Products and evaluation device of cosmetics for UV protection

— AIST commercialization based on regional collaboration that combines the current strategic logic, and an intermediary's experience and trial-and-error approach —

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We introduce a case study of UV-protective cosmetic product development. Recently, cosmetics need to solve 3 problems simultaneously: 1) UV-protective effect, 2) transparence, and 3) smooth-textured touch. However, the best recipe and usable evaluation methods are not established. This research is the result of a strategic regional cooperation of the AIST grant venture and the technical guidance that did not set a prior scenario with immediate effect of the national research institute. A new manufacturing and evaluation method has been commercialized in the forms of a highly original cosmetics and a new evaluation device. An example of the methodology is shown concerning social elements (regional cooperation), particularly. The example is illustrated by comparing 2 elements. The first is the R&D methodology that the *Synthesiology* journal advocates (the Aufheben type, breakthrough type and strategic selection type). The second is the humanities way of thinking by analogy with natural phenomena such as the evolutionary theory.

Keywords : Ceramic composite particles, UV-protective cosmetic, shearing evaluation of powder-bed, apparatus engineering, Agency of Industrial Science and Technology, AIST grant venture

1 Background of research: Issues and problems of the "UV-protective cosmetics"

The objective of this paper is to present a case study for an R&D methodology that combines a strategic scenario and the empirical trial-and-error, taking the ceramic powder technology as an example (Fig. 1).

For today's cosmetics, the technological element that is most desired is to block off the harmful ultraviolet (UV) rays, in addition to transparency and good texture. As shown in Fig. 2(a), when nanoparticles, which consist of particles of several 10 nm size for light scattering effect and titania with band gap effect for blocking the UV-B, are added to the cosmetic ceramic particles for UV protection, uneven nanoparticle aggregations occur among the ceramic particles. The nanoparticles must be added excessively to achieve the desired UV protection, and the resultant aggregate particles shield the visible light and therefore decrease transparency, and produce high friction or decrease smoothness of the texture. Yet, the UV protection effect will be insufficient when the amount of nanoparticles is decreased to prevent the decline in transparency and texture, and we are faced with a dilemma[1][2].

Therefore, in this study, we propose the composite particle[1] and the least-square (LS) approximation model[2] as the AIST-style strategic approach[3]-[7] to solve the "technological elements" of UV protection, transparency, and texture. The AIST-style strategic approach is the development and collaboration method based on short-term contract that clearly states the expected result and responsibility. The detailed scenario is described in chapter 2, and the synthesis methodology is discussed in chapter 3.

For the "social elements" including the specific idea suggestions for materials and manufacture methods, as well as the adjustments of differences in organizational interests, we propose the regional cooperation in the style of the Agency of Industrial Science and Technology[1][2], or trial-and-error based on experience (Fig. 1(b)).

The powder material for cosmetics and the evaluation device were commercialized[14]-[21], through the application of core technology for the ceramic powder unit operation[1], the establishment of evaluation technology by AIST grant venture[2], and the long-term cooperation where short-term organizational interests are temporarily suspended[8]-[13] (chapter 4). We shall investigate the process of solving the social elements as an R&D methodology by referencing the recent comparative researches[3]-[8] or the analogies to the natural phenomena[22]-[29] (chapter 5).

2 Scenario for solution

2.1 Scenario for solving the technological elements

To achieve (1) UV protection, (2) transparency, and (3) good texture in cosmetics, it is mandatory to establish a manufacturing method where the three technological elements (1) high UV blocking, (2) high visible light

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transmissivity, and (3) high lubriciousness can be achieved at the same time[1][2]. Especially, the only evaluation of lubriciousness for (3) good texture is the qualitative sensitivity test conducted mainly by questionnaire survey, as shown in Fig. 3(a). It is necessary to immediately standardize the evaluation test and device, and then provide a guideline for the powder design that may improve the lubriciousness[2].

In this study, we focused on the point that the nanoparticle segregation had never been considered in the design and mixing processes of the current cosmetics, and the most prevalent method was the simple mechanical mixing. As shown in Fig. 4, the composite particle method was created as the core technology by combining the particle packing model (solid phase method), the homogenous dispersion of nanoparticles in aquatic environment (liquid phase method), and the rapid solidification of droplets (gas phase method)[1][2][14]-[21]. The details of the synthetic methodology are discussed in chapter 3.

For the lubriciousness evaluation, we looked at the difficulty of stabilizing the sample packing density to the tools and the low reproducibility of the side-grinding force, that is, it was difficult to set the consolidation condition. As the core technology that enables evaluation in a short time and at small amounts, we devised a LS approximation model of the normal force and side-grinding force. As shown in Fig. 5(a), the powder was compacted until the packing density stabilized in the conventional method, and except for certain powder unit operation such as the silo, this evaluation method

