KUREHA

The Art of Manufacturing

Avoiding pitfalls along the royal road

To Our Employees

The current turbulent economic environment has provided a suitable backdrop to reconsider Kureha's identity. I would like to share with you my thoughts on the direction I believe we should be taking as a company.

Kureha has historically proclaimed to be a company built on technology. Simply put, I believe this to be a way of considering how the company exists through manufacturing rooted in chemistry. I have given much thought to my ideas on Kureha and "The Art of Manufacturing," and it is my sincere hope that this booklet will be an inspiration for you to join me in contemplating the meaning of Kureha.

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President &
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Introduction

Industry around the world is still coming to terms with the economic turmoil precipitated by the financial crisis in the United States, and it is likely that the scars will take several years to heal. The events that unfolded constitute more than just an economic shock. As the dust begins to settle, we can see that values have been fundamentally changed. Aside from witnessing the collapse of the speculative financial bubble, it also became apparent that the industrial world was locked in excessive competition and the pursuit of overly sophisticated products, ultimately exposing a business environment that fostered prosperity without profit. What we have seen, I believe, is the collapse of a "technology bubble" as the result of too many companies investing in research and development in the same technology fields.

In the auto industry, more people are coming around to the view that environmentally friendly vehicles are a smarter choice than large gas-guzzlers, which has consequently shifted the spotlight to electric vehicles.
A friend of mine, a university professor, is conducting research on an electric car (the Ellica, an eight-wheeled vehicle that can reach speeds of up to 370km/h). Almost twenty years ago, when he was working in a national environmental research institute, I remember him saying, "The era of the electric car will inevitably arrive, and when it does the world's technology will undergo a dramatic change."

He argued that the leading horse-drawn carriage companies in the 19th century did not transition into automobile companies of the 20th and, similarly, today's top automakers may not emerge as the leaders in the electric vehicle era. The reason, he said, is that the core technological components differ. For makers of carriages the primary focus was on developing a structure that offered passengers a comfortable ride, whereas in the early years of the automobile the basic proposition was producing an efficient engine and transferring energy to the wheels. Carriage manufacturers were unable to adapt to the revolutionary technological shift and as a result failed to evolve. Today's leading automakers must attempt to overcome similar challenges. Rather than tackling conventional challenges such as the transfer of energy, my friend foresaw electric vehicles opening the door to technical possibilities, such as positioning electric motors in each wheel. With everything electronically controlled, external control

Electric vehicle, "Ellica"

should be relatively simple. Vehicles could even theoretically be controlled via satellite, making it possible to resolve issues such as drunk driving and traffic jams. These remarks twenty years ago have recently begun to take on a newfound reality.

Further considering the implications of such a shift, if the energy source for electric vehicles is derived from renewable sources such as solar or wind generation, the world's industrial framework would be entirely transformed. The current economic crisis could, I believe, trigger a revolution in global industry on the scale of the Industrial Revolution in Britain that followed the invention of the steam engine, or the IT revolution in the U.S. that accompanied the emergence of the personal computer. The era we are entering may come to be known as the "Environmental Technology Revolution."

It is often said that Japan should leverage its technological and manufacturing strengths to meet today's global challenges. This is a natural opportunity for Japan, which has been acclaimed for the way it has overcome a lack of natural resources and achieved prosperity based on its technological prowess. I hope that the coming Environmental Technology Revolution will be thought of as having started in Japan.

Two Types of Manufacturing

Thinking about how Kureha, an acknowledged world leader in technology, will survive in such a world naturally leads one to question the nature of Kureha's fundamental approach to the art of manufacturing.

I have recently come to believe that there are two basic approaches to manufacturing. If asked for an example of the representative style of manufacturing in Japan, most people would immediately think of companies such as Toyota or Sony. These companies produce complete, finalized products. The key concern, therefore, is whether products meet consumer needs. It is essential for such firms to adopt market-oriented business strategies that are easily understood by ordinary consumers. Japan's strength has been to use its inherent diligence and skill to create sophisticated products of high quality. Even though the period of rapid growth has ended, I believe this ability remains fundamentally unchanged. The manner in which emerging countries have caught up recently has been remarkable, causing a certain amount of anxiety for Japan over the manufacturing capabilities that it prides itself on. However, Japanese manufacturing is still paramount in terms of offering the most advanced products and assured quality.

Hunting-Style Manufacturing

The manufacturing approach adopted by makers of automobiles, appliances and electronics is fundamentally assembling technology. Manufacturers procure the necessary components and use their technology to assemble the product and deliver it to the world. This approach is what I would call "hunting-style manufacturing." Hunters have a range of unique characteristics, but the core points related to business are:

1. Pursuit of prey (consumers)

Hunters move by nature, and when their prey disappears from one hunting ground (market) the hunters move to another. When there is a change in the climate or season (shift in the business environment), hunters respond by pursuing prey that has adapted to that change.

2. Sensitive to trends

Successful hunting is dictated in large part by awareness of the behavioral patterns of prey (accumulating consumer data) and providing the preferred type of bait (new product development).

3. Vigilance in maintaining tools and implements (production machinery, logistics network, product features, etc.)

Hunters constantly ponder ways to improve the capabilities of their tools (upgrades and continuous improvements, or *kaizen*) in order to enhance the effectiveness of their hunting (business efficiency).

Consumers of final products are the prey in these examples, and exercising maximum ingenuity to catch the quarry (consumer) is a natural course of action. To catch large numbers of prey, hunters need high-performance tools and must use inventiveness and creativity to improve the capabilities of these tools (product strategies). The importance of compiling information on the prey's location and habits (market research) also goes without saying. To efficiently capture prey it is also of course essential to have the right kind of bait and high performance implements (attractive products, prices and features). Looking at it this way, I feel that assembly-style manufacturing represented by the production of cars or televisions could be considered "hunting-style."

Farming-Style Manufacturing

The opposite of hunting is farming, which has characteristics similar to the materials manufacturing industry. From the standpoint of new materials development in particular, the following traits seem apparent:

1. A consistent location (or technology base for specialty fields) where one harvests what has been grown when the time comes

Farmers plant seeds, water, endure storms and wait patiently for their crop to bear fruit, gaining the harvest they seek (products) as a result of relatively long-term, planned action (new materials development plan).

2. Sensitivity to price information for crops

Because the crop (new material), rather than being consumed as is, only begins to increase in value once transformed into a meal (final product), information on how it is used to create a particular flavor (material characteristics and performance) is important. In effect, the consumer of the harvest is the chef (assembler) that uses the ingredients to prepare a meal, rather than the end customer. The needs of the chef (considerations regarding quality, performance, price and stability of supply of the material) become the market needs.

