Interview with the winner of the 68th "Kahoku Culture Award" /Takeo Ebina (Prime Senior Researcher of AIST Tohoku Center) "Contribution to the Tohoku region through development and industrialization of the film material 'Claist'"

Actively utilizing the blessings of nature, for sustainable manufacturing with low environmental impact

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The 68th (2018) Kahoku Culture Award was given to Takeo Ebina, Prime Senior Researcher of the Chemical Process Department in the AIST Tohoku Center, for the development of "Claist®." Claist is a high-functioning film material that uses clay as its raw material, which is produced in abundance in the Tohoku Region. The award was also given for contributing to Tohoku industries through the industrialization of the material. Claist is a flexible material, in which plate-shaped clay crystals of a thickness of 1 nanometer (1 billionth of a meter) are elaborately layered. As a film material, it has high gas barrier properties and heat resistance not seen in conventional materials, and is being commercialized in products in a wide range of industrial fields. We interviewed Prime Senior Researcher Ebina, the “father” of Claist, on the circumstances involved in its development and the concept(s) behind the research.

１．Development of the High-Functional Clay Film “Claist” and Contribution to Industrialization in Tohoku

－　Congratulations on receiving the Kahoku Culture Award on this occasion. How was “Claist”, the clay film material for which the award was received, developed?

◆ Making clay, produced in abundance in Tohoku, into barrier materials

In 1993, when I first joined the Government Industrial Research Institute, Tohoku (※), this was already being tackled as a laboratory theme. I researched the clay known as “bentonite,” which is abundant in the Tohoku region.

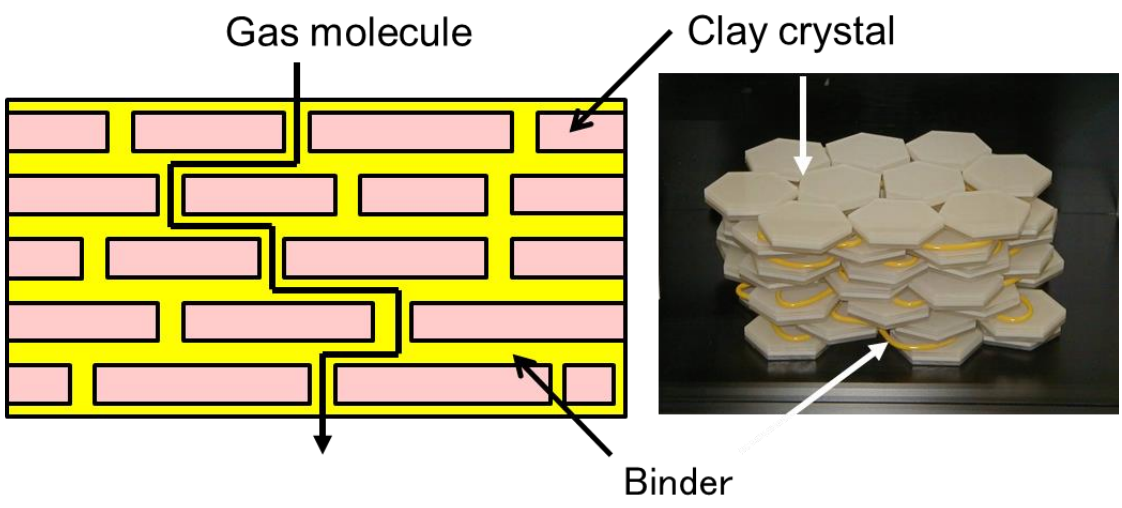
※　The National Institute of Advanced Industrial Science and Technology (AIST) Tohoku Center started as the National Tohoku Craftworks Institute (1928), and became the Government Industrial Research Institute, Tohoku, before its name was changed to the AIST. The organization was renamed the AIST Tohoku Center in 2001.

Ebina-san collecting samples at a bentonite mine (Kawasaki City, Miyagi Prefecture)

Generally, when we think of clay, I think the prevalent image is one of earthenware; however, bentonite is not suited to earthenware. Bentonite has characteristics such that it thickens water (water retention), making it difficult for water to pass through (impermeability). We researched bentonite to see how, by utilizing these features, it could be used as an inundation barrier material to prevent the leakage of harmful substances from waste disposal plants.