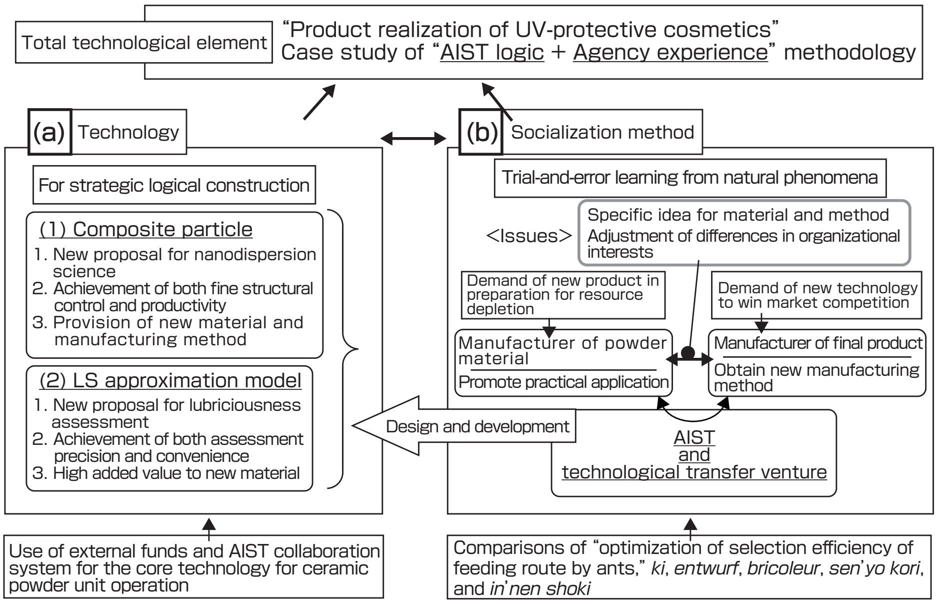

Fig. 1 Structure of the paper: Technological and social solutions to overcome the "valley of death"

(a) Solution for technological elements (logical and strategic scenario for using the powder technology)

(b) Solution for social elements (regional collaboration in the style of technical assistance during the Agency period where quick-acting scenario was not set)

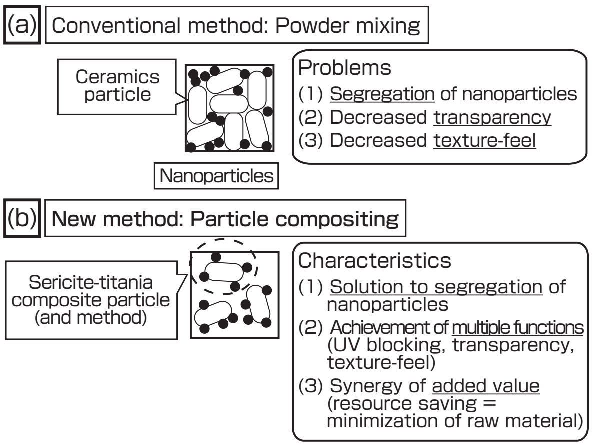

Fig. 2 Issues and problems of UV-protective cosmetics (technological point of this study)

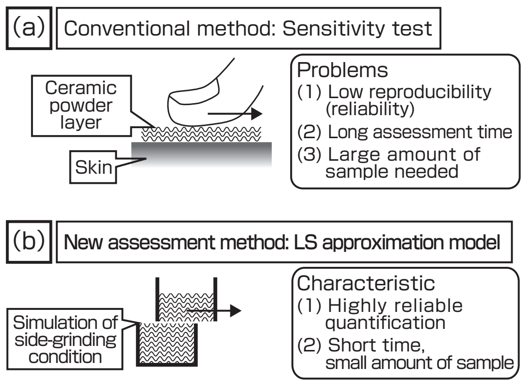

Fig. 3 Issues and problems in the texture-feel of cosmetics (technological point of this study – part 2)

did not reflect the actual ceramic manufacturing process. As shown in Fig. 5(b), the problem of consolidation condition setting in the new model was solved by continuously monitoring the normal and side-grinding forces in the transition state[1][2][14]-[21]. The details of the methodology are discussed in chapter 3.

2.2 Scenario for solving the social elements

The solution for the social elements such as the adjustment of conflicting organizational interests or the originality of idea was necessary. Before the 1990s, industry-government collaborations were conducted particularly in the regional laboratories as supportive measures that prioritized the practical application and commercialization, parallel to the R&D of science and technology[1][2]. This was followed by the practice of logical and strategic measures to build the win-win relationship between the companies and AIST based on the wide research foundation and trusting relationships[3]-[7].

As shown in Fig. 1(b), in this research, we faced the social issue of adjusting the differences in the interests of the organizations, and the realization of the development policy for the material and manufacturing method in the situation where the material manufacturer wanted a new product in preparation of resource depletion[15], and the product manufacturer wanted new technology quickly to win the market competition[17].

The solution for the social elements selected in this research is shown in Fig. 6. This shows the basic research of the ceramic powder unit operation and the history of the use of external funds and alliance system, starting with the Government Industrial Research Institute, Nagoya. The central part is the chronology, the upper part shows the material development, and the lower part shows the history of the evaluation device. Starting from the technical assistance for adding higher value to the regional specialty products in the 1990s, the pilot plant for powder synthesis was constructed using external budget in 2003, a public venture was started for the lubriciousness evaluation in 2005, a loose regional cooperation that did not require a contract was formed in 2007, and the powder material and evaluation device were realized in 2010[1][2][14]-[21]. The details of the synthesis methodology are described in chapter 3.

The following methodologies for solving the social elements were published in *Synthesiology* last year: (1) the aufheben type where a new concept is created by temporarily "sublating" the two contradicting propositions, (2) breakthrough type which is a unique "growth" model of the core technology, and (3) the strategic selection type which is an investigation of a hypothesis by a "logical" scenario[5]. This research can be considered a case where (1) aufheben thinking was applied to the social elements, in the sense that the decision for short-term organizational interests was temporarily suspended or postponed, although we were unaware of that when we were actually engaging in the research.

