the National Academy of Engineering

Pilchak:

So, Lee, you're a very modest man and not one to toot your own horn ever, as long as I've known you. But, have there been any great personal recognitions you've received throughout your career?

Semiatin:

Well, I've been very fortunate that our work has been recognized. I think in my early life, the work we did on gamma titanium aluminides with Rockwell International, as part of the NASP program, was rewarding. In recognition, Rockwell gave me an artistic rendering of the National AeroSpace Plane, a little wooden model. I still have that on my bookshelf at home. That was really nice. I think the recognition that I've gotten at Battelle for some of the process development, some of the patents, and seeing them introduced has been heartwarming. Both TMS and ASM have recognized our work through awards, such as the Bruce Chalmers Award and the Albert Sauveur award, and the ASM gold medal. I think from a team standpoint, AFOSR has recognized our work in-house through the star team awards five or six times.

I think the latter (AFOSR) recognitions have really been appropriate because of what we're doing has been a group effort. Being "anointed", so to speak, as a star team by AFOSR is a high honor for all of us. Also, I started out as an engineer in high school, and most recently, I was inducted into the National Academy of Engineering. Hence, my life has come full circle. I started out working in the foundry and forge in high school, and being inducted into the National Academy of Engineering was something that you may dream about, but very few of us get so recognized. Receiving that recognition was very touching. Especially when I see who else has been elected. Also, it's very nice because it's indicative of the fact that we, in the government lab, are doing something useful, not only for engineering but also for our country and for the international community, because a lot of our research is basic but involves both science and engineering. The theme of using science to solve engineering problems has been a main part of my life, my professional life. Hence, to be recognized by the National Academy was very nice, and I'm very appreciative of that. And, I hope that our staff realizes how much I appreciate their work and that they really have been an important part of my life.

33:47 Research is 1% Inspiration, 99% Perspiration – Students at the Air Force Research Laboratory

Pilchak:

So, you mentioned that there's excellent scientific staff, wonderful technicians working at the Air Force Research Laboratory, but I also know there's a lot of students there. Can you describe some of your interactions with some of the students?

Semiatin:

Yeah. We've actually had a very large number of students I've worked with over the years, both undergraduate and graduate students. The undergraduate students have been largely from the University of Dayton and from Wright State University, a few from Ohio State. I'm an Adjunct Pofessor at all three of those universities. The undergraduates work part-time in our lab. They actually do some of the grunt work at the same time that they get to see what real-life research is. It involves a lot of perspiration. I think it was Edison's well-known aphorism that invention or genius is 1% inspiration, 99% perspiration. So, it's very easy for somebody like me to have the inspiration, but still, we have to put in the perspiration, the sweat. I probably have had the order of 50-ish undergraduate students working with me over the years from the different universities. Most of those students have been mechanical engineers. Some were materials engineers, some were physicists, physics majors, some were chemists. We even had a pre-med guy from biology to whom we assigned work dealing with a characterization of microstructure using automated techniques.

Pilchak:

But they all sweat when you come in for a notebook check, right?

Semiatin:

Ooh, guilty as charged. That was a low blow, Adam. One thing we teach them (besides how to work in the lab and how to get good data) is how to organize their thoughts and their data. One of the things I used to do in the pre-electronic age was to make sure they had lab notebooks that were kept up to date with all the nitty-gritty details. Since we've become more electronic and everything is stored on our computers, I still like to have them organize their data on the computer, but it becomes less important because the files can be moved around more easily. But, I used to spring surprise checks of notebooks every once in a while, just to keep the students honest. And, to know that organization and accounting of your data, your observations is such an important part of research, because a lot of research, if you don't discover something new, being able to integrate it with other ideas is really important.

In other words, it's one thing to get a data point and another thing to integrate everything you observed and to obtain a holistic overview of a problem. So, we've had a great number of undergraduates work with us. A number of them have gone on to graduate school. Some of them have even gotten jobs with our lab after being a co-op student. That's been very, very exciting. We have a few right now who are very good. They always bring a fresh perspective, not only to the research but also how society is moving with regard to the interests of the young folks.

37:23 Adjunct Professor at the University of Dayton, Ohio State, and Wright State University

Semiatin:

I mentioned being an Adjunct Professor at Ohio State in the Industrial and Systems Engineering department where a lot of the processing research has been done, but I also have good contacts with the Material)s Science and Engineering (MSE department, as well as with the University of Dayton and Wright State University. My main role there, besides giving seminars, has consisted of advising MS and PhD students on thesis research, typically on problems that are of interest to the Air Force. A lot of those students have done some very interesting things and, in some cases, that research has been continued after the thesis has been completed.