◆ Improving barrier properties by thinning clay specimen

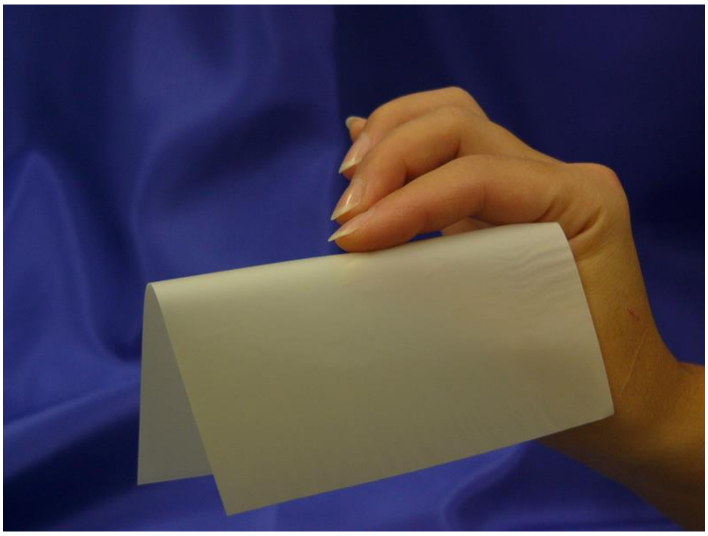
We first measured its water barrier qualities by sampling a mass in which bentonite had been consolidated. However, as the water did not soak through, no matter how long we waited, we decided to make the sample thinner. When doing this, the result was surprising in that, the thinner we made the bentonite layer, the slower the speed at which water passed through. Moreover, its barrier features were greatest when thinned to a film form. We discovered that the reason for this is that, with plate-shaped clay crystals of a thickness of 1 nanometer, it becomes easier to lay them out orderly in one direction, and by overlapping multiple layers, this plays the role of a “blocking plate.”



Structure of clay-based-film and its gas barrier mechanism

◆ The start of research of film using clay

In terms of industrial uses, there is an extremely high needed for “gas barriers” that prevent gases from passing, and it is well-known that the gas barrier features can be enhanced by mixing clay in plastic. Additionally, contrary to plastic which melts and is flammable at high temperatures, clay has high heat-resistance. Therefore, the idea arose of putting clay to practical use as a heat-resistant barrier material that could be used at high temperatures without using plastic. Furthermore, in 2003, my boss at the time, Fujio Mizukami, instructed me to investigate high-pressure hydrogen gas sealing materials. Following this, as a result of testing the performance of the clay, we became aware of its high heat-resistance and strong gas barrier qualities.



Flexible clay film. It was given the name CLAIST® as a combination of "CLAY" and the English abbreviation for the National Institute of Advanced Industrial Science and Technology (AIST).

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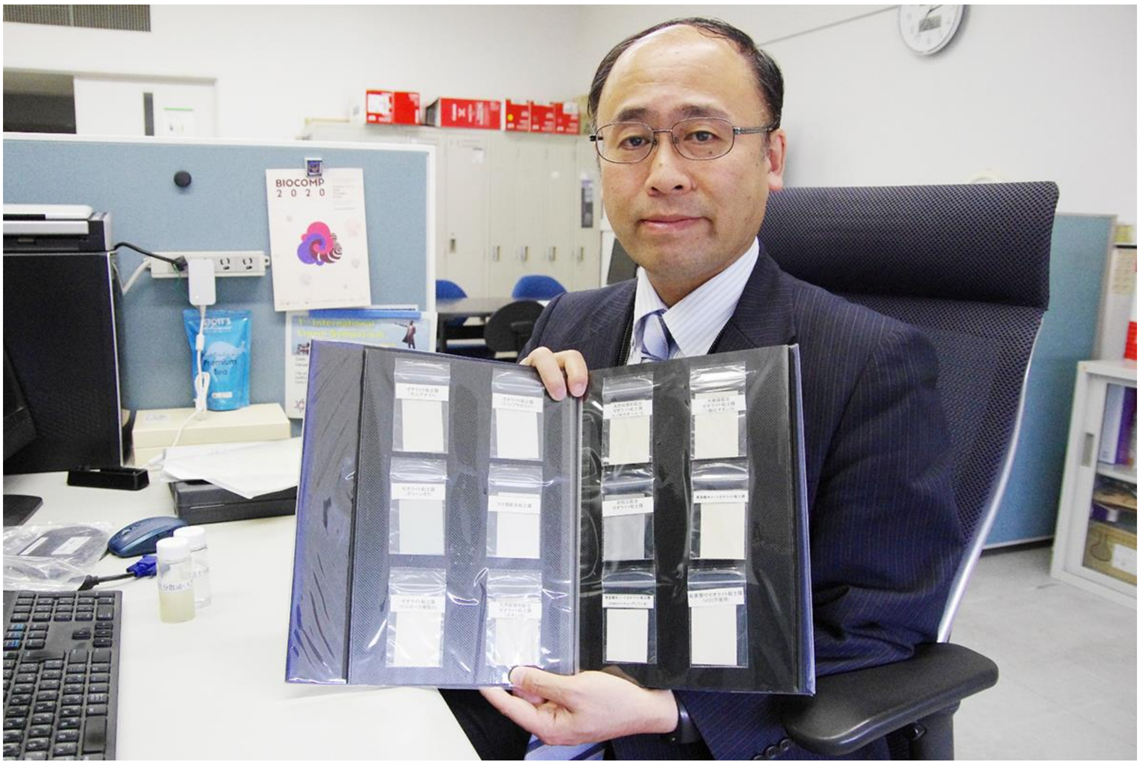
— **How did you link the clay film materials you developed to practical applications?**