3 Solution (synthetic methodology)

3.1 Logical and strategic solution of the technological elements

< Ceramic powder material for cosmetics >

As shown in Fig. 4, the condition at which the nanoparticles do not segregate among the mica particles when the cosmetics is in its final form, that is, ceramic compact mixed with other ingredients such as polymers, was calculated using the DLVO

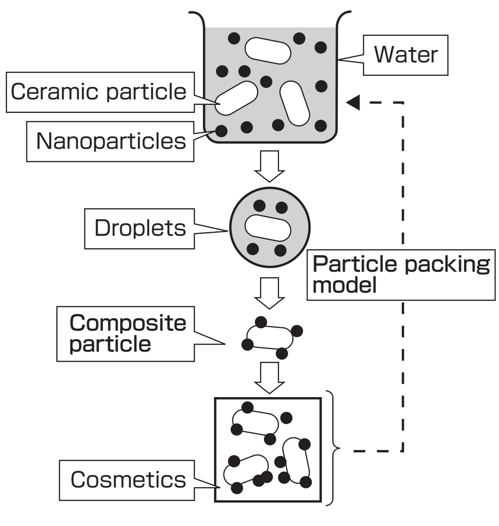

Fig. 4 Technological solution: New manufacturing method - Composite particle method with controllability and cost adjustments

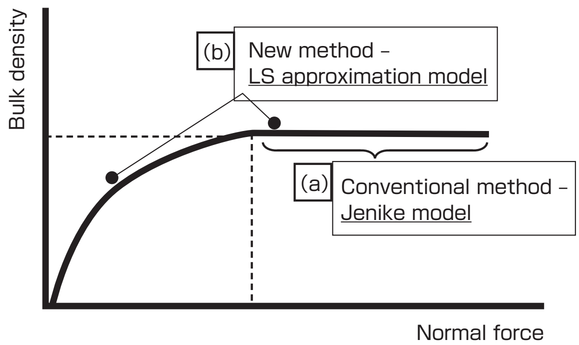

Fig. 5 Technological solution: New manufacturing method - Least-square approximation model for normal and side-grinding forces

(a) Conventional method – Jenike method: Corresponds to static friction, reproduces the consolidation condition in the hopper.

(b) New method – LS approximation model: Dynamic and static frictions are covered. Non-steady (dynamic friction) condition in the consolidation process can be quantified, as this was not possible in the conventional method, and has the following characteristics: (1) reproduces the condition in which the powder materials are actually used, and (2) has high cost performance with small amount of sample and short time.

theory (liquid phase method) for the aquatic scattering of nanoparticles and the particle packing model (solid phase method). The result was reflected in the starting composition of the raw material powder[1][21].

Figure 7 shows the structural control process of the powder including the composite particle. The slurry, which is a mixture of sericite[15] and nanoparticles, is sprayed (gas phase method), and the slurry is broken down into droplets that contain only a single or several units of sericite and nanoparticles. The droplets are continuously dried or reacted, and the composite particles (Fig. 7(a)) or granules are synthesized where the nanoparticles adhere only to the surface of the ceramic unit particle[1][2][14]-[21]. Figure 7(b)~(d) will be discussed in chapter 4.

< Evaluation device for the property of ceramic powder >

As shown in Fig. 5(a), the current lubriciousness evaluation technology requires excessive preliminary consolidation, or a state of high bulk density, to resolve the low reproducibility of the side-grinding force due to the instability of the packing density of the powder into the measuring container. This condition is not applicable to the general ceramic powder materials such as cosmetics and electronic fillers, except for some powder unit operation where over-packing may occur as in the case of the hopper[2][14][16].

Figure 8 shows the LS approximation model. As shown in Fig. 8(a)~(b), the normal and the side-grinding forces are measured sequentially from 0, whereas in the conventional method, the samples are changed for each condition from packing to consolidation. Next, the gradient, or the angle of internal friction, is calculated using the LS approximation of the normal and side-grinding forces assuming the clone powder (Fig. 8(c)). Compared to the conventional mathematical envelop approximation shown in Fig. 5(a), the new model shown in Fig. 5(b) enables the evaluation of the relationship of the normal and side-grinding forces in wider range from transition to compacting state, and it is a simple evaluation method that reflects the general ceramics process. Currently, this method is applied to the JIS standard powder as well as the materials for cosmetics, fillers, drugs, and foods, to guarantee the reproducibility and reliability as a powder evaluation method, and to confirm the adequacy as a quality control technology[1][2][14]-[21].

3.2 Empirical and trial-and-error solution of the social elements

< Basic regional industry-government alliance (former technical assistance system) >

As shown in Fig. 6, the joint work with the local mica company[15] in the form of technical assistance that suspended the short-term organizational profit was started to add high value to the specialty product (natural minerals) of Aichi Prefecture during the days of the Agency of Industrial Science and Technology in the 1990s, before the Agency became an independent administrative agency. In that process, crises in the alliance were experienced several times