3. Place value on development of new types of crops (new materials)

As the world evolves (consumers with more discerning palates), valuable components become important, i.e. those ingredients (new materials) essential to make appealing meals (products).

Analyzing the process of new materials development more closely reinforces the sense that the materials industry is a farming-style business. Technological progress opens doors to new technologies and materials or enhanced capabilities from existing ones. Inventions and discoveries are the starting point to generate something new. Nothing can begin otherwise. This is the same as growing crops, where everything begins only when a seed is planted and germinates. Even if the seed germinates properly, it must be watered, fertilized, and absorb sufficient sunlight to blossom, or there will ultimately be no fruit to harvest. This is similar to the extreme effort that goes into establishing manufacturing techniques able to industrially produce what is discovered in the research lab. Even after clearing this hurdle, it is necessary to eliminate harmful insect pests until the final harvest, as well as protect against the occasional storms that have the potential to wipe out the fruits of labor. This resembles how, even when a product is industrially produced, a viable business will only be established if the intellectual property is protected from competitors and the product's value is accepted by the market.

Iwaki factory

Potential Pitfalls: the Devil's River; the Valley of Death; the Darwinian Sea

It's often said that there are three main barriers that must be overcome to successfully develop a viable new business, commonly referred to as the "Devil's River," the "Valley of Death," and the "Darwinian Sea." I'd like to look at these three pitfalls a little more closely.

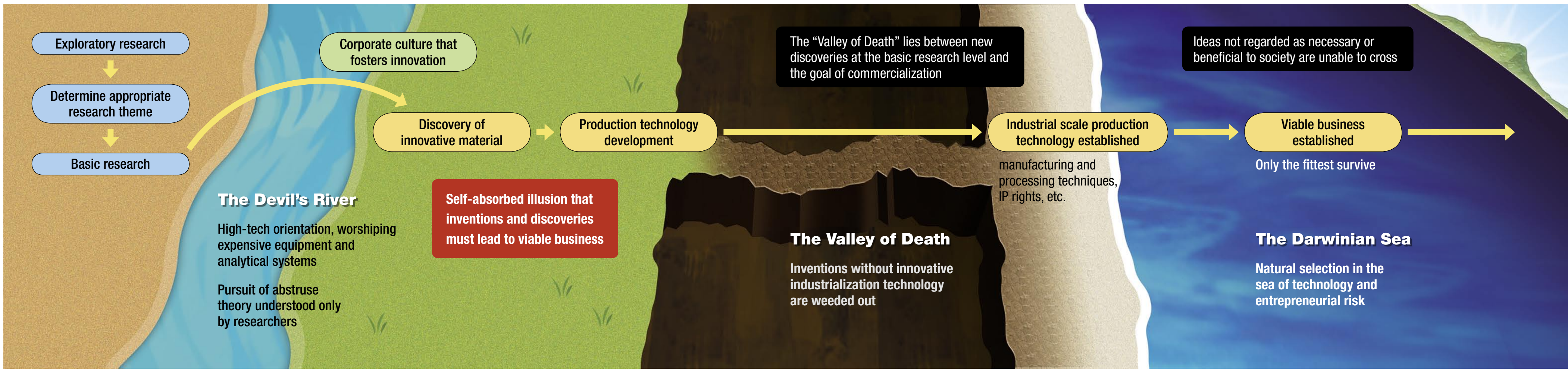
There are many reasons why a seed might fail to germinate, one of which could be unsuitable soil. Cases such as this, where research investment fails to produce any inventions or discoveries, usually result because the research environment is not properly equipped (lacking personnel, the correct mindset, or adequate funding). Whether a company is able to generate the initial inventions or discoveries is likened to crossing the "Devil's River."

The Devil's River is an apt expression for the many demons lurking at the research and development stage. Demons that can result in efforts being swept away in the Devil's River include a steadfast belief in the illusion that R&D is the pursuit of abstruse theories only comprehensible to a handful of specialists, or the worship of high-tech to the point of believing that R&D will be hindered without high-priced equipment or analytical systems. The fiercest demon, however, appears at the moment you attempt to cross the Devil's River.

Suppose that, at the end of a hard-fought struggle during basic research, you've discovered a material with properties unlike any other in the world. One of the traps that scientists are prone to is excessive satisfaction and overconfidence in their inventions and discoveries. It is easy for them to believe that the material they've developed is wonderful like no other. Once patents have been granted and praise offered, the tendency is to immediately seek to commercialize the material. This was possible during the postwar reconstruction and early stages of the era of rapid economic growth, when goods were scarce and anything manufactured could be easily sold.

The material that has been discovered is at this point still just a seed, or at most a seedling. It must be carefully nurtured to become

The Devil's River; the Valley of Death; the Darwinian Sea



truly viable, in the same way that rough diamonds must be polished before they can be distinguished from other stones. For a new material, polishing means establishing the manufacturing technologies able to produce it at an appropriate cost so that it can actually be used, as well as establishing processing technologies that can maximize the material's intrinsic value. Without these, it cannot be called a viable material.

This is what follows the Devil's River, commonly called the "Valley of Death." One must traverse narrow mountain passes to cross the valley, where a single wrong step can send you tumbling down to the valley floor. Looking down into the valley, you can see the scattered corpses of inventions and discoveries that could not be industrialized. The process of creating an industrial product from the samples produced in the research lab is truly the equivalent. Crossing this valley includes, in addition to establishing manufacturing and processing technologies, receiving certification from public institutions and users, and putting in place a product supply chain appropriate to the expected market scale.

The most important thing, though, is whether the product can be produced industrially at a suitable price. Different focus and preparation is necessary for traversing the Valley of Death than crossing the Devil's River, requiring different abilities and sensibilities in those who undertake these challenges. Just as different runners are best suited to different legs of a relay race, companies need the right player to pick up the baton after crossing the Devil's River, and an appropriate person to hand it off to for the next leg after the Valley of Death.

Once the Valley of Death has been safely traversed and an innovative new product is complete, it still cannot yet be called a commercial product. Even innovative new materials face barriers to actual use in the market. This final hurdle is aptly called the "Darwinian Sea." Can the product survive the circling sharks? Can it adapt to sudden shifts in climate? This final trial is a survival of the fittest, the ability to continue to exist in a changing environment as described by Darwin's theory of evolution.

