Construction of the Ceramic Color Database

— Database of more than 300,000 glaze test pieces and its application to industrial research —

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AIST has more than 300,000 glaze test pieces, from over 80 years of ceramic studies by the Imperial Ceramic Experimental Institute and the Government Industrial Research Institute of Nagoya. These pieces are the physical evidence of the processes and the results of glaze test experiments. As such, they provide valuable information for glaze and ceramic research. The Ceramic Color Database has been constructed to make this fundamentally important information widely accessible in support of R&D in the ceramics industry. The database includes: glaze name, firing temperature, firing atmosphere, coloring, chemical composition, recipe, physical state, and other information, as well as images of the glaze pieces. The database has been used in recent ceramics research, and its effectiveness has been verified.

Keywords : Glaze, ceramics, color, database, test piece

1 Introduction

There are over 300 thousand test pieces for ceramic glaze stored at AIST. They were created in the 80 plus years of ceramics research activities. While the research objectives and research phases may vary, the individual test pieces are basic data that represent the experimental results in a visible manner. By systemically organizing these test pieces, we constructed a database that was made available to the industry and the academia, so the pieces would be useful for new R&D.

As the database construction progressed and specific use started, we made improvements to accommodate specific usages. The glaze test pieces are actual samples of the experimental results, and are different from simple numerical data. It is necessary to predict the users and the users' activities to determine what kind of information should be extracted and organized from the test pieces. This is also related to the future direction of the research in this field, or what its direction should be.

Unlike a normal case of research that progresses from the results of basic research to practical application, the main usage expected for this database is that the researcher engaging in product realization research searches the basic data that match the research objective from the vast sea of information. The target of search may be direct, single information, group of information, collateral data, or information that provides a hint for the research. To respond to such usage, it is important to understand the values and characteristics of the original data, and systematically organize them accordingly. In this paper, the construction and the use of the Ceramic Color Database are described, and the new developments that may be possible from such database will be considered.

2 Construction of the database

2.1 Objective of the database

The glaze test pieces were accumulated in the research processes that started at the Imperial Ceramic Experimental Institute. The ICEI was established in Kyoto in 1919 for the purpose of conducting R&D "through the research of applied state-of-the-art basic science" with "close linkage with practical use." Various researches were conducted to lead the industry, with emphasis on prototype construction.[1] At the Government Industrial Research Institute of Nagoya that succeeded the ICEI, many new pigments were developed and advanced glaze researches were conducted, and the glaze test pieces were created in the course of such researches. Some of the researches are known worldwide, and the R&Ds were high level even according to the current standards. The test pieces are valuable source materials in terms of academic and scientific history, from the perspective that the research processes and the results are preserved in a visible manner. The test pieces are disclosed to the public and are used by the manufacturers and researchers of ceramics and glazes. With the attention given to the high value of the pieces, creation of the database was planned to further promote their use. The test pieces are considered directly useful to industry because of the following points:

(1) In the development and manufacture of the glaze, the

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work of fabricating the glaze test piece and improving the recipe is repeated. By using the information of the huge amount of existing glaze test pieces, the time required for testing may be shortened.

(2) They can be used for searching the glaze and glass materials to be used for certain ceramics or ceramic products under certain conditions.

(3) They provide technical information such as the relationship between the color and colored elements, glass composition, and firing condition.

Considering the universal applicability to items other than ceramics, the name "Ceramic Color Database" was used, and the systematic organization of the vast amount of material was started in 1997.

2.2 Design philosophy of the database

The primary objective of the database is to provide fundamental information to the manufacturers of ceramics and glaze. The ways in which the test pieces have been used are covered, and their use is promoted through added convenience. Figure 1 shows the scenario of the Ceramic Color Database construction.

The size of an average test piece is 30×45×5 mm. The pieces are affixed on mounting boards in groups of pieces per test, and the information such as the firing temperature and percentage of formulae are written on the board (Fig. 2). In many cases, the information is insufficient because preservation was not considered when the test pieces were made. The written information is different for each test piece. For the purpose of the database, it is desirable to include all information for all test pieces. However, from the aspect of workload and efficiency, the number of items entered and data were narrowed down. There are over 300 thousand test pieces and about 10,000 mounting boards. The database design was started assuming about five test pieces would be selected and entered per board. We thought the information of the entire group of test pieces could be utilized based on this data entry.

The structure of the data item was based on general, important information for glazes, and the content and search functions were designed assuming use by the researchers and engineers of ceramics. To understand the usage status, the logs for search and other activities were kept. The database also had images. The details of the data item structure and search functions will be discussed in the next chapter. The following two points were considered in organizing the large amount of test pieces that contain various kinds of information, and these two points are the foundation of the concept of the entire database design.