◆ **Active development of barrier functions for industrial use**

Since 2004, as the seeds of the AIST in terms of clay film as a heat-resistant barrier material, we actively promoted it with press releases and exhibitions, etc., and asked the wide-ranging question "in what ways could you use this new material?" By 2010, we had received approximately 400 domestic and international technical consultations, and based on this information, we built a strong group of patents.



Clay film sample book. Various trials, from zeolite clay film to oyster shell blended clay film etc. have done.

◆ **The first product was a replacement material for asbestos**

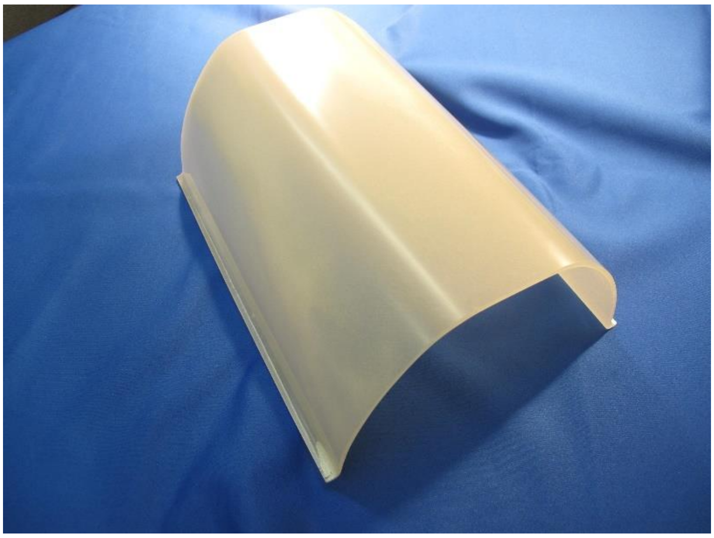
The first commercialization initiative for Claist was the development of a gasket that did not use asbestos. Until that point, asbestos had been used as the sealing material for what was known as a gasket, that filled the gaps in the connections between industrial pipes to prevent gas leaks. Due to its effects on health, the development of an alternative material had been urgently sought. For that reason, we started joint development of an asbestos alternative gasket with Japan Matex (Osaka). The product was successfully developed in 2007, and it has been widely introduced in power plants and chemical plants.

Gasket coated with Claist that does not use asbestos (Japan Matex)

― What kind of contribution has been made to Tohoku through the industrialization of Claist?

◆ Combine Tohoku olignated raw materials with technology

The clay used as the raw material and technology were both made in Tohoku; we wanted these seeds created in Tohoku to be used by Tohoku regional companies, thus contributing to the revitalization of the region. Based on this, we carried out joint development with Miyagi Kasei (Miyagi Prefecture) on a non-flammable plastic material. It required 6-7 years for commercialization, but we succeeded in the development of non-flammable, non-breakable light covers with high levels of safety that could be used for ceiling materials in the "shinkansen" bullet trains.