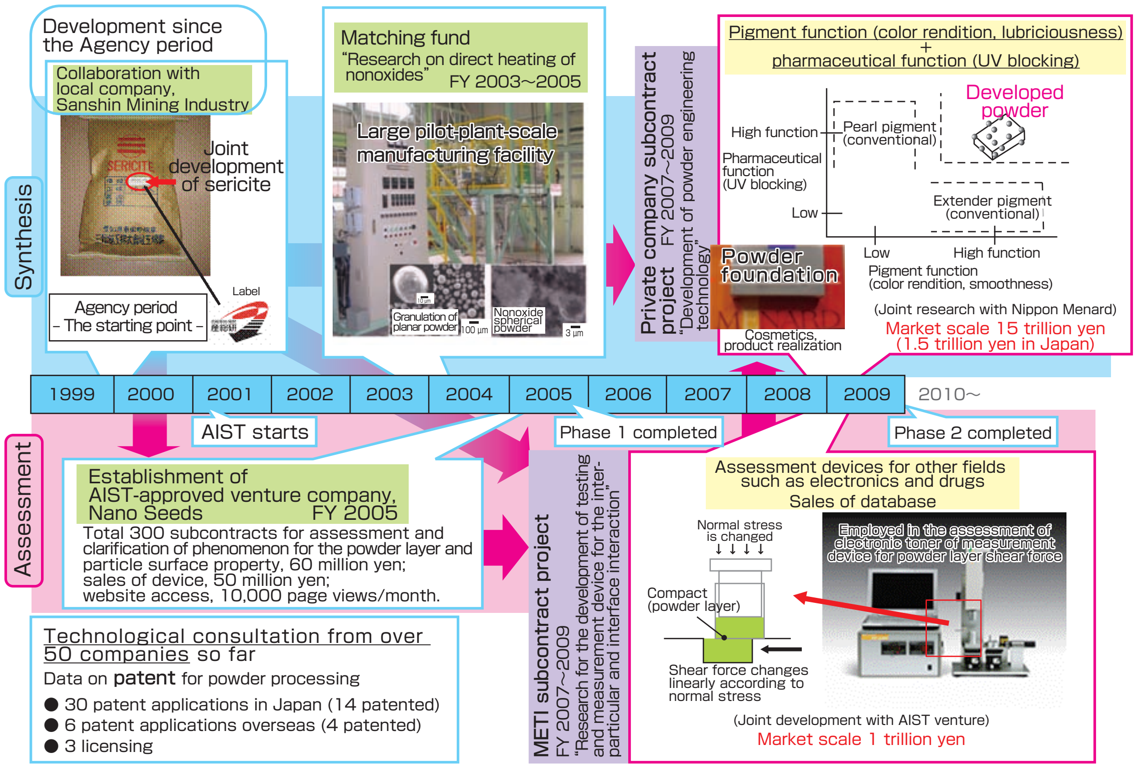

Fig. 6 Research roadmap: The chronology of the solutions for the social issues in this research

due to the different objectives of the organizations, but as a result, a trusting relationship was established for the core research of ceramic powder, including the new composite particles and morphological control[2].

< Plans for product realization of the powder materials >
While certain advancements were obtained for the ceramic powder unit operation at the level of *Type 1 Basic Research*[6][7], we were unable to realize the actual product or the implementation contract for the UV-protective cosmetics, and failed to achieve the level of *Type 2 Basic Research*. Neither the local material company[15] nor the product manufacturer[17] had much experience in signing an implementation contract. They also were hampered by intra-company barriers such as the inability to fund the project at the start, as well as the psychological barrier of whether or not to place emphasis on highly reproducible synthesis condition. From such differences in the objectives of the organizations, a crisis occurred in the collaboration and the project fell into the valley of death[3]-[7].

In general, the social elements such as the adjustment of organizational interests may not be necessarily solved by the inductive method of logic and strategy. The necessity of economic methods (such as the LCC, environmental risk science, and Pigovian tax) that internalize the technological external diseconomy is proposed, including increasing the number of elements, complicating the relationship, or temporarily suspending the project[8]-[13]. The adequacy of the synthetic methodology is discussed in chapter 5.

Based on this thinking, in 2002, we constructed a loose information provision relationship with the manufacturer by temporarily "sublating[5]" or suspending AIST's immediate profit and system, such as the implementation contract, as shown in Fig. 1(b). Using this cooperative relationship,

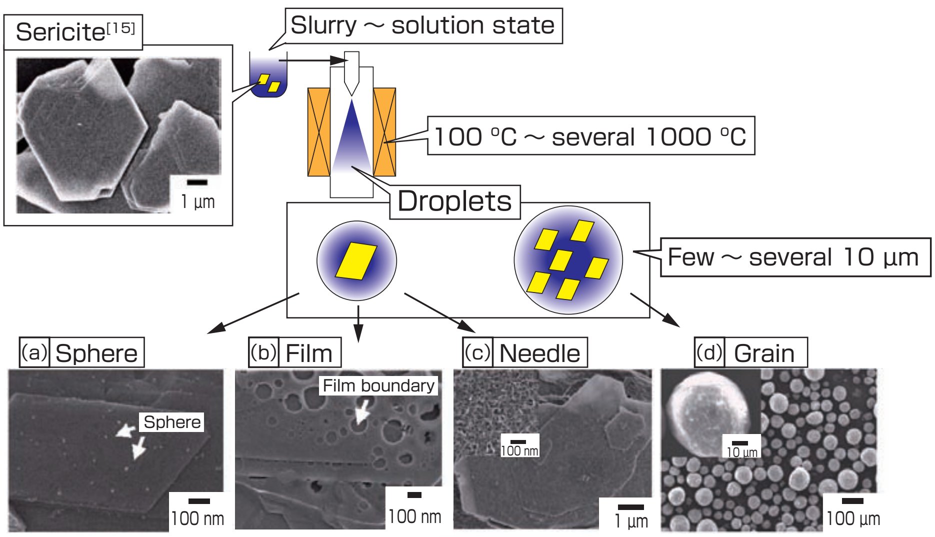

Fig. 7 Technological result: Variations in morphological control
(a) Sphere-coated composite particle: Spherical titania nanoparticles are composited evenly onto the mica surface.
(b) Film-coated composite particle: Titania film is composited evenly on the mica surface. To show the film clearly, the FESEC photo shows the area where the film has flaked off.
(c) Needle-coated composite particle: Needle-shaped titania particles are composited evenly on the mica surface.
(d) Solid mica grain: It is also possible to create hollow structure and solid/hollow titania grains.