The original data that are the subjects of the database consist of the test result samples in the form of glaze test pieces, and a variety of information can be extracted from them. It is necessary to determine which information should be extracted in what format, considering the characteristic of the original data and the future usage. In designing the data items and the database structure, we tried to set up a guideline by considering the present situation of ceramics and glaze and the future direction of their R&D. For example, in glaze recipe, importance was placed on the type of raw materials. Due to the characteristics of natural raw materials, even if the chemical composition of the main ingredient is the same, the result may vary due to the trace elements and mineral composition (such as type and degree of crystallization) of the raw material. Considering the current practical use in industry, organization based on the name of the raw material seemed to be beneficial. However, the chemical composition was emphasized for this database, and the items for element

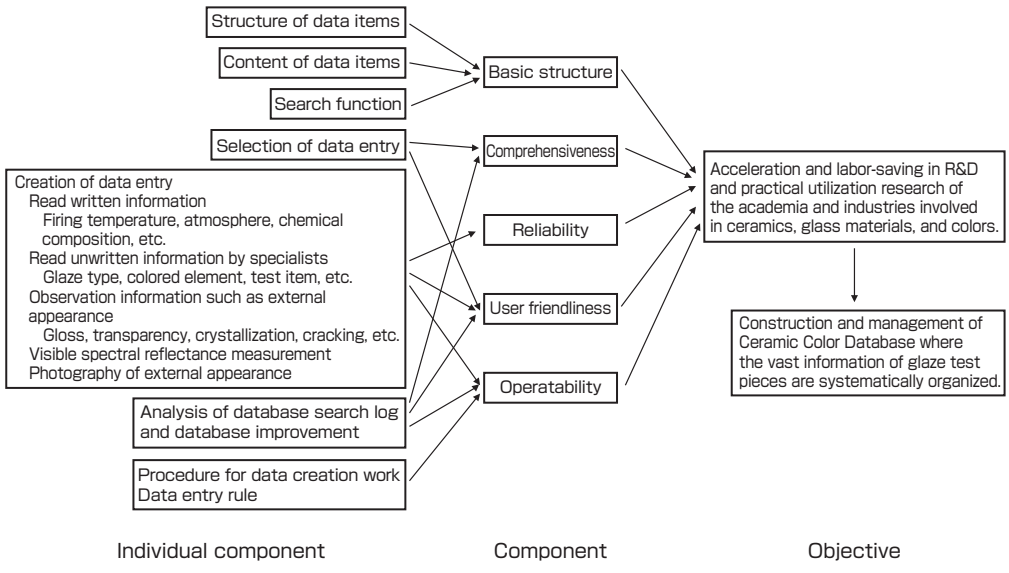

Fig. 1 Scenario for Ceramic Color Database construction

content were fortified. This was done because the natural resources change according to age and their stable supply is not guaranteed in the future. Also, there are possibilities that the database may be used widely by different fields in the future.

Another important perspective was the value of test piece information. In glaze firing, there are many factors for the test condition because the reaction may be stopped in the non-equilibrium state during the melting process. For example, the starting material may be affected not only by chemical composition but also by the mineral composition, grain size, mixing state, and other factors. Firing is also affected by the uneven temperature and the cooling process. This is one reason that a glaze that cannot be reproduced easily exists as a work of art. Normally, in a glaze test, comparisons are made by selecting target factors rather than trying to control all the factors. On the other hand, many of the stored glaze test pieces may not have written description of the main text data. Therefore, the information may be insufficient or there may be problems in reproducibility if the test pieces are seen individually. In contrast, the information that can be obtained from the series of test pieces affixed on one or several mounting boards can be highly useful because they present the information of a test result conducted with an objective. However, it is necessary to set the unit of data to individual test pieces when searching the database. Therefore, the database was designed by setting the individual test pieces as the basic data unit, but access to the information of the group of test pieces was allowed.

At the same time the database construction started, it was decided this database would be publicized on the Internet (as research information open database RIO-DB). Therefore two databases were constructed, one to be constructed within the research institute and the other to be publicized on the Internet. The characteristics of the two databases are shown in Table 1. The open database on the Internet assumed a variety of users. We emphasized ease of operation for people who did not have expertise in glaze or those not used to working with computers. Therefore, the open database was designed so the search result could be obtained in a short time, by selecting only the typical test pieces from the original database. Due to the communication speed and memory capacity of the Internet at the time, the data items were simplified for easy navigation. Unlike the original database set in proximity to the test pieces, the original test piece cannot be seen on the open database. Therefore, in the open database, we worked on the method of searching the test pieces related to the search-target test piece using the catalog number.

Table 1. Original database and open database

	Original database	Open database
Subject to be entered	All test pieces	Typical test pieces
Entry data	Detailed	Simple
Operator, user	User + Personnel	General user
Environment in which DB is provided	Specific place	On Internet
Objective of use	Specialty	Universality
Characteristic	Based on test pieces	Independent from test pieces
Goal of number of entries	50,000 entries	10,000 entries
Completed number of entries (*)	About 33,000 entries	3,826 entries

(*) As of November 2012, the original database includes the data that are in the process of being entered.