The key to navigating the Darwinian Sea is for the new material to be essential to technological innovation, and create value by being beneficial to society and easy to use. To turn a manufactured product into a commercial success, an appropriate strategy and business model must be put in place. In industries of the future, such as solar power generation and electric vehicles, concerted efforts are being made around the world to secure technological innovation and effective business models. In this sense many people have begun to sail out across the Darwinian Sea.

Viable Materials

To those of us in the chemical manufacturing industry, the development of materials is truly a world of farming-style manufacturing, in that it begins with planting the seed of basic research and reaches fruition through a wide array of technological development. In this section I'd like to introduce some examples from Kureha.

Petroleum Pitch-based Carbon Materials

The Story of an Insulating Material

Kureha produces carbon fiber products that are marketed under the brand name KRECA. Application as an insulating material used in high-temperature furnaces that are essential to the production of silicon used in solar cells has seen demand grow substantially during the recent boom in solar cell production.

Most people view carbon fiber as a strong and lightweight material like that used in golf clubs or airplane components. This type is known as polyacrylonitrile-based carbon fiber (PAN), produced by melting polyacrylonitrile resin, stretching it into a fiber and exposing it to high temperature in a furnace. The carbon is aligned in an unisotropic manner making it extremely resilient to force, and because graphitization of the material through thermal treatment alters the molecular bond structure of the hydrogen and nitrogen leaving just the carbon, it is extremely light.

Rather than acrylic resin as a raw material, KRECA employs petroleum pitch, the residue that remains after extracting gasoline, naphtha and other elements from crude oil. Because crude oil is used as the raw material, the molecular sequence of the carbonized material is a jumbled mess when treated at high temperature. As opposed to the neat structure of PAN carbon fiber, the carbon chain of Kureha's carbon fiber – though seemingly fibrous – is entwined like a bird's nest. This makes it wholly unsuited to golf club shafts. However, since it has been treated at high temperature in the same way it demonstrates the same heat resistance properties as traditional carbon fiber, with the distinct advantage of low cost, since it is made from petroleum residue. Kureha was the first company to successfully industrialize pitch-based carbon fiber nearly 40 years ago. At the time it was derided as scrap or substandard carbon fiber, and though some applications as a packing material were found, not much was sold. Over time applications were expanded somewhat, including use as an alternative to asbestos in automobile brake pads, but the business recorded only scant earnings.

However, with the development of the semiconductor industry and rising worldwide demand for silicon, this pitch-based carbon fiber that is highly heat resistant and can be folded into a felt form, began to enter the spotlight for its ability to act as an insulating material in extremely high temperature silicon furnaces. With the rapid rise in demand for solar cells, silicon has become one of the most sought after materials. Kureha's carbon fiber has emerged as an essential insulating material for furnaces used to manufacture silicon ingots. One truly gets the sense of a flower blooming after 40 long, hard years. Despite initial demand being weak, we remained convinced of its viability and carefully nurtured the business while being buffeted by repeated storms calling for the product's withdrawal. Now transformed into a necessary technology supporting the world as it becomes more advanced, I am deeply moved at how the material has blossomed.

The Story of Kremezin

Viable materials are wonderful things and can lead to amazing developments. Thermally treating the petroleum pitch-based carbon into a spherical shape rather than stretching it into a fiber produces activated carbon, which Kureha markets as its well-known bead-shaped activated carbon (BAC). The emergence of this product, which has slightly different functions and possesses excellent adsorption capabilities, led to the development of a new set of manufacturing techniques. The more precise refinement of activated carbon as an adsorption agent further led to its development as a high-value-added pharmaceutical product, commercialized as Kremezin, a therapeutic agent that selectively adsorbs uremic toxins and excretes them out of the body. Kremezin not only contributes to Kureha's earnings in the pharmaceutical business, but its value is currently recognized by the medical community as the only drug for the treatment of kidney failure.

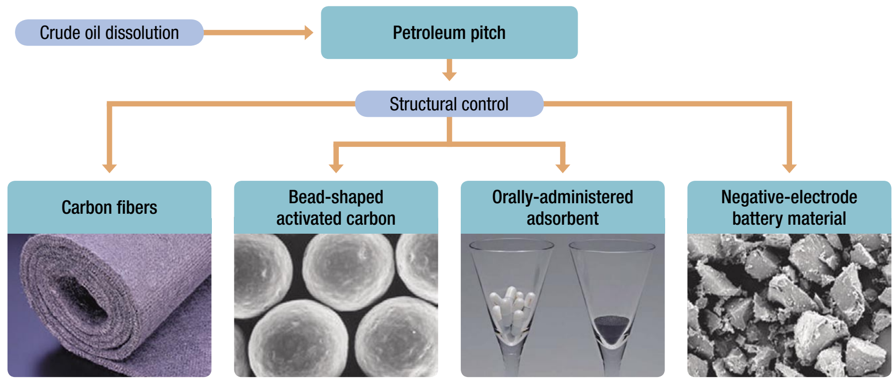
The Story of CARBOTRON

The techniques for processing petroleum pitch to create carbon materials led to the development of more applications, including as a negative-electrode material used in lithium-ion batteries. The story began in the late 1980s when Sony turned its focus to lithium, which offered the greatest theoretical electric potential and enhanced energy density, and began developing secondary (rechargeable) batteries. As part of its search for a negative-electrode material able to safely store large amounts of lithium ions, Sony requested support in thermally testing polymers. Kureha proposed its petroleum pitch-based carbon materials. The material did not perform as expected initially, suffering from such problems as low ion storage capacity and precipitation of the metallic lithium. However, through joint research Kureha was able to draw on its years of expertise in activated carbon to determine the best design for the molecular alignment in the carbon material, allowing us to clear the first hurdle.

Sony industrialized the process in 1991 and launched the world's first lithium-ion battery business. As an aside, Kureha and Sony adopted the term "lithium-ion" while conducting joint research, which has since gone on to become the common name that everyone uses today. Looking back, we should have registered it as a trademark. The world's first lithium-ion batteries used Kureha's carbon material (hard carbon), but the material would lose its position as the standard for negative electrodes as Matsushita, Sanyo and other battery manufacturers that were also developing lithium-ion batteries at the same time based their technology on the use of graphite.