Non-inflammable lighting cover（Miyagi Kasei）

Additionally, we carried out joint development on craft products that could be washed in a dishwasher, with TOHOKU KOGEI Co., Ltd. (Miyagi Prefecture). Clay and plastic were mixed at the nano level to develop a nano composite coating that could be used as a protective film for the Miyagi Prefecture-designated traditional craftwork "Tamamushi-nuri," and we were successful in commercializing a "Tamamushi-nuri" product that could be washed by dishwashers. This also required approximately 6 years before commercialization, but we were able to nurture a product that still receives a lot of enquiries to this day.

dishwasher-compatible Tamamushi-nuri（Tohoku Kogei Co. Ltd.）

When developing products, I think it is very difficult to create case studies where the resources are in Tohoku, the research is carried out in Tohoku, and Tohoku companies are successful in commercialization using that technology. However, on this occasion, we were fortunate to meet a wide range of people and create products consistently with Tohoku-olignated-materials, technology, and companies. I think that this was highly rated and led to me receiving the Kahoku Culture Award on this occasion.

2. Long road to "Technology Bridge Building"

— Creating new technology itself is not simple, and success stories where a practical usage is created for the developed technology are said to be extremely rare. I think that to "consistently achieve this with Tohoku-oliginated-materials" would be even more difficult, so what kind of challenges did you have to overcome to find a practical use for your research and development?

◆ Time is required for "Technology bridge building"

The main mission of the AIST is "technology bridge building." In the stage of bringing the developed technology to commercial fruition, commercialization will not be possible unless the surrounding technologies develop at the same time, so it may seem at a glance that nothing is actually happening. This is the so-called "valley of death." For AIST, we need to overcome this "valley of death," and looking at what ways research and development could link to practical application, we attempted the methodology of integration through the initiative of starting a laboratory. For me, there was the fact that we innovated to reduce the research and development period as much as possible. Even so, on reflection, it requires approximately 6-7 years to commercialize the developed technology.

◆ Water resistance of clay film was the greatest barrier

It is said that material development takes 20 years. The truth is that I was not the one who first developed clay film itself. In 1937, a researcher at the Massachusetts Institute of Technology (MIT) proposed a material called "AlSi film" made of aluminum and silica. The material was introduced in a renowned US news magazine as "usable as a permanent and eternal sheet material." This material was virtually the same as the clay film that I made, and its use was investigated as an electric insulation film. However, I have not heard that it reached the commercial phase.

— Why did the clay film proposed in 1937 not reach the commercial stage?

In addition to the fact that there was no significant need for gas barrier film at that time, water resistance was also considered to be an issue. The issue of water resistance was the final and greatest barrier to my research and development.

Claist can be made using a simple method in which water is added to the powder, which is the raw material, to make a paste that is like paint; this is then applied to flat boards, and dried before being peeled off to create a film. Up to this point, there was no problem. The issues came after this point. As it characteristically dissolves in water, the clay becomes a film; thus, after it has become a film, there will be issues if it is once again dissolved in water. Despite the fact that its dry gas barrier properties are extremely high, as it has low water vapor barrier resistance, there was the fatal problem that clay film could not be used as an industrial material.

Ebina-san providing an explanation while holding the bentonite, the Claist raw material, as paste dissolved in water

Earthenware is heated to extremely high temperatures in such a way that the nature of even inorganic crystals change, so that it does not dissolve in water; therefore, it does not have the problem of water resistance. However, when using clay as a film, if it is baked at very high temperatures, it becomes flakey and unusable; thus, there is an issue such that, to use it in its soft state, high temperatures cannot be used. Due to this, even after developing the clay film, there was the task of working out how to make this water-resistant; this, in fact, took the longest time, requiring 5 to 6 years.

◆ Development of an original clay film, with the three features of heat resistance, gas barrier properties, and water resistance

— How did you resolve the contradictory issues that, to make a film using the properties of clay that does not dissolve in water, it was necessary to change its properties to not dissolve in water?