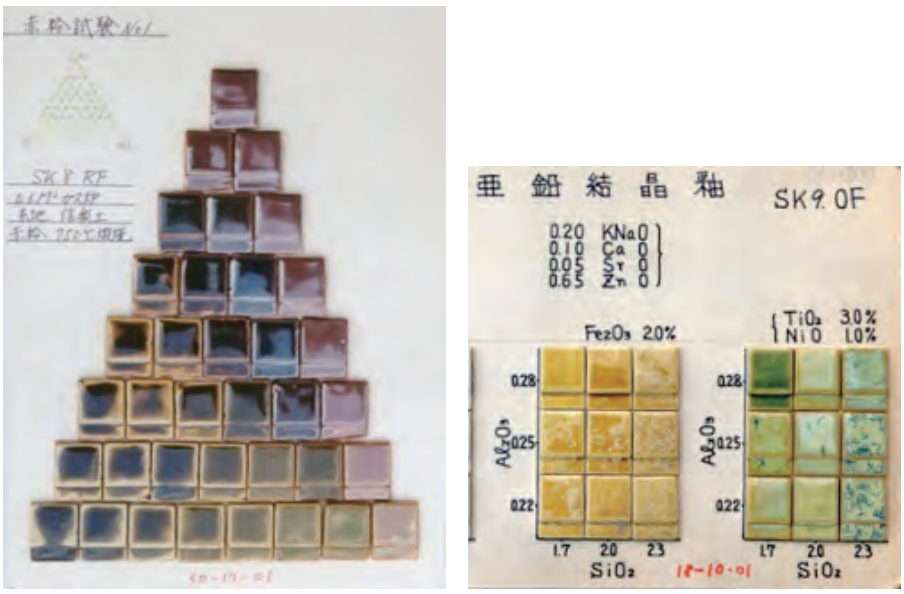

Fig. 2 Examples of glaze test pieces

2.3 Design of the database items and data entry

2.3.1 Overall composition of the data items

The following data items are set for the database. Items marked with "*1" have a format where the selection is made from the candidate list and the data are stored by code numbers. "*2" is numerical data and "*3" is text data.

(1) Information written on the mounting board: recipe[*3], chemical composition[*2], firing temperature[*2], firing condition[*1], body[*1], manufacture date[*2], manufacturer[*3], experimental objective[*3]
(2) Information obtained from the test pieces by specialists: glossiness[*1], transparency[*1], color[*2], physical appearance[*3], glaze type (glaze name)[*1], surface condition[*1], crystallization[*3], cracking[*3], colored element[*1], constituent element[*3], body type[*1], characteristic[*3]
(3) Information obtained by instrumental measurements: (visible spectral reflectance), color number according to color system[*2], image of external appearance

Figure 3 shows an example of the screen of the original database. Since the written information left with the glaze test pieces did not have uniform format or content, we set several data items in comment format to allow entry of a variety of information to the database. The open database on the Internet has similar basic structure for the data items.

2.3.2 Data items to obtain the written information

Various kinds of information are written on the mounting board for each test piece. Of such information, the recipe (chemical composition or raw material mixture) of the glaze and firing temperature are written for almost all test pieces. However, organization was necessary since the descriptions were not uniform even for such basic information.

The Seger formula is used for the chemical composition of the main ingredient of the glaze. Seger formula is a compositional equation that uses molar ratio, and the physical properties such as the melting point or coefficient of thermal expansion can be approximated from the coefficients. This makes possible the search, for example, of "content of sodium oxide 20 mol% or less." We thought such advantages were necessary for the future glaze research and development.

The additive elements such as the colorant and opacifier can be selected from the period table of elements. We also set the item to list all the elements contained in the glaze. The chemical equation data will be absent for the test pieces where the glaze recipe was described by raw material mixture, but in such cases, the elements are entered by the decision of the entry personnel. This enables search based on the presence or absence of an element.

Although the material mix, or the so-called "glaze recipe," is an important data, we employed the method of entering the text data as comments without digitization, because there are so many materials and because the chemical and mineral compositions differ by period even for materials with the same names. While this method allows entry of various material types, it is inferior to the search function organized by material and recipe percentage, and this is our future issue.