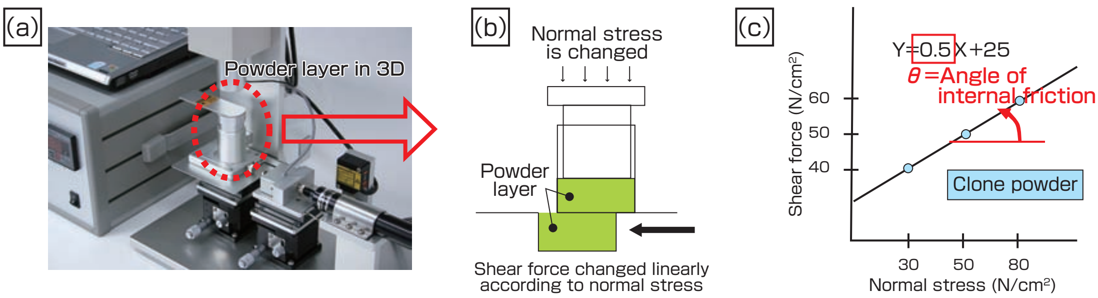

Fig. 8 Technological solution: Establishment of a simple quantification method for the angle of internal friction
(a) Central part of the assessment device that was realized as a product by the AIST-approved venture.
(b) Schematic diagram of the new least-square approximation mode.
(c) Assessment parameter: angle of internal friction

we extracted the issues such as the specific materials that do not violate the Japanese Standards of Cosmetic Ingredients (JSDI) to achieve the *Type 2 Basic Research* level. Next, the powder synthesis pilot plant was constructed at actual production level in 2003 using external budgets, and the technological element of section 3.1 was solved before the aforementioned social issues. After signing a research subcontract in 2007 with the material and product manufacturers, the relationships were adjusted for the product realization of the powder material scheduled for FY 2010[1][2][14]-[21].

< Product realization plan of powder property evaluation device >
Starting from the aforementioned material development, advancement in *Type 1 Basic Research* such as the idea for simple lubriciousness evaluation was obtained[2]. However, this was insufficient as *Type 2 Basic Research* that may provide quality control technology to other ceramic manufacturing and the design guideline for the material powder that provides high lubriciousness to the UV-protective cosmetics.

In general, the evaluation technology, like the JIS and ISO standards, should be in the form of a platform with multiple channels to pursue universality, such as subcontracting by evaluation organizations, rather than exclusive use as in the material product that demands originality and scarcity. Historically, the organizational format such as a company is like a lottery collected every time before maritime voyage, and the risk is equivalent to a modern space exploration[12]. In the current challenging social situation, the public venture theory has been developed as a way to buffer such risks[6][7].

Therefore, as shown in Fig. 6, using the AIST technology licensing organization system, we created a public venture[16] in 2005 to subcontract the lubriciousness evaluation and the development of the evaluation device. With this company as a window to the market, evaluation subcontracts were obtained routinely from several companies, and the product realization issues, such as obtaining the evaluation parameters lacking in the quality control technology, were clarified to achieve the *Type 2 Basic Research* level. As a result, among the technological elements described in section 3.1 including (1) high UV protection, (2) high visible light transmissivity, and (3) high lubriciousness, we were able to provide the design guideline to improve the lubriciousness of the material powder. At the same time, the accomplished fact that this was an evaluation method for the material design at the product realization level increased the social reliability of the evaluation device, and resulted in the adjustment of relationship where the device could be marketed widely and the orders for the device development be encouraged in the FY 2010[1][2][14]-[21].

4 Research result and discussion

4.1 Ordered mixture to resolve the nanoparticle segregation and the achievement of both UV protection and visible light transmissivity

The results of controlling the inter-particle segregation of the nanoparticles and synthesizing the composite particle (ordered mixture) where the nanoparticles are adsorbed only onto the surface of sericite[15], the cosmetic ceramic unit, are shown in the transmission electron microscope image in Fig. 9(a) and as the energy dispersive X-ray spectrometry map in Fig. 9(b)~(c). The spherical nanoparticles adhere finely and evenly on the surface of the planar sericite on both the top and edge faces of the cuboid. The nanoparticles are observed only on the unit surface, and the segregation between the particles is controlled[1].

Figures 7(a)~(c) show the results where the coating of the composite particles are morphologically controlled, and Fig. 7(d) shows the mica grains. The composite particle was created by depositing the titania on the surface of the ceramic unit particle in (a) particulate form, (b) film (the photograph shows the broken section of the film to present a clear view), and (c) needle form. The nanoparticles can be also coated in controlled uneven state on the top or edge facet only of the planar ceramic unit particle[1][2][14]-[21].

Figure 7(d) shows the solid grain of the ceramic unit (mica) particle. Other than these, different planar ceramic unit

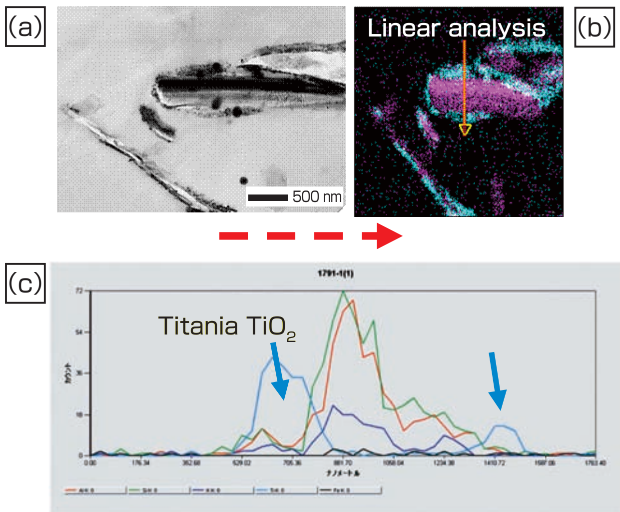

Fig. 9 Technological result: Realization of the "ordered mixture" state (resolved the issue nanoparticle segregation)
(a) TEM image: There is no titania nanoparticle that separated from the mica (embedded grinding).
(b) WDS surface analysis result: The planar particle in the center is mica, and the surrounding spherical particles are titania.
(c) EDS linear analysis result: Titania nanoparticles are composited evenly around the mica.