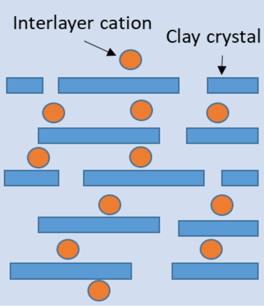
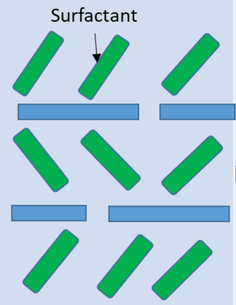
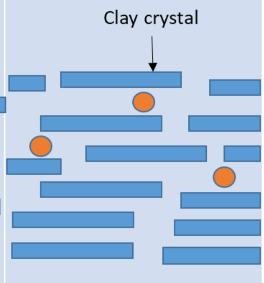
Was there not even one clay in the world with water resistance? In fact, there was one even at that time. Originally, clay is an inorganic compound; however, there is the method of "organic clay," in which an organic substance known as a surfactant is attached to the surface. Using the surfactant, the originally hydrophilic clay surface is changed to a hydrophobic surface, and the typical method at the point involved pre-processing in which, by mixing this into an organic solvent, it would not dissolve in water, and the clay would become water resistant.

However, when the clay is organically modified, a different and serious problem occurs. Despite the fact that the original advantage of clay was that it could be used at high temperatures in which plastic cannot be used, when a surfactant is used, it can no longer be used at high temperatures. Additionally, as the extremely strong gas barrier properties of clay film are a mechanism generated by layering plate-shaped clay crystals without gaps in a single direction, we realized that if an organic substance is attached to it, the clay crystals cannot be stacked in close proximity, and so the essential gas barrier properties do not increase.

That is to say, each method has advantages and disadvantages. Clay used as an inorganic substance can be used at high temperatures and has strong gas barrier properties, but dissolves in water. On the other hand, organic clay does not dissolve in water, but cannot be used at high temperatures and does not have strong gas barrier features. In other words, it was very difficult to develop a clay film containing all three features of heat resistance, gas barrier properties, and water resistance.

The clay developed at the end of this struggle had the same appearance as the clay up to that point; after the clay was made in the same aqueous way as before, it was made water resistant by applying a fixed amount of heat (approximately 100-200℃). This clay is called "heated water-resistant clay." As organic substances are not used, it can be used at high temperatures, has strong gas barrier properties, and does not dissolve in water. This development, which succeeded in 2009 was, in fact, our original technology, and this was a factor in the spread of the use of clay barriers. This heated water-resistant clay was also used for a "non-flammable lighting cover" developed jointly with the aforementioned Miyagi Kasei.

Comparison of conventional clay and water-resistant clay induced by heating

	Purified bentonite	Organized clay nanomaterial	Water-resistant clay nanomaterial
Maximum working temperature	600-700℃	200-400℃	600-700℃
Dry-gas barrier	High	Medium	High
Water vapor barrier	No	Medium	High
Water resistant property	No	Medium	High
Model structure (binder omitted)			

Comparison of previous clay and heat-resistant clay

◆ **If we are going to do it, we want to control the whole process until sales**

Even in the commercialization stage for newly developed technology, various new problems occur. For example, there may be process issues, such as "I need to model it in this shape," or other problems, such as "after it is made, I need the film to not peel off even if it is cleaned." In addition, the issue of cost always arises when commercializing the product.

Tamamushi-nuri is a product that also pursues beauty, so that customers will look at it; therefore, if we as researchers blithely say that "this level of beauty is probably fine," this will not work. If the appearance is white, it cannot be used, so in order for it to clear the hurdle of having beauty while maintaining its protective functions, we had to spend significant time on development.

As various problems such as these will always occur in the commercialization stage, it is surprisingly difficult. Then we have to go back to the raw materials, and there is a lot of to and fro, so naturally this takes time. Research for commercialization does not just end with writing a paper, and the feeling of wanting to control the process until the sale is a strong one, so we make sure to take adequate time at the stage where the link is formed with the company. The result of this is that it takes 6 to 7 years.

◆ AIST as the source of the Industrial Arts Institute, the origin of design research

I would like to take the discussion back again; on the "Sendai Design History Museum," website created by Professor Akiko Shoji of the Tohoku Institute of Technology, it states that the AIST Tohoku Center was the source of the Industrial Arts Institute, a national institution handling lacquerware, woodwork, and industrial design. Additionally, we were able to learn how to manufacture "Tamamushi-nuri" at Tohoku Kogei Co. Ltd.