Kureha's negative-electrode material offered excellent durability, easily charged and discharged at high-current capabilities and other advantages. However, compared to graphite negative-electrode material, it suffered drawbacks such as low storage capacitance to volume ratio and higher cost. Along with the impact of specification changes to batteries used in 8mm video cameras and laptops, the value of Kureha's

Examples of Viable Materials: Petroleum Pitch-based Carbon Materials



KRECA®
The world's first pitch-based carbon fiber, developed in 1970

The only bead-shaped activated carbon (BAC) derived from pitch

Kremezin®
Pioneering adsorbent pharmaceutical

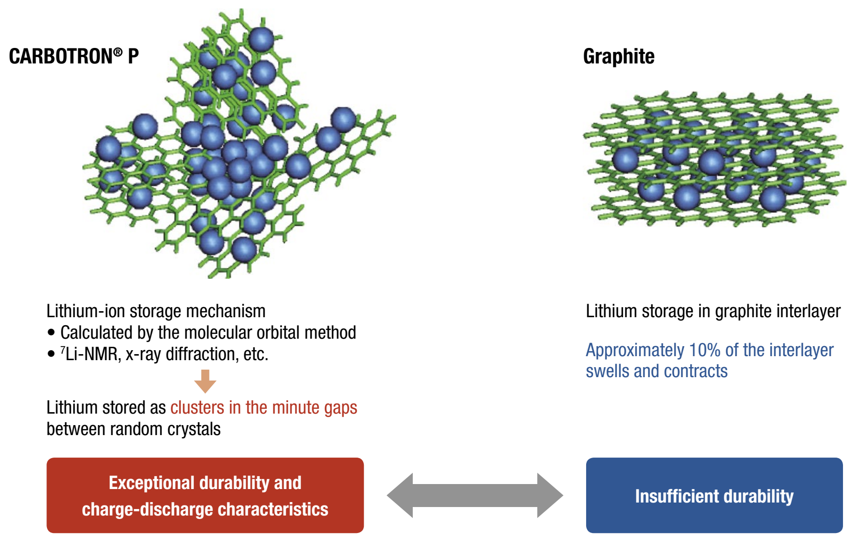
CARBOTRON® P
Negative-electrode battery material

negative-electrode material could not be fully recognized and Sony was also forced to switch to small lithium-ion batteries with graphite negative electrodes.

As a result, Kureha's business in this field declined sharply just a few years after production had begun. At one point we had plans to double capacity at the initial negative-electrode carbon plant and even build an additional facility, but these were canceled shortly before work was to begin. This story offers a sense of how we had crossed the Devil's River to successfully develop a prototype lithium-ion battery and traversed the Valley of Death to industrialization, only to founder when sailing across the Darwinian Sea to the successful commercialization of the business.

It seems, however, that as the business climate changes the gods once again smile on viable materials. Hybrid and electric vehicles now entering a boom period will likely require rechargeable lithium-ion batteries. The so-called first generation lithium-ion batteries used up to now have mainly been small units used in products such as mobile phones and laptops, but the second generation batteries will be for storing electricity for such applications as electric cars and solar power cells and will need to have tens, and in some cases hundreds, of times more capacity. The most important factors will be safety and durability. Hybrid vehicles employ energy regeneration systems that charge the batteries when applying the brakes, and whereas personal electronic devices such as mobile phones may be recharged perhaps 500 times over a five-year period, the batteries for hybrid cars must have negative electrodes able to withstand repeated charging hundreds or even thousands of times. Durability, a characteristic that received little emphasis for personal electronics, has regained the spotlight. Considering just this property alone, I have a feeling that the time has come for Kureha's hard carbon (CARBOTRON P). An emphasis on durability has already led to the use of Kureha's negative-electrode materials in lithium-ion batteries in satellites and, though it's not widely known, these have been in use for more than 15 years.

Characteristics of CARBOTRON® P



Based on recent discussions with battery manufacturers and automakers I believe that interest in Kureha's hard carbon (CARBO-TRON P) is growing daily, but it will take some time before we are able to discern to what degree this interest will transfer into the development of a major business. Fortunately Kureha has established the technology for industrialization of CARBOTRON, and despite relatively low numbers, is already selling the product on a commercial level. While we therefore may have traversed the Valley of Death, the new markets for automotive batteries and the overall size of the potential market is almost too large to envision at this stage. Developing a manufacturing platform able to meet global supply is also a major issue that we will need to overcome. The most important task now is to establish a proper navigation plan (business strategy) to allow us to safely plot a course across the Darwinian Sea that encompasses this new automotive battery market. Kureha foundered in the Darwinian Sea during the development of negative-electrode materials for first generation lithium-ion batteries, and it is important that with the opportunity provided by the changing winds we properly outfit the ship, break away from the reef, and begin rowing toward a new goal.

To digress a little, though many people know that the commercial name for Kureha's carbon material (pitch-based hard carbon) is CARBOTRON P, I suspect that few know what the "P" stands for. The "P" is the first letter of "Pseudo Isotropic Carbon," used to differentiate it from CARBOTRON F (Fine Mosaic Carbon) that was being developed at the same time. Ultimately the charge-discharge capacity of CARBOTRON P exceeded that of CARBOTRON F, and with the emphasis on capacity at the time CARBOTRON F never saw the light of day. However, considering the negative-electrode materials currently sought for car batteries and large-scale storage applications it may not necessarily have been a failure. It is even possible that CARBOTRON F could be revisited and could sparkle once again. Materials such as this always have the potential to be reborn as viable products with a new luster, by drawing on their inherent properties. How well a seed is nurtured determines whether it ripens into beautiful fruit. I believe this reaffirms that the development of new materials, as illustrated by the growth path for carbon materials, is representative of farming-style manufacturing.

Polymer Materials

The Story of PVDF

Kureha produces a resin known as polyvinylidene fluoride (PVDF), which also has a long history. Kureha made the decision to commercialize the product almost four decades ago, at a time when only a handful of companies manufactured the resin. This also remains the case today. During the initial development phase, when the substance itself was already known, the main applications were as a coating or chemical resistance component.

Kureha's concept during development was to maximize the resin's electrical properties, sacrificing productivity for the sake of a manufacturing method able to create a polymer with close to ideal properties. Since applications at the time were primarily coating materials and molded blocks, the emphasis in the market was on low-cost manufacturing methods able to achieve polymerization at relatively high temperatures, thereby increasing productivity. The high molecular weight polymers produced using these low-cost methods reduced the degree of crystallization, though this was not a problem for coating or molded product applications. However, the inherent electrical properties of polymers with reduced crystallization could not be fully exploited.

Kureha's method that sacrificed productivity for low-temperature polymerization produced a material with vastly improved electrical properties. Specifically, it created a material that outstripped all others with regards characteristics such as the piezo effect, in which the application of an electric current creates pressure that causes the material to change shape, as well as the pyro effect, in which the application of heat generates electricity.