So, it's been very nice to have access and to be welcomed by the universities, to work with their students. And, some of those students also eventually joined our lab, or, in some cases, they've actually been working in our lab, and they go back to graduate school. It's very good when you have a staff member who has an MS go back to school for a PhD. There's actually a couple of guys right now who we're encouraging to go back for PhDs, not only to these universities but to other universities as well. For instance, one of our students went to Michigan. I know you find that hard to believe being a Buckeye fan, me being a Buckeye fan, but, yes, we even will send a student to Michigan.

38:53 Advice for a Graduate – Apply Yourself, Work Hard, and Avoid Politics

Pilchak:

So, if you were going to recommend something to a graduating student, what might you tell them?

Semiatin:

Pardon?

Pilchak:

If you were going to recommend something to a graduating student, what might you tell them? What would you leave them with?

Semiatin:

Well, a couple of things to wax a little philosophical. When I finished my PhD at Carnegie Mellon, I had a conversation with Professor Low, who, at that time, was, I think, 70 years old, about the age I am now. And, he gave me some advice. The experience was sort of like that of Dustin Hoffman in the movie The Graduate, in which the advice he was given was simply, “plastics”. In my case, Professor Low said, “Whatever you select, apply yourself, and stay out of the politics. Just apply yourself, and work hard.” So, from a broad perspective I would say, focus on something that you like and work at it very hard. I think your advisor, Jim Williams, said something similar. He said all good things come to those who wait, as long as they work their butts off while they're waiting…but he used a different word than butts!

I think that's a very important thing to keep in mind. Be patient, and when you enter a field, if you enjoy it and you apply yourself, and you're honest, good things will come to you. With regard to specific technical areas, I think the area of modeling and simulation is still very important. It's a good framework, but I still believe strongly in doing problems that have a strong industrial flavor and that have some utility to them.

40:34 Importance of Basic Research to Solve Industrial Problems

Semiatin:

I'm a big believer in doing basic research but doing that basic research to solve an industrial problem. It's a lot of fun to transition things. I'll never forget Rollin Hook from Armco; when I was interviewing, when I was talking to him for a possible position at Armco, he told me that he really enjoyed the basic research in low carbon steel, but the one thing that he was most proud of was the fact that he was able to develop the interstitial free steel in the lab and transition it to industrial use, to make tons of it.

Rollin was challenged because the cheapest alloying element was actually being used already; the Japanese had a patent on it. So, he had to find another alloying element that was not quite as cheap, but he still managed to get the management to buy into, and he was successful. The ability to follow some research from A to Z, I think it's exciting. There are a lot of problems. Still, even in aerospace metals, the monolithic systems, a lot of work being done is interesting, but I think you have to keep in mind the transition path or how you're going to transfer it to a product, to scale up something.

It's one thing to make a shape. To actually make stuff, but you should always ask yourself who is the customer? If I was talking to a young person right now, I would say, keep in mind who eventually has to use this. Is it competitive, cost-competitive? Does it satisfy a need? And, if that's the case, then put your heart into it, do the basic research, and understand what you're doing, and have fun. If you don't have fun, don't do it. I remember I took one materials course as an undergraduate at Johns Hopkins when I was a mechanics major. It was taught by someone named Professor Robert Pond, Sr. Coincidentally, I had the honor to give the Bob Pond lecture at Johns Hopkins 10, 15 years ago. In his day, Bob Pond had a series of lectures; I think it was called Fun with Metallurgy. He used to wear an aluminum bow tie. Bob Pond epitomized the importance of teaching and having fun. So, I think there's still a lot of opportunity for having fun via work on a conventional as well as an emerging material, be it a conventional or emerging process. In other words, I would strongly recommend people look at the materials field for a career in the future still.

43:14 If You Don't Have Fun, Don't Do It – Satisfying My Intellectual Curiosity

Pilchak:

So clearly, you've had a lot of fun.

Semiatin:

I've had a lot of fun. Yes.

Pilchak:

So, what has been your favorite part of working in this field?

Semiatin:

From a personal standpoint, I think satisfying my intellectual curiosity. I am a very curious person. I was born in December, at the end of December, as I mentioned earlier. I'm a Capricorn. I don't give up easily. And, one thing that I've always kept in mind is how amazing the universe is put together. Even at the micro-scale of materials, or the mesoscale, it just amazes me, and it affects how I approach life. The wonder of metallurgy, it goes hand in hand with the wonder of life, I guess. I know that sounds a bit philosophical, but it really is true. I have a hard time seeing how anybody who has spent years in research, engineering, and science cannot be in awe of the world around him or her.