For firing condition, the figure for maximum firing temperature is entered, and selection can be made for oxidation or reduction of firing atmosphere. Depending on the glaze test piece, the firing conditions such as the maximum temperature retention time, temperature increase, and cooling schedule may be written. For some glazes, the results may be determined by the maximum temperature

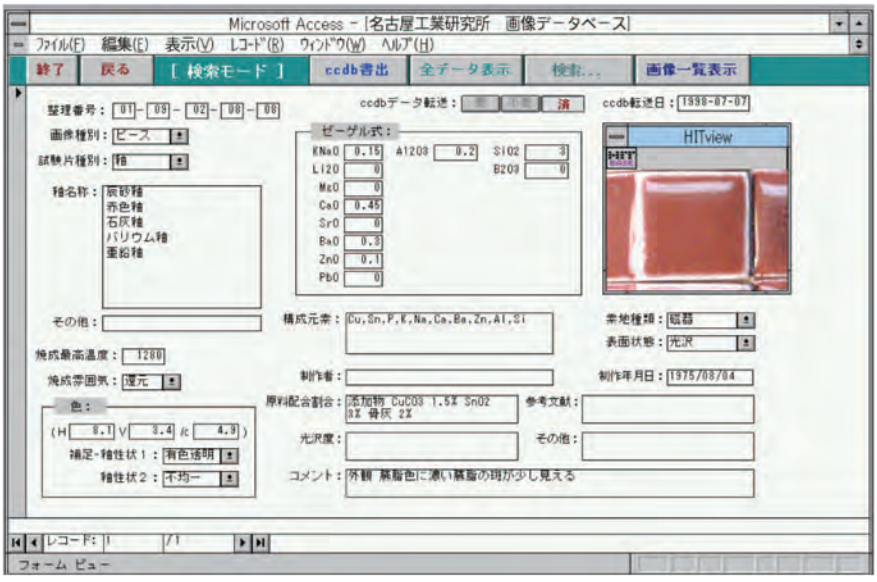

Fig. 3 Example of database screen

only, while for others, the cooling conditions such as the crystal precipitation are important. However, in many cases such conditions were missed and were not written. To fill in the gap, we set the data item for the kiln. This is because the approximate temperature increase and cooling rate can be estimated from the type and capacity of the kiln. There are many test pieces where the firing temperature was expressed as heatwork in terms of Seger cone. While the heatwork value evaluates the overall thermal history, not just the maximum temperature, there is no record of details such as the measurement status. Therefore, we considered the accuracy and use the simple temperature-converted value as data.

2.3.3 Data items from instrumental measurement and information obtained by specialists from the test pieces

The name of the glaze is the most basic information. Traditional names such as *kizeto* and *oribe*, names based on ingredients such as lime glaze, and names according to external appearance such as orange peel, cracking, and milky white were categorized and listed. For traditional names, special names were excluded and candidates were selected so most of the glazes can be categorized. Since there were cases where one glaze had several names, up to six glaze names can be selected from the list of candidates. There is no clear rule about the categorization and identification of the glaze names, and several specialists discussed the matter as necessary to choose the generally recognized use. Also, the ranking of the six selected glaze names were determined by the person in charge of data entry and registered to the database.

For the glaze name, there is the problem of failed test pieces. For example, a test piece for testing the *kizeto* glaze may not be called *kizeto* due to failure. When searching for a typical *kizeto* glaze, it may be an inconvenience if such failure data shows up on search, but it may be useful as reference for R&D. In the database, the item for the experimental objective of the test piece was newly set up, to describe that a certain piece was an experimental result of the *kizeto* glaze. The glaze name is the item most frequently used in search. This is clear from the search log of the open database on the Internet. While the glaze name is basic, simple, and important, it is very complex and represents one characteristic of this database.

The color of the external appearance of the glaze is an important data. The color is expressed as the number according to the Munsell Color System, by measuring the hemispherical integrated spectral reflectance of 5~10 mm diameter circular area on the glaze test piece using an optical device (Hitachi C2000S and Minolta CM2002), and then by calculating the color under illuminant C from the spectral reflectance.[2] The reason Munsell system is used is because the enumeration of the three color values, hue, brightness, and saturation, is optimal for intuitive search by the user. One of the issues in the external color of the glaze was the unevenness of glaze color. In case of two-colored mottling, the spectral reflectance does not reflect the original color correctly since it is the average value of the measured surface area. However, the average value of the surface area may be meaningful in the cases of clear dot pattern, asymptotic color changes, or changes in very small surface areas. In the database, the data for the spectral measurement and color calculation for all test pieces are provided, and at the same time, a separate item is set for the evenness of external appearance. Another issue for color was transparency. In the case where the glaze is highly transparent, the external color is affected by the body beneath the glaze. For transparent glaze, the external color is meaningless. In case of translucent glaze, external color is meaningful but is affected by the body. Separate item is set for the transparency of the glaze. By combining these items, the information on color can be provided and searched. By using the three values expressed by the Munsell system, the search can be done by indicating the range of color. Also, search such as “glaze with high saturation regardless of hue” is possible. This is one advantage of the database.

In the comment section of the data item, the ceramics specialists enter the characteristics and observations of the test piece. When describing the characteristic of the glaze, observation by optical microscope is always done. In the database, although the image of external appearance is provided, the actual test piece cannot be seen. Similar impressions are made when the specialists such as the glaze researcher look at a certain test piece. We believe that the comments made by the specialist in charge of data entry provide an alternative to looking at the actual piece. Therefore, we consider the comments made when creating the data as something very important.

