Durable Media for Long-Term Preservation of Geological Repository Records - 8320

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ABSTRACT

Durability of selected hard materials as information preserving media has been studied, leading to some promising results. Several engraving experiments on the selected materials confirmed that characters and patterns can be expressed along with shading and gradation.

INTRODUCTION

There are two fundamental methods for the preservation and transfer of information across future generations. One is the method relying on the institutional control in which information can be entrusted to the next generation. This method is called the “Relay System”.

On the other hand, another method called the “Permanent System” uses selected hard materials to engrave the information, for example, on durable containers or in places to preserve it. In this paper, study results are given of silicon materials which are supposed to be one of the most hard and durable materials in the world. Silicon carbide in particular is expected to be one of the most durable media for long term preservation of information.

The preservation of information is a fundamental component of any waste disposal program, as it provides the foundation for knowledge transfer across experts and successive generations. Paper, film and digital media are usually used as recording media for preserving documents in record management institutions such as the national and regional archives. Paper, most common for documents, could remain more than several hundreds years in an appropriate storage environment. However, a quantitative assessment concerning the long-term durability of written ink has not been made.

However, though the current technology is trying to strengthen the long-term durability of these media, human control would be needed for keeping a suitable environment such as temperature and humidity controls to preserve these documents. To preserve documents for a thousand years or more without human control, a physically durable recording media is desirable.

Engraving experiments on selected artificial materials such as metals and ceramics were carried out by laser technology to develop a long-term recording media. As for metallic materials, hastelloy was selected, and as inorganic materials, sintered compacts of alumina, zirconia and silicon carbide were chosen.

According to the preliminary trench-engraved experiment using laser, successful results were obtained in the case of hastelloy and silicon carbide. As for alumina and zirconia, successful results have not been obtained.

OVERALL PLAN

To study and demonstrate the long term information preservation technology, characters, figures, and graphs were engraved on the materials which seemed to be hard and durable. Considering the environment for information preservation in the future, selection of materials was the first step in the process, followed by selection of the machining technologies for engraving information on those materials. Possible materials as recording media were selected from the viewpoint of long-term durability.

The fineness of materials, surface finish specification, molding, etc. were considered in the selection process. (1, 4) Lines, characters and graphics were proposed as targets to be engraved. In the case of characters, examination was made with regard to how complicated characters could be reproduced. Shading or gradation of graphics, possibility of reproducing photographs by means of engraving, and reproducibility of colors were also examined. Possible choices for engraving methods were elimination machining, oxide film treatment, etching, physical deposition and chemical deposition. (2, 4) Engraving experiments were performed on the selected materials by using laser technologies. (2, 3, 4) The following items were considered: appropriate materials as recording media, types of records that can be engraved, precision, and machining effectiveness (cost, time, etc.). (2, 3, 4)

RESULTS OF ENGRAVING EXPERIMENT

The results of the engraving test of lines, characters and graphics on selected materials as mentioned above are given below. (2, 3, 4)

The selected materials were metals and inorganic materials. As for metallic materials, hastelloy was selected, and as inorganic materials, sintered compacts of alumina, zirconia and silicon carbide as well as CVD (Chemical Vapor Deposition) of silicon carbide were chosen.

Table I presents a list of these materials. By considering the ease of procurement of specimens and implementation of experiments, plate materials of 100×100×5 mm were used in the case of hastelloy and ceramic sintered compacts, and, in the case of silicon carbide CVD, disc-shaped specimens of 12.5 cm diameter×1 mm thickness were used. Lines, characters and graphics were engraved on these materials. In addition, shading and gradation were also examined.

The machining methods used were trench engraving and dot engraving by laser. The selected language writing to be engraved was Japanese characters, including Chinese characters, because of the great number of strokes and because they are ideographic characters superior in communicating information.

Table I: List of Materials Used for Experiments

Material	Density (g/cm3)	Hardness (MPa)
Hastelloy C22 (Ni-base alloy)	8.7	0.6
Alumina sintered compact (Al_2O_3 99.9%)	4.0	19
Zirconia sintered compact (ZrO_2 94.7%)	5.5-6.1	12-14
Silicon carbide sintered compact (α-SiC 98%)	3.2	25-31
Silicon carbide-CVD	3.2	34

Trench Engraving

On hastelloy and sintered ceramics, simple graphics were trench-engraved by use of laser. The resulting groove depth and minimum intervals between grooved portions were examined. Simple characters were also engraved to check the stability of the projecting portions, so that the size of the font to be used in the trench engraving could be determined. Figure 1 shows the image of Laser/Water-Jet Hybrid Machining adopted in the present experiment. In this machining method, laser is enclosed within a water column, and condensed into a microscopic spot. The cutting sections are cooled off by water to eliminate effects and distortion due to heat, and chips are washed away by water jet to facilitate the engraving operation.