The company, what would now be called a venture company, started by the Industrial Arts Institute, is carrying out the ambitious initiative of blending crafts with cutting-edge materials, and even though this was before the war, we can feel their vigorous pioneering spirit as something even freer than what we have now. Therefore, thinking that "history is not something we should learn but something we should utilize now," I visited the showroom of Tohoku Kogei Co. Ltd without an appointment, and proposed to Ms. Midori Saura, who was working there, that "we should do something together," whereupon we started developing the aforementioned dishwasher-compatible earthenware.

As the AIST Tohoku Center was the source of the Industrial Arts Institute where the design research originated, we wanted to include design as part of our appeal. As this is a new material, it will not be possible to make it cheaply at the beginning; however, as we are aware that designs that are recognized by users as having high-added value are strong, we aim to add design elements to our manufacturing to achieve higher added value.

3． Motivation to overcome the "valley of death"

— What is your motivation to overcome such huge obstacles?

◆ It is because we run together that we have no awareness of giving up

The reason I could give my all was because there were people jointly researching with me on the company side that were also giving their all. When talking to those enthusiastically carrying out in-house development, and receiving their expectations as well, seeing as our work is "technology bridge building," I feel the need to make sure I pass on the baton reliably. Rather than running solo, we have a strong feeling that we are running together, and that provides me with the mental support I need to carry on.

The President of Japan Matex at the time, President Katsuro Tsukamoto, with whom we first collaborated to commercialize Claist, has an extremely bubbly personality; I was affected by President Tsukamoto's guidelines for action, namely to "do it now, do it as much as we can, and definitely do it." This is the so-called power of the mind, but when President Tsukamoto said that we "can do it," it really became commercialized in the product. Dragged forward by President Tsukamoto's unyielding conviction, I was able to move forward without flinching at all. The same is true now.

Put the opposite way, unless I tackle the issue while believing within myself that "I can definitely do it," I will not be able to succeed. If we divide this based on the number of inquiries, approximately 99% do not become products. Additionally, the probability of commercialization after R&D, with joint research, etc., officially begins is only about 1/5. If we think of this as a batting average, that is only around 20%, and this corresponds to a batter who is not really up to the mark. Having said that, from the start, the idea of failing is nowhere near my mind. We just need to keep accumulating success stories one by one.

◆ The reason I do not become discouraged can be found in the clay itself

There is another “reason I don’t get discouraged” that is peculiar to me. The answer to this can be found in the clay itself. Bentonite is said to be a “material with a thousand uses.” To say it is used in a thousand different ways industrially would certainly be untruthful, but in terms of potential it is true in a sense. This is because it can be used in a number of different ways.

The reason is that, first, there is a large amount of it around the world. Further, it does not need to be synthesized one by one. Additionally, bentonite is so safe for humans that it can practically be eaten. The cost, of course, will increase as you handle it more meticulously, but in terms of digging and collecting it, it is not an outrageously high-priced item. There is also the fact that, as stated earlier, it also has features such that it can be mixed with water, and by modified organically, it can be mixed into an organic solvent, so it certainly has a lot of potential.

It would be hard to think of such a functional material. Normally, when making a new material we are struck by the question “what can we use it for?” With bentonite, however, we were told from the start that it is a “material with a thousand uses”, so we think “it can definitely be used for something, so we just need to find a use for it”. We know that it is not impossible, so we can develop it without giving up.

The fact is that, in the world of researchers, there are certain trendy research themes that researchers are concentrating on, so even if the researchers actually know that it will not become a product, when writing their papers, they put in the epithet that “this is attracting attention as a material for ____.” The reason for this is that they are research professionals. On the other hand, before starting the research, there may be materials for which we know that “if we develop this seriously, there may be many uses for it,” and I want to be involved in the latter type.

4 . The starting point of my research is that “I want to do a job that saves the human race from extinction”

— Rather than research that is widely praised by the world of researchers, what is the origin of material R&D linked to commercialization in the industrial world?