The external photograph of the test piece is shot by adjusting the lighting, focus, and brightness so the characteristic of the glaze will be maximized. Initially we considered obtaining the color information from the photographs. We thought the colors from various areas could be measured and the color distribution can be analyzed even for mottled patterns. However, when we obtained an image that correctly reproduced the color properties, the image was dark, the details of the pattern could not be discerned, and the characteristic of the glaze could not be discerned from the image. To show the impression of the glaze that we normally perceive when seen by the naked eye, multiple images with different exposures are needed. For the external images shown on the database, photographs are shot under conditions that maximize the perceived characteristics of the colors and patterns of the test pieces when seen by the ceramics specialist, and they are often different from the

strict brightness and hue.

2.3.4 Data entry work

The data entry is done with consideration that there will be various types of glazes in the database. The test pieces are selected by giving priority to the ones that are generally considered good glazes to be used on ceramic products. However, when using the database for R&D, failed test pieces may be important, and considerations are made accordingly.

The series of task include reading the information of the data items, entry to computer, color measurement, and photography. If errors in entry or placement of wrong photographs occur, large amount of work is necessary to find and correct such errors as the amount of data increases. Therefore, we established the work procedure through much trial-and-error, and multiple personnel check and recheck the data during each work phase.

Technical terms, acronyms, and proper nouns are included in the written information, and advanced expert knowledge may be necessary to read them. Also, decisions and corrections must be made when there are errors in the original written information. From this perspective, double checks by multiple people are done.

In conducting data entry, there are many cases where review and assessment are necessary. For example, the "reduction firing" in porcelain manufacture generally requires that the reduction state is maintained from the point the firing temperature reaches 800-900 °C to cooling. Some test pieces were treated in special atmosphere for experiment. For the data entry for firing atmosphere in such special cases, "oxidation" or "reduction" can be selected, considering the use by ceramics researcher. To make decisions about such minor but specific problems that arise as we proceed, we weighed the significance and value of the database.

The goal of entries of the original database is 50,000 entries, and the open database on the Internet aims for 10,000 entries (Table 1). The data entry for the original database was started in 1997, and the recent number of entries is about 2,000 per year. The completed number of entries is about 33,000 as of November 2012, although there are some data that are in the process of entry. The number of entries in the open database is 3,826 as of November 2012.

3 Usage and product of the database

3.1 Usage on the Internet

The test piece search became easy by this database construction. Since it is available on the Internet, it is used by the general public. One of the methods for knowing the usage status is the number of accesses and the search log installed in the database. The number of access is average 6,000 per month, and may reach 10,000 per month. However, specific status of use cannot be fully understood through the Internet. The opportunity to know the usage is when we directly or by mail receive response, comments, and inquiries from the users.

We received comments from the researchers of the research institutes and corporations that the database has been used frequently and is highly useful when starting a glaze R&D. This is the case when a specific glaze must be realized. In the development by the glaze manufacturing company, the glaze test piece is made and the recipes are improved. At least one day or normally several days are needed for firing and cooling. Much time and labor are necessary since the recipe improvement is repeated upon observing the firing effect. If the large amount of existing glaze test pieces can be used, the time needed for experiment can be shortened. Several months may be necessary to seek a recipe particularly in products that demand both the physical property and strict color matching, and the usefulness of the database is high.

Another assumed usage is the search of a glaze without specific search conditions. Loose conditions such as "bright and brilliant color" or "baked at 1250 °C" may be set, and such search is made possible by this database. In such usage, many users have actually visited the institute to directly view the test pieces.

The usage and the responses of users are fed back to the database for improvement. There was a demand for simplifying the color search. Since color is important information in glaze search, we responded to the demand by adding simplified color search based on color names in the item of glaze names for users who are not used to the search by numerical classification of color.

3.2 Usage in technical consultations

The technical consultation is an opportunity to learn about the usage of the database. There are a number of consultations indicating the color and property of a desired glaze and wanting to know the recipe and the manufacture method. As a specific example, there was a consultation by a company that wished to create a glaze that was exactly the same as the sample. The company researcher said that they repeated tests over several months but could not make the same glaze. Using the database, about half a day was spent to search for a similar test piece, a test piece with completely the same property was found, and the information for its recipe and firing condition were obtained. In another consultation, there was a request for a glass material with a composition that devitrified without containing a certain element. The target manufacturing condition was found from the database. In this case also, the issue that could not be solved by other methods was solved by the database.