(boron nitride), hollow or solid grain of titania nanoparticles, and swelling grain that can include and discharge water can be fabricated[1][21].

The above morphological control can be conducted by appropriate selection of the control elements in the solid, liquid, and gas phase methods described in chapters 2 and 3, such as the parallel use of static hetero-aggregation and homo-repulsion in the solution and the particle packing model[1][2][14]-[21].

Figure 10 shows the result of achieving both the UV protection and transparency as material characteristics. In the current product shown in Fig. 10(b), the light transmissivity does not decrease in the UV range of about 400 nm or less. Not only is the blocking of UV insufficient, but also the transmissivity drops exceedingly in the visible light range of 400 nm or over, and this decreases the transparency. On the other hand, in the product developed by the composite particle method in Fig. 10(a), the decrease in low transmissivity of the UV range to achieve high blocking capability and the decrease in transmissivity in the visible light range were controlled to achieve the high transparency as shown in Fig. 10(c)[1]. For the three issues of cosmetics - (1) UV protection, (2) transparency, and (3) texture - the (1) high blocking of UV only and (2) high visible light transmissivity were achieved. One of the reasons for realizing the specific blocking of the UV range only was because the controllability of color tone improved due to the prevention of segregation between the planar ceramic unit particle (sericite) of nanoparticles, and the particles could be arranged with "controlled anisotropy" on the top or edge of the surface of the material particle[21].

4.2 Quantification of lubriciousness and good texture-feel achieved simultaneously

Figure 11 shows the graph of the normal and side-grinding forces evaluated by the LS approximation model shown in Fig. 5 and 8, for the (3) high lubriciousness, the remaining technological element of the UV-protective cosmetics. The current product shown in Fig. 11(b) has poor texture-feel due to the increased gradient of the normal and side-grinding forces, or the angle of internal friction, compared to the raw material unit shown in Fig. 11(c). In the developed product in Fig. 11(a), the internal friction angle is reduced to achieve high lubriciousness or good texture-feel.

One of the reasons for good texture-feel was the realization of the extremely small amount of sericite and nanoparticles used due to the controlled segregation of nanoparticles among the sericite, as they were deposited only on the surface of the material powder.

The effect of controlling the excessive use of the material corresponds to the reduction or resource-saving of 3R (reduce, reuse, and recycle), and presents the contribution to the mission of the Materials Research Institute for Sustainable Development: "to promote innovation and effective use of resource for the development of materials that enable sustainable development"[1][2][14]-[21].

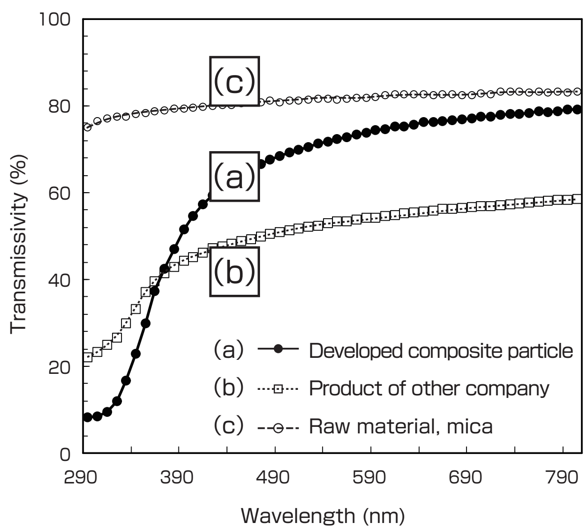

Fig. 10 Technological result: Achievement of both UV protection and visible light transmissivity

(a) Developed composite particle: Corresponds to static friction and reproduces the consolidation state in the hopper (ideal condition).
(b) Product of other company: UV protectiveness increases but transmissivity (transparency) decreases due to the aggregation of nanoparticles, and the face may look "powdery".
(c) Raw material mica powder: Transmissivity of visible light (transparency) is high but has no UV protection function.

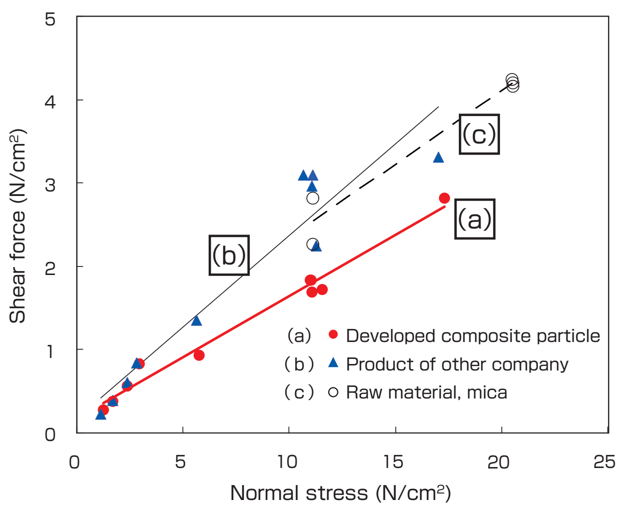

Fig. 11 Technological result: In addition to the optical property (Fig. 10), quantifications of lubriciousness and good texture-feel (skin-touch) are both achieved

(a) Developed composite particle: Angle of internal friction is minimum value.
(b) Product of other company: UV protection function increases, but lubriciousness or texture-feel decreases due to nanoparticle aggregation, and angle of internal friction increases.
(c) Angle of internal friction of the mica particle (median of the two composites).