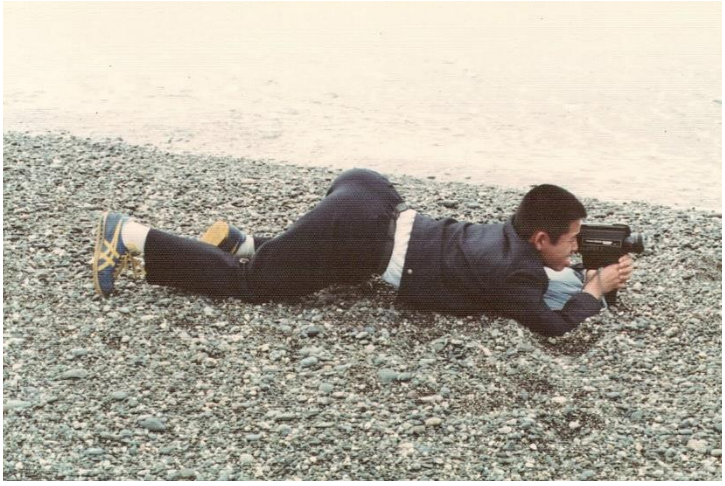
◆ **At the age of 18, I decided to "save mankind from extinction"**

I need to take the discussion back to my high school days. In 1979, I was invited by my advisor, Dr. Masao Taguchi, to enter the Biology club of Kanagawa Prefectural Hashimoto High School. In the Yato (ravine) paddy fields, when researching the population ecology of dragon flies, I learned to use the catch and release method for field work. I then published this at an academic meeting, and learned a research methods here.

Ebina as a young man, in the second year of high school, holding an insect net in the club competition relay. "This is about the only photo I have from my club activities."

At that time, seven years had passed since 1972, when the international study/proposal organization "Rome Club" had published its "Limits of growth" report. Until then, the impact of human activities on the global environment were not considered to be that significant; however, around this time, people began to consider the significant impact on ecosystems at the global level and the depletion of resources. At that time, I was a high school student; however, thinking of my future, I decided "I want to save mankind from extinction."

Around the age of 18, I produced an 8-mm film called "Mankind and the environment-balance of global systems." At that time, I went "on location" to a site called "Yume-no-shima" (currently in the vicinity of Shin-Kiba), and expressed my thinking regarding recycling through the medium of film. Basically, the theme was "saving mankind from extinction." For that reason, I felt I had to become useful to the world, and "research for research's sake" was not consistent with what I wanted to do.



The young Ebina on a film shoot. "This is a photo from around the time I woke up to the fact that I needed to save the world."

５． "Megumi manufacturing" which actively utilizes the blessings of nature

◆ Proposal of "Megumi manufacturing" in 2010

If we calculate the average composition of the earth, the material I have developed is almost the same. Therefore, when sampling, we just need to collect it from the earth, and when disposing of the same, we can just dispose of it on the earth's surface; thus, there is no burden on the environment. Aiming to realize a sustainable society, in 2010, we proposed "Megumi manufacturing," which utilizes the composition, function, and shape of such natural inorganic materials.

For example, weight stones are not weight stones unless they satisfy particular conditions. First, in terms of the shape, the bottom surface must be flat to a certain extent, so that they can be stacked, and the place they are held needs to be smooth. Furthermore, while you can add a certain amount of weight, they must not be too heavy to the extent that they damage one's back. Weight stones can be collected in a dry riverbed, and can be disposed of there again when they are no longer needed. If weight stones could be artificially made, this would be a troublesome exercise, but this can be done naturally using the power of the river.

Similarly, with clay, the stones are weathered in the beginning; then, while being rolled by the power of the stream, they become fine sand, and sediment. This sinks deep into the ground, and with heat and the addition of water, this becomes a natural reaction tank, and the material becomes nano particles known as clay. These clay nano particles, which are safe for humans, become clay without humans needing to do anything, so when we made the film, the film was very clean. It is this low-environmental impact sustainable manufacturing, which actively utilizes the blessings of nature, that is "Megumi manufacturing."

◆ Using the foundation of experience with environmental purification in graduation research

The concept of "Megumi manufacturing" was based on experience with measures carried out for acid water at the Matsuo mine and rectification at the Kitakami river carried out during graduation research at Iwate University. Professor Tatsuo Goto of Iwate University carried out treatment for the neutralization of acid water flowing from the Matsuo mine, succeeding in the rectification of the Kitakami river, and I also participated in the water analysis. Normally, it is not considered possible for us to control the surrounding world, but I think that it was through the experience of creating neutralization treatment facilities, and achieving environmental purification, that we were able to put the concept behind "Megumi manufacturing" into words.

— So, moving forward, you want to promote R&D and commercialization based on the theme of "Megumi manufacturing," right?