This material, KF POLYMER, was used in high-end goods that utilized these properties, such high quality speakers and specialty sensors, but just as if the material was born slightly too soon, market growth was relatively limited. The PVDF business continued at a modest level, in part because there were so few competitors. Some additional applications were discovered, such as high-strength fishing lines, while it also found a niche in existing applications such as valves and fittings due the material's excellent chemical resistance and inherently ease of processing. The business endured with a relatively low profile, only to blossom with the arrival of the lithium-ion battery. KF POLYMER is now used as a binder to stabilize the negative and positive electrode material in the collectors for copper and aluminum foil, and commands approximately 70% share of the worldwide market. This is an acknowledgement of Kureha's advanced technologies in polymerization, acquired while making improvements to fishing line and other products, the material's improved bonding performance realized by modification techniques, and its inherent stability even under electric current conditions.

The number of companies around the world that manufacture PVDF is limited. Kureha is the only producer in Japan, and is also the only manufacturer globally with the technology to produce a resin that displays easily exploitable electrical properties and a high level of crystallization. The development of businesses for applications that utilize these properties is still relatively small in scale. However, as we stand on the verge of what feels like a major transformation in the automotive industry, I sense that we may soon witness major advancements in sensor technology. It was just such sensor applications that Kureha had in mind when developing KF POLYMER, which is one of the reasons why it may now find its time to blossom, a full four decades since development.

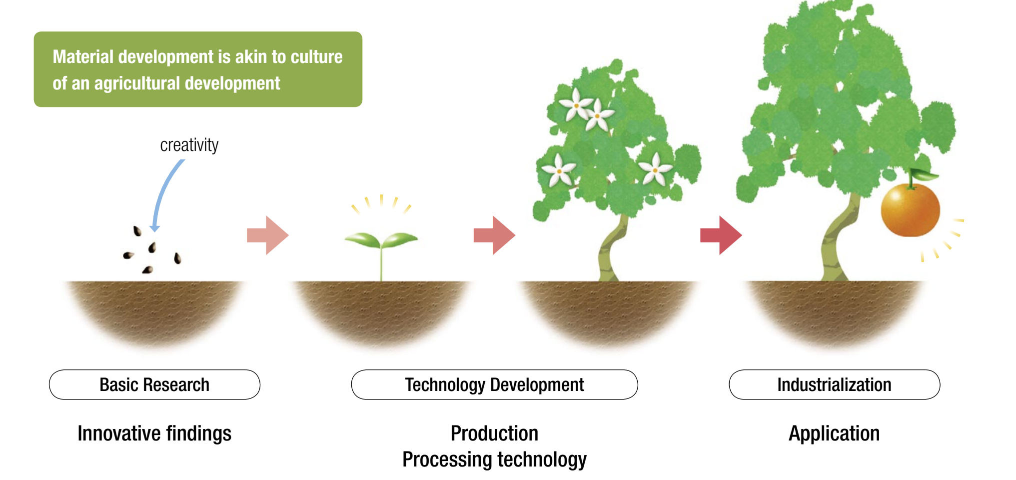
Recognizing Viable Materials

Viable materials are those that at the time of their creation may not immediately appear vitally necessary, but which possess a fundamental essence that will one day allow them to blossom. Some people will no doubt see this as just a distant dream and may argue that diligent R&D with no distinct prospect of success is nothing less than gambling. That is exactly right. However, I would contend that corporate management must incorporate an element of gambling. The development of materials is not simply the discovery of something with primary properties that surpass those of existing materials, or properties that do not exist elsewhere. The important thing is to focus intently on those properties, refine them, and nurture them to a point where they can be delivered to society when an appropriate need arises. No matter how good the seed, considerable time is required for it to sprout, become a seedling, and eventually flower and bear fruit. In the meantime you need to give it water, fertilizer and kept it free of weeds, as well as be prepared for occasional storms. Once you have a material that you've carefully nurtured, if you cannot determine in what form it will provide value, it will wither as unused treasure. Therefore, you must either choose to walk away from an R&D gamble, or decide that it can become the cornerstone of a new business.

This is easy to say, of course, but calculating the exact needs or applications for the material you have nurtured is no simple matter. Today, in fields related to environmental or resource conservation technology, food-related issues or health-science, there is only vague recognition of the direction to be taken, or the necessity for brand new technologies. Even if you know the basic direction for a technology's development, for example knowing that it will be required in the solar industry or for electric vehicles, without proper awareness of the degree of perfection required in the material for it to be utilized in the final product, it will not be adopted. Products cannot be completed without close communication between material suppliers and those who assemble them into their final form.

In other words, the farming-style materials industry must be constantly aware of the mindset and technologies of the hunting-style manufacturers. Without a collaborative spirit that facilitates coordinated discussions on technology, R&D becomes nothing more than a hobby and business opportunities remain elusive. As for the best way to recognize viable materials, I have no definitive answer. However, I can say that major changes in industry or society bring with them an abrupt shift in the necessary technology, which ultimately means that materials with different properties are required. The final piece of the puzzle is instinct. Many people tend to think of instinct as akin to guesswork, but the kind I'm referring to is that which has been developed and refined through diligent development and improvement of technology, and which comes into play through an intimate understanding of the materials one handles.

The Nature of Material Development



The Story of PGA

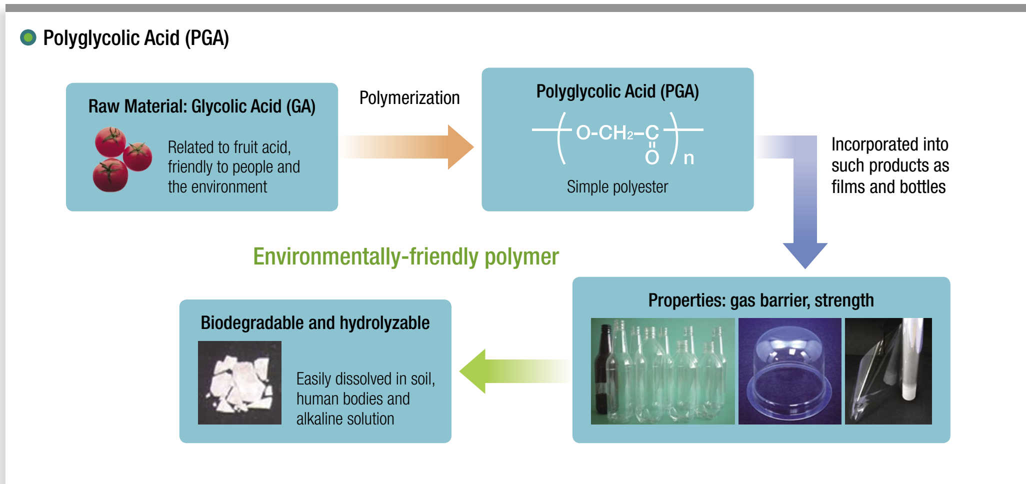
Kureha is making a concerted effort to commercialize polyglycolic acid (PGA), under its trade name Kuredux™. With a firm belief in the viability of this material, we are now building a new production plant in the United States, while at the same time striving day and night to develop applications. Research is still ongoing and the business has yet to be launched, but looking back on the development of PGA up to this point, a story of farming-style manufacturing is apparent.