3.3 Usage in joint research and R&Ds

The usefulness of the database was clearly recognized in new R&D. In the research for reducing the use of boron and other hazardous elements in the mid-fire glaze used in roof tiles and semiporcelain, the issue was the development of a glaze that melted at 1150 °C or less with reduced content of such elements. The database search was conducted along with the work of finding the optimal glaze by testing various glaze compositions. The search conditions were the firing temperature of 1150 °C or less and a glossy glaze, instead of the melting status. The search result of the database and the result of the experiment showed almost the same range of composition.

In the development for a glaze suitable for recycled porcelain, the glaze candidates were searched from the firing temperature, the glaze name, and the chemical composition. Various types of glazes with optimal thermal expansion coefficient were developed including the crystalline glaze that could be used at low firing temperature for recycled porcelain. This contributed to the practical use of recycled porcelain.

The database was used in fields other than ceramics. Use was considered in the fields of printing and armoring, and this led to joint research where the database was used in the basic research for color and external appearance. In research related to the solar reflectance of building material, the data for color and spectral reflectance were used. Applications that were not considered before became possible through the database construction and its publication.

3.4 Collaboration with other institutes

The possibility of collaboration with other databases was considered from the beginning of database construction. In the ceramics field, the physical property prediction system was studied to obtain the relationship among the chemical composition, thermal expansion rate, firing temperature, and others. In the field of ceramics design, the prototype fabrication system using CAD and 3D modeling is studied through the design development support on the computer. The joint use of the data with other institutes was considered by linking with the other systems. It was technically simple and partial test implementations were done, but there has been no further development due to the problems in publicizing the data.

On the other hand, progress was seen in the collaboration with overseas public institutes, and the other countries have built the glaze database with common data items and formats in accordance with our database. In the future, we expect the mutual utilizations of data and system collaborations.

4 Future issues and prospects

The number of users and usage frequency of the glaze test piece information increased dramatically through the publication on the Internet. Its usefulness increased with the added search function that used to be impossible. The possibilities for new developments and the issues are becoming clear. Three of them will be considered.

First, the effectiveness of the database in nonconventional ways or fields other than ceramics was recognized. In the future, developments are expected for use in various ceramics and glass materials as well as color research. From this perspective, the future issue is to further enhance the data items.

The candidates for new data items include the data for glossiness and spectral reflectivity. The measurement of glossiness of the test pieces in compliance with the JIS measurement method can be done relatively easily.[3] Also, visible spectral reflectivity is already measured in the color measurement, and this can be provided as numerical data. Other than this, information that can be obtained from the test pieces include surface roughness, crystallization, infrared reflectance, optical properties (such as refraction index), water repellency, cracking, phase state (mottling pattern), and others. Just as in the case where glossiness was used as the guideline of the molten state in the R&D, the matte state of the surface reflects the type and size of the precipitated crystals, and the cracking indicates the thermal expansion and hardness. The data can be utilized from those perspectives. Also, the selection of test pieces entered in the database and the creation of comments and data are being done based on the basic design concept. If the use other than for ceramics is considered, expansion and redesign of the standard will be an issue.

Second, the following development can be considered in using the test piece information. Although the database was designed focusing on the importance of the information that can be obtained from the test piece group, the basic design is based on the individual test pieces. The glaze test pieces were made for some kind of experimental purpose. For example, the experiments might have been done to study the molten state of the glaze by gradually and systematically changing the chemical composition, or to review the color by changing the type and percentage of the colored elements added to the basic glaze, or to observe the state of the glaze by changing the firing condition. The primary information of the test pieces is the results of such experimental objectives. While some accommodations were made to the data items so the experimental objective can be entered, the organization and utilization of the information that can be obtained from the test pieces are major, unachieved issues. We conducted partial survey correlating the test pieces and the research reports. This is useful in strengthening the information for individual test pieces. Only a few test pieces showed

complete correspondence to the details of the experiments as shown in the research reports. However, if a specialist studies the information on the mounting boards, the outline of the experiments can be determined. The categorization and organization can be done based on the conditional factors that were emphasized in the experiment, such as the chemical composition, firing temperature, and additives. Then, the method for providing the information should be considered. Since these cannot be handled in the current database structure, it is necessary to construct a new sub-database. It is necessary to study the construction of a small-scale test database.

Third, the development utilizing the vast amount of data can be considered. The advanced search of the test pieces became possible through the database construction, but the voluminous data have the potential for a new kind of development. For example, the database mainly assumes looking up a single test piece that best matches the search condition. However, even if there are no data that completely matches, the information can be epidemiologically extracted from the large amount of data. In the R&D for a glaze that melts at low temperature while reducing the content of hazardous elements or in the development of a low-fire crystalline glaze for recycled porcelain, various glazes related to the conditions were searched and extracted, and the information of such glazes were used as reference of R&D. In the search of numerical data, wide range of search can be done by setting the upper and lower limits, but further fuzzy search conditions may be employed. Also, the function to extract common information and trends from the various data group obtained as search results can be considered. The ceramic industry is a world of craftsman, and glaze is a field that is characterized by craftsmanship. In the development of a new glaze, along with the external appearance such as color and gloss, various conflicting conditions such as thermal expansion and molten states must be satisfied simultaneously, and this depends largely on the experience and insight of a skilled craftsman. Recently, the decrease in the number of skilled people and the transfer of technology are the issues of the industry. This database was constructed in the hopes of replacing the “experience” of the craftsman through large amount of data, and we believe the objective has been achieved. We are not sure whether we can step into the “insight” of the craftsman by improving the database, but that is one of our future topics.