Fig. 1: Laser/Water Jet Hybrid Machining

The results of the preliminary experiment show that a promising accuracy can be obtained in the case of hastelloy and silicon carbide, and no major alteration of machined portions was detected. Lines were successfully engraved with promising accuracy at intervals of 0.3 mm and at depths of 0.15 mm in the case of silicon carbide and 0.8 mm in the case of hastelloy. As for alumina and zirconia, successful results have not been obtained with the method, and, therefore, the common laser (YAG fundamental wave) machining was used. After groove machining, the grooved portions were washed by water jet. No promising results could be obtained on these materials.

Based on the above results, sentences were engraved on hastelloy and silicon carbide (Fig. 2). Laser/Water Jet Hybrid Machining was adopted as the operation. The results of the engraving shows that at parts where two lines overlap, the minimum interval is less than 0.3 mm and the groove widths are wider. However, these widened grooves occur only at small parts of the overall configuration, and, therefore, have little impact on the ability to decipher the characters.

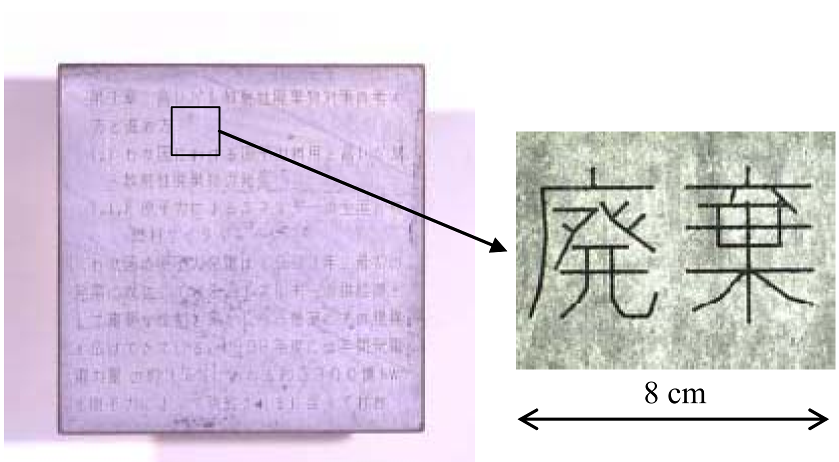

Fig. 2: Example of Results of Trench Engraving Test (Hastelloy)
(Engraved sentences are extracts from literature by JNC (1999) (5)

High-accuracy engraving using the Dot Matrix Method was performed on hastelloy, alumina, zirconia and silicon carbide (sintered compact) as well as on high-fineness silicon carbide manufactured by Chemical Vapor Deposition (CVD), in order to examine the accuracy of characters, the shading of graphics and the accuracy of gradation.

Figure 3 shows the images of the dot engraving of Chinese characters and alphabets with sizes of 1 point to 12 points as well as the machining to achieve gradation to express graphics. Figure 4 shows the results of dot engraving on sintered silicon carbide. The sizes of characters were gradually decreased from 12 points to 1 point.