The story begins nearly two decades ago, when the head of the R&D department at the time talked about how despite his success in developing many different polymers, he would become depressed whenever he saw plastic bottles and containers floating in the river or sea. He began wondering whether it was possible to create a polymer that would decompose after use like paper or wood. From this idea began underground research that was neither authorized nor for pure self-interest. Biodegradable plastic was already known at the time, with PGA being one of the most biodegradable. My understanding is that it had first been polymerized in 1932 by Dr. Wallace Carothers, the DuPont chemist and Nobel Prize recipient famous as the inventor of Nylon. The scholarly record on PGA afterward is sketchy, but by the 1950s DuPont was working to industrialize the material. The company received several patents, but never succeeded in industrialization. Several methods were later devised to produce PGA on a laboratory scale, while at the same time demand emerged for use in surgical sutures. Today around 200 tonnes of the resin is produced globally per year, making it an extremely expensive material.

Kureha began conducting exploratory research, following our instinct that PGA may be a seed that could be nurtured into a viable material. This was motivated by factors including: 1) new technological challenges being part of Kureha's corporate DNA, 2) Kureha's long-standing foundation in polymer research, and 3) a conviction that the challenge to discover an exclusive manufacturing method, one that eluded even DuPont, was a worthwhile endeavor. Once the research began we gained an idea of the difficulties that faced DuPont, and were initially unable to create a proper polymer. We were unable to cross the Devil's River. Research continued for several years, until one day during discussions the researchers decided to try making their own solvents needed for the reaction and manufacturing process. Interestingly, the team utilized the expertise in organic synthesis of an agricultural chemical researcher not directly connected with the project to develop a solvent that would meet cost targets, successfully creating a polymer prototype using an entirely new polymerization route.

That was in 1995, but this success was nothing more than finally crossing the Devil's River. We were only then set to begin traversing the Valley of Death toward industrialization. At this same time, while researching the properties of the PGA that had been polymerized in the lab, we discovered that in addition to biodegradability, the material had characteristics including previously unobserved gas barrier properties (impermeable to gases such as carbon dioxide or oxygen), strength comparable to the strongest plastics, and the ability to be easily molded even in a crystalline state. Glimpses of a viable material continued to be revealed and motivation among the development team intensified.

A series of hurdles to industrialization were overcome in the course of basic research, such as the development of molecular end-modification techniques to control biodegradability and a thermal stabilizer to prevent decomposition during processing. The most perplexing problem, however, in terms of developing a manufacturing process for this new substance, was how to devise an industrialization framework for a substance that was designed to easily biodegrade. The creation of a pilot plant (10 tonnes per month) in 2002 was a positive step, but when put into



operation the material would constantly stick, break apart or become jammed.

The resolution to these issues was found principally in the work of chemical engineers rather than chemists. They persevered in the development of equipment that exists nowhere in the world and, taking into consideration future costs, worked to develop a continuous polymerization reactor for a material that could only be polymerized in batches in the lab (repeatedly placing a batch of material in a container, and removing it when the reaction is complete). The establishment of manufacturing technology for industrialization took close to five years.

At this point we had more or less traversed the Valley of Death and industrialization was within our grasp, but still ahead was the Darwinian Sea and the need to establish product applications that would allow us to reach the final stage of commercialization. We were actively developing applications in parallel with manufacturing technology. Use in surgical sutures was already established, but this would amount to just a handful of the 4,000 tonnes per year to be produced at the plant under construction.

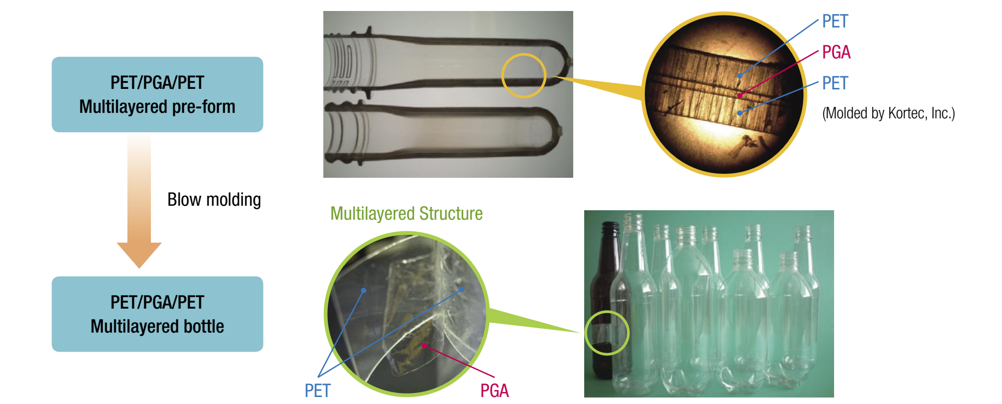
Kureha turned its attention to the gas barrier properties that I mentioned earlier. Most bottles for carbonated beverages are made from polyethylene terephthalate (PET) resin. By placing a thin layer of PGA resin, which is up to 100 times more impermeable to gas, in between the PET, bottles can be made around 20% thinner than those currently in use. PGA's biodegradability also ensured that there would be no problems when it came to recycling the PET bottles. This application required further technological developments, however, as no processing machinery existed that could insert a layer of PGA film just a few micrometers thick into a PET bottle. Without the establishment of such technology for commercialization, widespread adoption of the material could not be secured. New technology was needed, but the development of processing machinery was not something that Kureha could do alone.

Kureha needed to collaborate with processing machinery manufacturers, bottle producers, and the beverage companies that would use the product. We realized as we set out across the Darwinian Sea that commercialization with our abilities alone would be difficult, reinforcing the idea of a joint venture with the companies that would make use of this new material, that is, those that would draw on this viable material to assemble a final product or rather the master chefs (assemblers).

Kureha is pursing development of many potential applications besides carbonated drinks bottles. Nearly all of these applications require a collaborative relationship built on partnership with the companies that will use the material. I believe that going forward, the type of business model in which the developer of the material holds a monopoly on the business will no longer be possible.