4.3 Example of specific product

As an example of the product of the synthesis and evaluation research, (a) the cosmetic material product, (b) the evaluation device product, and (c) the public venture[16] are shown in Fig. 12(a)~(c). As discussed in section 3.2, the researches for synthesis (material) and evaluation (device) were not delineated in the preliminary scenario, to enable flexible use of any usable core technologies. As a result, the composite particle method of the material synthesis research guaranteed the wide applicability of the evaluation device, and the evaluation device research contributed to the increased function of the powder material.

The above synergy effect promoted the solution of the mutual technological elements, increased the competitiveness of the social elements, and resulted in the marketing of cosmetics with the "AIST product used" label and the evaluation device by the venture[1][2][14]-[21].

5 Verification of the R&D methodology through the analogy to natural phenomenon and summary

5.1 Verification of empirical and trial-and-error solution of the social elements

The solution of the social elements of this research will be reviewed, and the adequacy of the decision to temporarily suspend the organizational objectives and rules of AIST will be discussed.

Fig. 12 Technological and sociological result: Example of the product

(a) Material (synthesized) product: The developed powder was realized as a product by a local company[15][17] . Patent implementation contract and placement of "AIST research result used" label on the product provide high marketing value.
(b) Method (assessment) product: New assessment method was realized as an assessment device by an AIST-approved venture.
(c) AIST-approved venture[16]

Unlike the technological elements where the unification of the goal is relatively easily done as in improving the property or seeking novelty, the social elements such as the adjustment of organizational interests may not be solved by the inductive method of logic and strategy alone[8]-[13].

As methodologies for solution, *Synthesiology* states (a) the aufheben type, (b) the breakthrough type, and (c) the strategic selection type[5]. These are mainly discussed as measures to solve the technological elements. In this paper, as stated in section 2.2, the idea presented there[5] was applied to the social element in the sense that the decision of the short-term organizational profit was temporarily suspended.

Recently, the R&D methodologies include the thinking of the flow from *Type 1 Basic Research* (observation), *Synthesiology* (factual knowledge), then to *Type 2 Basic Research* (design), using the ideas of humanities such as the continuous and sustained evolution of Popper and Saussure or the cyclic hypothesis verification model[6][7]. The analogy with the natural phenomena such as the theory of evolution[3]-[7] indicates that the optimization at individual level does not necessarily lead to optimization of the whole, hence the synthesis error, as similarly reported in the adjustment of inter-organizational interests[8]-[13].

For example, the neutral theory by Motoo Kimura is a concept that dissects the natural phenomena into plant and animal individuals (logical subject) and environment (empirical object) by refining the theory of evolution, that mutations do not occur only through natural selection but also by trial-and-error at the DNA level[29]. In the selection of feeding route of ants, it is reported that the feeding efficiency of the group is higher in the presence of individuals with low feeding capacity than in a group consisting only of highly capable ants, because the probability of finding a new route increases[23][24]. The competitive society as reported[8]-[13] tends to fall into a decision-making bias where a one-way logical and strategic inductive method is only employed, and there is a heuristic cognitive tendency of becoming a red ocean on a shoestring operation that cannot survive unless it is always involved in some new activity[22][25][29]. The study of historical demography shows that there were four cycles of population increase and decrease in 10,000 years, and in the period of population decline or the period of maturation of the civilization, the concept of *sanpo yoshi* (good for three parties) or *senyo kori* (clients may go ahead and use the product, seek benefit from the product, and then pay for it afterwards) as exemplified by the ways of companies such as Toyama Medicine and Office Glico become prevalent[25]-[28]. The thinking of expanding the target range of logic to unknown clients rather than sitting on a unique logic of cause-effect can be seen in the *ki* (opportunity) of *budo* or martial arts, and *engi* (dependent arising) and *sekishu onjo* (the sound of one hand clapping) of Zen Buddhism, and *bricoleur* (do-ityourself man) of Claude Lévi-Strauss (Fig. 1(b))[11][13].

That local optimization does not equal overall optimization (synthesis error) is an assumption in the natural phenomena such as evolution. Therefore, the aforementioned analogies[3]-[7] are thought to include the solutions of the social elements where the short-term organizational interest is suspended as a cradle of the seeds for next-generation technology in the modern society, which at least is in the maturation stage. This study can be positioned as the segmentation of the aforementioned methodologies[3]-[13] into technological elements (logic and strategy of section 3.1) and social elements (suspension of short-term interest in section 3.2), as in the neutrality in the theory of evolution.

5.2 Summary and future development

This study can be categorized as an aufheben type[5] as stated by *Synthesiology*, and the logical and strategic scenario method using powder technology to solve the technological element was combined with the regional cooperation efforts in the form of technical assistance to solve the social element, although no quick-acting scenario was set. As a result, we succeeded in the development of the cosmetics using sericite[15], a regional brand product, as well as the sales of evaluation device through the public venture. Later, these led to the implementation contract and the practical application of the basic research through the "AIST research result used" product label.

Current issues are the overcoming of the valley of death upon reaching the product realization after R&D, and the market competition with the existing products, known as the Darwin's sea, for wider business development of the technology and product[3]-[7]. Since multiple manufacturing processes are combined in the composite particle method, the unit price of the product increases due to increased processes. Its use becomes limited to high-function cosmetics, and its use in general-use product with larger market scale becomes difficult. The LS approximation method is technically complex, and is not sufficiently recognized as a simple ceramic quality control technology. Although the development period was limited, we must reflect on the fact that the functional development of the materials and the consideration of cost versus effect of the manufacturing and evaluation methods were insufficient.