5 Summary

The Ceramic Color Database was constructed by organizing the data of glaze test pieces. The 300 thousand glaze test pieces were created in the course of more than 80 years of ceramics research. The usefulness of the database is affected by the research level of the original test pieces and the quality of the task of creating the database. The database construction has being continued for more than a decade. This database was created in a very good environment, and its usefulness was proven through the various usages by the industry and in new R&D. The use expanded as the open database was publicized on the Internet. It was also useful in the material development and basic research of fields other than ceramic glaze. The improvement of the database is based on such usage status, but we must return to the basic concept of the database for future development.

Acknowledgement

Although this paper was written by a single author, the construction of the Ceramic Color Database was done as an organization. The database construction was started under the cooperation of the Applied Technology with Ceramics Group and the Planning Office of the Government Industrial Research Institute of Nagoya. For the creation of the open database, we received support from the personnel of the International Standards Promotion Division and the Tsukuba Advanced Computing Center, AIST. The improvement of the database was done through the discussions with the part-time personnel who are in charge of data entry for more than a decade and are experts of the ceramics field.

The database construction became possible because over 300 thousand glaze test pieces were created, organized, and stored. I pay my respect to the seniors of our Institute who engaged in glaze research.

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[2] JIS Z8721 (in Japanese)
[3] JIS Z8741 (in Japanese)

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Completed the master's course at the Department of Earth Sciences, Graduate School of Science, Nagoya University in 1984. Joined the Government Industrial Research Institute of Nagoya (currently, AIST) in 1984. Engaged in the researches of far-infrared radiation ceramics, ceramics, and glaze. Currently, leader of the Applied Technology with Traditional Ceramics Research Group, Materials Research Institute for Sustainable Development, AIST. In this research, was in charge of the overall construction of the Ceramic Color Database, including its design and data entry. Executed the joint researches and technical consultations using this database.

Discussions with Reviewers

1 Overall structure of the paper

Question (Hiroshi Tateishi, AIST Tsukuba)

This paper describes the structure and usage of the Ceramic Color Database that was constructed based on the glaze test pieces left at the AIST Chubu, but I don't feel much impact. One of the greatest reasons is because the start up of the database is mentioned only lightly. When shifting from the physical entity called test pieces to the virtual resource called database, the initial design of what the content should be is extremely important. There must have been lots of arguments, but there is hardly any description of this process, and this shortage makes the paper just an ordinary technical report. To clearly state the "creation of social value" that is the hallmark of *Synthesiology*, I think you should consider the following structure of the paper.

Between subchapters 2.1 and 2.2, you should set a subchapter on "database design," and explain the scenario of Fig. 1. The points are as follows:

- How did the talk about creating a database start?
- What is the specific objective?
- To achieve the objective, what kind of structure should the database have?
- In what form should it be opened to the general public?

Question (Kazuo Igarashi, Institute of National Colleges of Technology)

Although each chapter is interesting, overall, it is difficult to see what this paper is trying to convey. I think the problem is the overall structure of the paper. In the issue of database construction explained in this paper, on what design philosophy the construction was done is important. However, the descriptions pertaining to this are dispersed throughout the chapters, and the most important part is placed at the middle and the end of chapter 4 "Future issues and prospects." For example, why not separate the background/objective and the conclusion, and bring the design philosophy to the top using the following chapter configuration? Please consider revising.

(1) Design philosophy of the database
(2) Scenario to realize the database
(3) Items and considerations needed for construction
(4) Utilization of the database
(5) Extracted issues and future development

Answer (Toyohiko Sugiyama)

I was wondering how to structure this paper as I wrote. Based on your comments, I created subchapter 2.2 on the database design, and described the scenario. Also, the explanation of the glaze test piece of subchapter 2.1 was allotted to the previous and the following subchapters.

2 Relationship between the detailed DB and open DB

Question (Hiroshi Tateishi)

In subchapter 2.2, you explain the content of the original database, but you go on to the explanation of the open DB after 2.3 without clearly giving the reason why you have the dual structure of the original DB and the open DB, so it is confusing. I think it will be easier to understand if you correlate to the items in Fig. 3 that you give as examples, and provide explanation in the main text.