Japan's national broadcaster NHK each year produces a historical drama. This year the title is "Tenchijin," a name that combines the characters for "heaven," "earth" and "people." The phrase is based on the fundamental idea that a bountiful harvest is a combination of the "time of heaven," i.e. when to plant the seeds, the "quality of land," i.e. fertile soil and ample water, and the "harmony of people" with each person carrying out his or her assigned task. A culture that follows this philosophy is the culture of an agricultural people. The art of manufacturing when applied to the development of materials is almost certainly a product of this agricultural culture. The difference between growing crops and developing materials is that you can more or less predict when the harvest for crops will arrive, but with materials there is really no way to foretell when they will blossom. Even if you develop a material with exceptional viability, in the absence of a fortuitous encounter with an assembler, the material may never find its way into a product. In the same way, procuring excellent ingredients alone will not result in a delicious meal without an encounter with a skilled chef. In other words, I believe that we have reached an era in which the creation of new technologies and products will no long occur unless the farming-style materials industry and the hunting-style assembly industry can establish a relationship in which they perform their respective roles as partners.

PGA as a Barrier Material



Hunting-Style Products at Kureha

Up to this point I have focused mainly on farming-style manufacturing, but it is important to note that Kureha has also applied hunting-style manufacturing techniques to the development of new products. One such example is the familiar household product NEW Krewrap. A long-selling food wrap launched over five decades ago, the product uses a plastic material known as vinylidene chloride, which is resistant to odor permeation and clings easily to containers. At one time the main focus was on improving the material itself, such as adhesion or making it easier to cut, but as the product matured attention has shifted instead to making the packaging easier to use.

Essentially the focus became increasingly market-oriented, developing and improving the product in line with customer needs. A sustained effort has produced numerous improvements each year, such as the recent adoption of a plant-derived plastic cutter that can be easily sorted for disposal in these environmentally conscious times. Though the product was renamed twenty years ago as NEW Krewrap, we continue to strive for improvements to justify the “new” moniker.

Such efforts in pursuit of greater usability and the continual layering of technology to support this are in a sense like an assembly industry for ideas. That is, the constant pursuit of the business “prey” of customers and the refining of one’s skills greatly resembles hunting-style manufacturing.

1960

1973

1989

2004

2005

2008

2010

Kureha's Manufacturing Culture

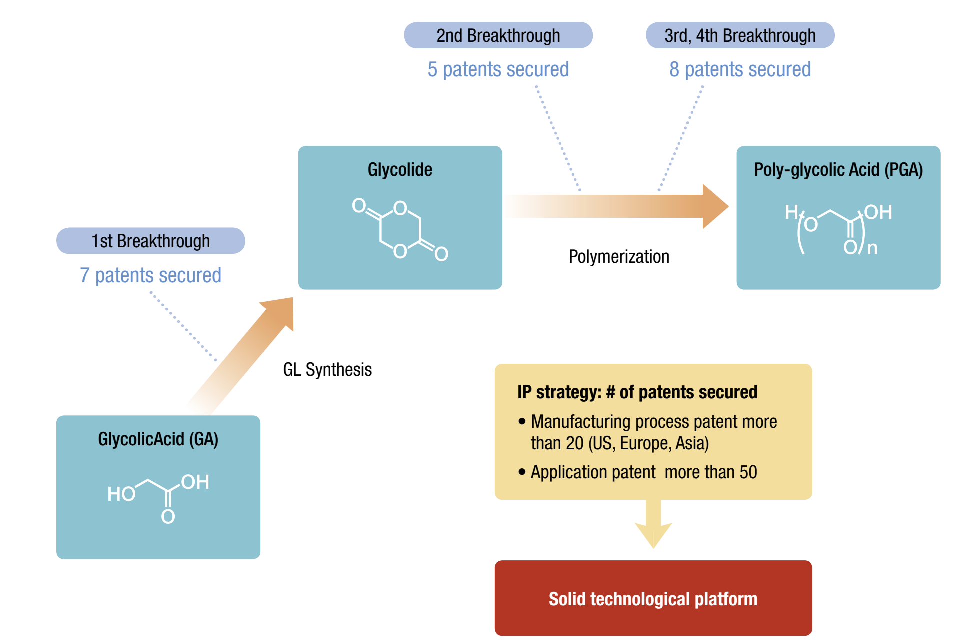
The inclusion of products utilizing hunting-style manufacturing technologies in Kureha's lineup offers particular advantages. More than anything else, hunting-style manufacturing forces companies to pay attention to the needs of the average consumer, the final user of the product. In other words, it fosters a market-oriented mindset. The presence of in-house teams with a strong market awareness helps to promote a slightly different approach toward certain issues compared to the farming-style manufacturing teams, which tend toward a product-oriented outlook. The era when it was possible to find a market for anything you produced is over. Even when producing high quality materials, only by working with the assembler to determine whether demand for the final product exists do the two parties become equal partners.

In the world of materials, just as polishing a rough stone requires time and masterly skill before exquisite shine can be assured, the processes cannot be handled by one person alone from start to finish. It is like a relay race, where each runner has responsibility for a specific segment and only as the baton is passed along does it reach the goal. A relay race is won only by a team and obviously if only one member is a champion athlete the team will not be victorious. Also in a relay race there are many people cheering at the start and finish, but this does not necessarily mean that the motivation of the runners in the middle segments is diminished. I think this is because these runners fully recognize their individual responsibilities and have a mission to pass the baton to the next runner. Of course, individual runners can also receive recognition and glory for their performance in their segment. In materials development this is similar to how researchers and engineers who make breakthroughs are able to receive patents and be recognized as inventors. However, the world of technology today is not as simple as it once was, when for example with Edison and the light bulb it was clear exactly who invented what and the inventions of an individual could immediately become products. In today's world it is the combination of many discoveries, inventions and technological breakthroughs that completes the technological matrix and allows products to be born.

It is challenging for a company with the scale of Kureha to exert its presence in the chemical industry while positioning itself as a company built on technology. I believe that an ideal strategy for the current age is to leverage our accumulated technological expertise in specialty fields to develop new materials that allow for the realization of products that meet today's market demands (a recent example being environmental technology). I also believe we have reached an era in the farming-style materials industry where Kureha's approach of applying carefully honed product-focused development capabilities to refine market-oriented ideas will gain considerable traction.

Relay races are very popular at Kureha and the entire company bristles with excitement during the annual competition. I think this is because the relay style of competition whereby the baton is passed along the line to achieve a team victory strikes a chord in the farming-style manufacturing culture, and reflects the Kureha corporate culture of business success through teamwork.