In the future, we shall promote the wider use of the product through expansion of morphological control case studies for high-control manufacturing method, pioneer new function and use, clarify the scientific aspects of evaluation parameters, and establish the database and JIS. We shall also emphasize the "reduce" aspect of 3R, utilize the trusting relationship nurtured through the adjustment of interests through regional cooperation, and seek ways to uphold the mission of the Materials Research Institute for Sustainable Development: "to promote innovation and effective use of resource for the development of materials that enable sustainable development".

6 Acknowledgements

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Discussions with Reviewers

1 Technological elements and social elements

Comment (Toshimi Shimizu, Research Coordinator, AIST)

In the first draft, in categorizing the synthesis method of the technological elements, the discussion is a mixture of the so-called "technological elements" and the "social background and social elements" such as the budget allocation and support system. I think you should categorize the synthetic method by focusing on the technological elements only.

Comment (Kazuo Igarashi, Measurement Solution Research Center, AIST(current affiliation: Institute of National Colleges of Technology, Japan))

In the first draft, you write in the beginning, "We propose a method that combines the composite particle method and least-square approximation model, and the AIST-style strategic scenario and the regional collaboration of the Agency period". However in the conclusion, you state, "We reproduced the aufheben style". You must clearly describe what is the specific proposal.

Answer (Yasumasa Takao)

To clearly separate the technological elements (logical and strategic scenario) and the social elements (empirical trial-and-error), we revised the structure of the paper after the introduction and the figures of the revised draft. Also, the solution was to combine the logical strategic scenario using the powder technology as the solution for the technological element, and the technical assistance style regional collaboration of the Agency period, where no quick-acting scenario was set, as the solution of the social elements.

2 UV blocking

Question (Toshimi Shimizu)

The objective of this research is to achieve both the transparency and texture-feel of the cosmetic powder by developing a new compositing technology for the UV-blocking nanoparticles and cosmetic ceramics. However, the text states the achievement of all three issues including UV-blocking, transparency, and texture. Since UV blocking is a default for cosmetics, I think there are two issues, the achievement of transparency and texture. What is your reason for setting UV blocking as a distinctive issue?

Answer (Yasumasa Takao)

As you indicated, it is not necessary to list UV blocking because it will be consequently obtained by using the nanoparticles. Since currently there is no technology to arrange the nanoparticles appropriately on the surface of the particle, the nanoparticles must be restrained excessively to achieve both transparency and texture, and as a result, UV blocking function may be lost.

3 Issues of technological elements

Comment (Toshimi Shimizu)

In the first draft, you write that the issues of technological element are "UV blocking", "transparency", and "texture-feel". These terminologies are perceptive and non-technological expressions. From the perspective of basic physical properties, I recommend they be, for example, reworded as "high UV blocking property", "high transmissivity of visible light", and "high lubriciousness".

Answer (Yasumasa Takao)

As you indicated, I made revisions to use the appropriate terms that express the physical properties.

4 Relationship between lubriciousness evaluation device and technological issues

Question (Toshimi Shimizu)

I understand that you first developed the evaluation device for lubriciousness to qualitatively assess the texture-feel. However, you did not describe how you overcame the technological issues by setting what kind of manufacturing condition as technological issues to obtain good texture-feel, or in another word, high lubriciousness, for the UV nanoparticle-ceramics composite material. Does it mean you solved this technological problem simply by trial-and-error? I cannot quite follow the logic of how the good texture-feel was achieved by developing the evaluation device.

Answer (Yasumasa Takao)

One of the reasons for good texture-feel is the effect achieved by controlling the segregation of nanoparticles between the sericite and arranging them only on the material particle surface, and as a result, minimizing the use of sericite and nanoparticles. This point was added to the text.

5 Three types of synthesis method in *Synthesiology*

Question (Kazuo Igarashi)

In the first draft, you cite the three types of synthesis method described in *Synthesiology*, 1(2), 139-143 (2008) (*Synthesiology* English edition 1(2), 131-137 (2008)). When you are comparing them to the case reported in this paper, what exactly are you comparing? Also, you mention the integration type technological and social solutions, but what does this mean?

Answer (Yasumasa Takao)

As the methodology for solving the social elements, *Synthesiology* proposes three types of methods: (1) aufheben type, where two contradicting proposals are temporarily "sublated" to create a new concept, (2) breakthrough type, which is the unique growth model of the core technology, and (3) strategic selection type, which is the investigation of hypothesis through a logical scenario. This research can be considered a case where the (1) aufheben type idea is applied to the social elements in the sense that the short-term organizational interests are temporarily sublated or suspended.

6 Social solution

Question (Kazuo Igarashi)

Please describe what you mean when you say that the social solution will increase the product competitiveness by a combination of regional brand and original manufacturing method.

Answer (Yasumasa Takao)

The researches of synthesis (material) and evaluation (device) were not set in the preliminary scenario, to enable flexible use of the usable core technology. As a result, the composite particle from the synthesis research guaranteed the wide applicability of the evaluation device, and therefore, the device research contributed in achieving the higher function of the powder material. In another word, the researches for synthesis and evaluation contributed to the mutual solution of the technological elements and to the increased competitiveness of the social elements.

7 Feeding route selection by ants

Comment (Kazuo Igarashi)

In the first draft, you mention the "feeding route selection by ants" as a comparison to the natural phenomenon, and describe the similarity of the logical structure to that. However, the general reader does not know about the logical structure of the feeding route selection by ants. Moreover, I cannot see the relationship between the scenario of this paper and the advantage of enhancing the method by promoting the discovery of a new route.

Answer (Yasumasa Takao)

The important viewpoint of this paper is "the optimization of the individual may not necessarily be the optimization of the whole", and I added the description to clarify this point in the revised text.