Answer (Toyohiko Sugiyama)

Since the two databases were unclear, I added a description in the new subchapter 2.2. Fig. 3 and 2.3 are mainly about the original DB. Since the open DB has almost the same structure, the content refers to both the two databases. I added a description in 2.3.1. I organized the description by making sections in 2.3. Although it has a different order compared to the data items in Fig. 3 and the correspondence is insufficient, the items follow the categorization of the data items shown in the scenario diagram.

3 Explanation of the database usages

Question (Hiroshi Tateishi)

The description of database usage in chapter 3 is a cluttered list. I think you should set up some categories and organize them. You should also include the specific comments from the users and their feedback. Also, what specifically are "various non-technical concerns"? Can you describe them clearly as much as you can? You write, "the usage and effectiveness of this column is untested, but it is positioned highly in data creation." Please indicate the reason why you consider it important even when untested.

Question (Kazuo Igarashi)

In "Database usage" in chapter 3, not only are there several cases that are listed given the same weight of importance, but there are some conclusive sentences and I am not sure what you are trying to say. Please organize the text by either setting up sections or giving priorities to the cases.

Answer (Toyohiko Sugiyama)

I created subchapters. Also, part of the text was moved to another chapter. Along with the revision of the overall chapter structure, I transferred part of the text to "Design philosophy." I also created sections. The specific example of "various non-technical concerns" was that the local industrial association commented against the corporate research institute, and limited the disclosure to public (limited disclosure to people of the same industry in other regions) for the software and data created by the research institute.

For the description of "untested," I added the reasons in the appropriate places in 2.3.2. The reason I wrote "untested" is because there is no user log left in the comment column. I deleted this expression in the revised text.

4 Collaboration with the overseas database

Question (Kazuo Igarashi)

In the last paragraph of chapter 3, you write, "Collaboration with other databases is technologically simple but has not been realized due to various reasons. On the other hand, in overseas public institutes, similar databases with uniform data items and data formats are being constructed, and there are progresses in mutual use of data and system linkages." Does this mean that a database system that surpasses this database has been built

abroad? If so, I think you should explain the "various reasons" that prevented the author from doing so. I think you should also reference the overseas system.

Answer (Naoto Kobayashi)

The overseas research institute (specifically, National Metal and Materials Technology Center, Thailand) created the glaze database with matching data items and format with the AIST database. The researchers visited each other's institutes and engaged in research cooperation. The reason I wrote "progress in collaboration" is to mean the collaboration with this database. I revised the text.

5 Adequacy of the research level of the test pieces

Question (Kazuo Igarashi)

In the summary, you write, "The high or low of the usefulness of the database depends on the research level of the original test pieces and the quality of the work to create the database." I think this is certainly true. How was the research level of the test pieces that continued over 80 years guaranteed, and what made you decide the research level was adequate to create the database?

Answer (Toyohiko Sugiyama)

Before starting the database, the corporate researchers used the test pieces, and their usefulness was recognized. The researchers at AIST (Government Industrial Research Institute of Nagoya) were also aware of the benefit of the test pieces as they used them in research. Particularly, when considering the direction of the experiments at the initial stage of research, the reference to the past experimental data was useful, and vast data provided on-target information in many cases.

Also, there were test pieces related to world renowned R&D such as the ones for iron-based glaze, and this drew attention in Japan and overseas.

On the other hand, there is the problem that not all test pieces have guaranteed research levels. I think the remaining test pieces are only those considered to meet a certain level as judged by the person who was in charge of the research when they were created. We also select the pieces in the data entry work.

6 Number of data entered and future prospect

Question (Hiroshi Tateishi)

In the beginning of subchapter 2.2, you write, "The database design was started assuming the data capacity of 50,000 cases." Then, on the third page, you write, "By selecting more typical test pieces from the original database (for open database on the Internet), the search results could be obtained in a short time." However, in the paper, it is not written how many data are entered in the original and the open database. Why don't you add the figures in Table 1?

Also, if you have a goal for the final entered number, please explain that, and mention the prospect of when this work will be completed.

Answer (Toyohiko Sugiyama)

I added the number of current data entries and the goal to Table 1. At the end of section 2.3.4, I added the description of the number of data entries. About 15 years have passed since the start of data entry. The number of registered data for the original database is about 33,000 entries including the data that are currently under construction, and there are over 20,000 entries with which the work is completely finished. We set our goal as 50,000 entries. When we started the database, we could hardly enter 1,000 entries per year. With improvements in the entry system and work procedure, the efficiency of the entry work increased dramatically. Meanwhile, we strengthened the recheck of data correctness so that the workload doubled. Currently, the rate of entry is about 2,000 entries per year. If the work continues at this pace, about ten years will be required to reach the goal of 50,000 entries. The glaze databases are being constructed in many public research institutes, but there is no other case where the project is continuing for so long. This is one great advantage or our database.

I did not write the prospective achievement date of the goal in the paper, because that can change according to the external factors such as future work situation or number of personnel allotted.