Kureha's technology development —polymerzation process—



The Pitfalls of Being the Exclusive Leader

Taking into account that polishing a rough stone to create a brilliantly shining viable material, carefully observing the progress of technology around the world, and searching for encounters with the hunting-style assembly industry is the art of manufacturing for the farming-style materials industry, this final section highlights one more potential pitfall that we must be aware of. Companies whose materials are created through novel ideas and polished with masterly skill naturally become exclusive leaders in their fields. This leading position gives them exceptional viability and creates opportunities for encounters with assemblers that use them to create the final products, and interest in forming partnerships grows quickly. Dreams of successful business become inflated and it is here that the pitfall lies. In the late 1950s and early 1960s the market for the materials industry in Japan was mainly domestic. It was possible that the leading material would be supplied exclusively to a single company and that the business could be monopolized from a position of technological superiority. This was the strength of an exclusive leader. The blossoming of a unique technology seemed to symbolize victory.

However, new businesses that are growing out of the environmental technology revolution are visible throughout the world and the need to target a global marketplace is fundamental. In such a business environment, when considering how to supply materials that match new technologies, the materials business also obviously needs a business model with a global perspective. The more a material is the exclusive leader with no obvious alternative, the greater the duty and responsibility to provide a stable supply throughout the world. In such cases the risks may sometimes be too high for a single private company. For example, industries currently receiving much attention, such as solar cells and electric vehicle batteries, are emblematic new businesses and will offer essential new materials that had not previously existed.

Since a material alone does not constitute a final product, in cases where the new product would be at the mercy of the material or if a stable global supply cannot be guaranteed, the business risk for the product manufacturer may prove to be too great even for an exceptional material. Consequently, without establishing a business model that combines a position as an exclusive leader with stable supply as a global standard, the future path for the materials industry will be limited. It is therefore not enough to only secure a position as an exclusive leader, but also important to avoid arrogance. Companies possessing exclusive leading materials must seek not to become the masters, but must walk the royal road of the manufacturing art.

Epilogue

It had been my intention to write freely on the broad subject of "The Art of Manufacturing," but reading through the text again I feel that perhaps my ideas are somewhat overpowering. Thinking back on what contributed to such ideas, I sense that the experiences I had since joining the company and in particular the exchanges with my colleagues and superiors led to the development of my philosophy.

I joined Kureha in 1971 and was assigned to the VDF Group in Polymer Production Section No. 1 of the Composites Department at the Nishiki Plant (currently Iwaki Factory). This coincided with the period when KF polymers were moving from trial to full production. I was assigned to plant operations, working on a three-shift system. Even though the plant itself had been completed, the manufacturing technology was not fully developed and over a week of unstable operations we fought an uphill battle armed with helmets and wrenches. However, the products we manufactured failed to sell, and after operating for just three months the plant was closed and we were transferred to providing support at other factories. This was an extraordinary experience for a newly hired employee.

The facilities where we provided support varied, but the one that sticks out in my mind is the trial production for Seaguar fishing lines, which at that time was close to completion. I operated an extruder at the Mibu Factory of Kureha Gosen Co., Ltd., and wore a happi coat while helping with sales promotion for Seaguar products at trade fairs. It was rather disconcerting for someone who had joined the company as a plant engineer, but I was fortunate to have the opportunity to experience the entire material-to-manufactured product value chain at an early stage in my career. I remember becoming aware for the first time that a manufacturing company does more than simply make things.

I later gained my first overseas experience as a member of a team responsible for exporting a modifier (BTA) plant. This taught me that technology has no borders, and that technology can create mutual understanding and trust even in the face of a language barrier. It was at this point that I began to think that if Kureha did not possess world-class technology its future survival would come into question.

I worked in research labs for a total of about 15 years. I feel extremely fortunate that during that time I was involved in the development of new technologies and materials that are distinctively Kureha, including the development of new processes for modifiers, PPS (polyphenylene sulfide), and negative-electrode material for lithium-ion batteries. Working in the research lab focuses the mind on product development and to this day I am still embarrassed about harboring ill feelings toward salesmen, wondering why they couldn't sell the wondrous things we had created.

Sometime later I was involved in the export of a plant to Singapore. The lesson I took away from negotiations with the government and the various companies involved was that when cooperation is necessary, it's not possible for one side alone to win. Everything depends on how to achieve mutual acceptance of the "win-win" relationship.

Following my time in Singapore, I was dispatched as the vice president representing Kureha to Fortron Industries LLC, the U.S. joint venture between Kureha and Hoechst Celanese Corporation, now Ticona GmbH. My assignment was to work with the president of the partner company to as quickly as possible achieve profitability for the PPS business, which at the time was still a loss-making enterprise. My duties were almost entirely related to marketing, which was often bewildering for someone who until then had spent his career in manufacturing and research. Since the president from our partner firm was a marketing and sales specialist, I was blessed to have someone who could teach me the ABCs from the ground up. I was able to see first hand the need to constantly explain to customers the viability of a material, especially when selling a functional material like Fortron (PPS), while also building a relationship as a trusted partner in the development of a new product.

After returning to Japan I spent two years in the manufacturing division, before suddenly being appointed to head the planning division at headquarters. Under the advisors to Hiroshi Amano, Kureha's president at the time, I received guidance on the path that Kureha should follow in the future. It was at this point that I began to believe that for

Kureha to rank among world leaders of a similar scale and to remain viable, it must be a company founded on technology. In particular, when considering the establishment of a new business the idea was reaffirmed that in terms of commercialization, it is important to consider not only the technological foundations, but business aspects such as global business development. In businesses such as polyglycolic acid (PGA), many potential applications are unknown and it is evident that without collaborating with various companies both upstream and downstream, it is impossible to establish and commercialize these applications. From this aspect alone, Kureha faces challenges in establishing these new businesses.

In negative-electrode materials for lithium-ion batteries, which have recently generated much interest, considerable effort is underway to ensure Kureha's CARBOTRON becomes the de-facto industry standard. If we are successful, it will confer on us a responsibility and duty to supply this material throughout the world. When forming a new industrial structure, I believe it is an important responsibility of the president to clarify the business strategies Kureha will use to establish its presence.

I believe the world will change dramatically in the near future. In this pamphlet I've attempted to consider the path Kureha should be following in terms of its approach to manufacturing. These views were derived from exchanges I've had with employees, former colleagues and others in the manufacturing industry, and after ruminating on these various opinions I've tried to apply them to the Kureha way of being. It is my hope that together we will continue to think about the future of Kureha.

KUREHA CORPORATION