◆ Accumulating research based on the multilamina of sea flows

Yes, I think that I want to consider the multi-layered nature of research like the multilamina of sea flows. My job is, basically, like looking at surface waves. Surfers look for chronological changes in waves to avoid falling from their surf boards when surfing, and this daily resolution of issues, to fix the approach, and avoid being sucked in by the waves, comprises approximately 80% of my R&D. In contrast to this, I think tides would be a national project of between four and ten years. Additionally, the flows of "Oyashio" and "Kuroshio" are more gentle flows, but in the sense that the direction is determined, I think that I would like to make Claist and biomass my life's work. Actually, it appears that there are even deeper flows that take a thousand years to do a lap of the world, known as deep ocean currents, and there are things that need to carry on even when I die. That is "Megumi manufacturing." "Megumi manufacturing" refers to flows at the most fundamental level, so the respective directions will not necessarily be the same. I myself do not see this as doing anything contradictory, and this can be resolved within the same flow.

◆ Research is a lighthouse collecting people and shining afar

When considering the hierarchical relationship of the multi-layered flows, I have the image of myself as a lighthouse. As is demonstrated by the phrase "it is hard to see what is under your nose," it is dark directly under the lighthouse, but the lighthouse shines afar. Research has to attract people and shine afar, so if we consider this vertically, research must indicate the depths rather than the surface.

In other words, what I want to say is that even if the daily work you are involved in every day is at the surface, the researcher is able to point to the light in the distance. Beyond that is "Megumi manufacturing." Even if the respective layers are not directly connected, if you look in the distance, and propose that you want to perform R&D, gradually people will begin to look in your direction. It plays this role. I try to understand it myself in this way and normally conduct my research in a way that focuses on problem solving.

◆ Thinking based on the experience of the Great East-Japan Earthquake

After the Great East-Japan earthquake occurred in 2011, we finally restarted our research and development after a delay of approximately six months for the recovery. What I thought when experiencing the earthquake was that "whereas nature both gives and takes away, the fact that nature gives means that people will return." These activities do not cease, and whereas they are not ever completely solved, I think it is important to consider in what way we can make use of what is produced naturally.

Since 2016, we started joint research with the Forestry and Forest Products Research Institute on practical uses for wooden materials. With a disaster that affects not only the sea, but also the mountains, how we protect and use the limited forestry resources is very important. It is as a result of being in the Tohoku Center, that I have been able to experience this. I hope that I can continue confronting nature through R&D in the Tohoku region.

◆Approaching the 10th anniversary of the foundation of "Clayteam"

The clay film developed in 2003 has reached a certain level and been put into practical use; however, many technical and economic issues remain in terms of its use as a general-purpose material. With the objective of resolving this situation, we established the "Claist Liaison Group" in 2008; as the number of members rapidly increased, we established "Clayteam" in 2010 as an AIST consortium. In collaboration with private companies, we provided clay as a raw material and clay-related technologies, collaboration and coordination, joint research, and support including product evaluation, and this contributed to a marked acceleration in the speed of research and development. 2019 is the tenth anniversary of the establishment of "Clayteam." During this time, we have successfully developed many products using nano materials, such as clay. Nano tech business with nano-based added value functions are forecast to lead to sustained growth moving forward.

Finally, I have been fortunate enough to meet and receive the help of a large number of people related to AIST. However, as I meet current AIST staff every day, I am somewhat embarrassed to mention them here, so I will save this for a separate occasion.

— Thank you very much, Ebina-san.

Appendix:

At the New Functional Materials Exhibition 2020, we exhibited an aircraft made of almost wood in Tokyo from January 29 to 31, 2020. The aircraft commemorates the 80th anniversary of Tendo Co., Ltd., the 10th anniversary of Clayteam, and the establishment of the Lignin Network. The craft uses advanced woodworking techniques. The wood is highly durable due to compaction impregnation techniques and coatings containing clay. FRP consisting of plant fiber and cedar extract is used for the wings. The cockpit is equipped with high-resolution speakers with vibration parts made of clay and cedar, and the control stick is equipped with a high-sensitivity strain sensor that can control the rotation of the propeller. The propeller has a hard coating containing clay. Parts are made of natural / synthetic materials, mixtures / pure substances, etc. in good balance as raw materials. This aircraft is one of the ideals of our future manufacturing.

Wooden airplane