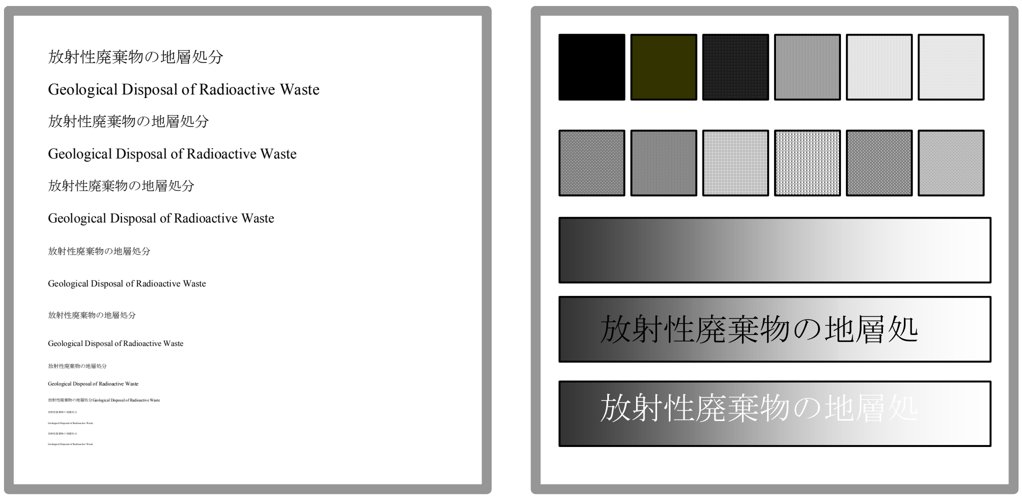

Fig. 3: Images of High-Accuracy Engraving Test of Records

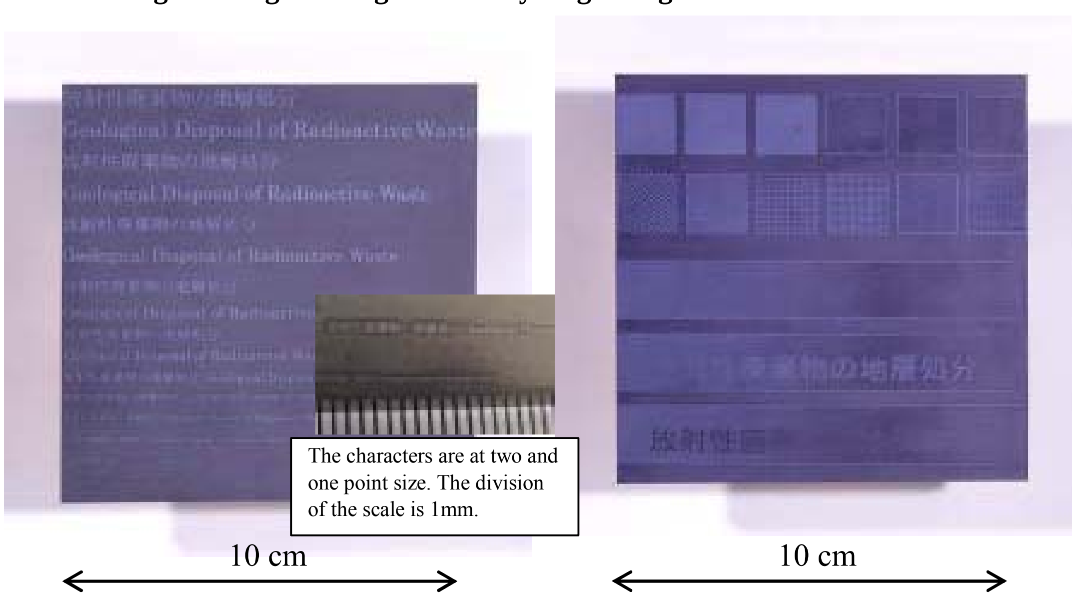

Fig. 4: Results of Dot Engraving Test (Sintered Silicon Carbide) Dot Engraving

With all materials, characters (the alphabets and Japanese characters including Kanji) of sizes down to 2 points (~0.7mm) were readable by the naked eye or using a magnifying glass. With hastelloy, sintered silicon carbide, and silicon carbide CVD, characters of 1 point were especially readable. As shown in the picture (right-side) in Figure 4, patterns and graduation were also discernable.

Figure 5 shows 11-point characters engraved on different materials. As for alumina and zirconia, slight inconsistency of color and blurred profiles of marking portions were observed. By examining the machined portions on alumina and zirconia materials using a magnifying glass, it was confirmed that fine dots were not formed as with hastelloy and silicon carbide.

Figure 6 shows the results of dot engraving on sintered silicon carbide. The right-side shows the reproduction of 6 pages of sentences on A4 size page on a 10 cm×10 cm plate. In this case, the size of the characters is 2 points (~0.7mm), and sentences were readable with the naked eye or using a magnifying glass.

Fig. 5: Comparison of the Results of the Dot Engraving Test (From above to bottom, hastelloy, alumina, zirconia, silicon carbide sintered compact, and silicon carbide (CVD). The size of character is 11 points.)

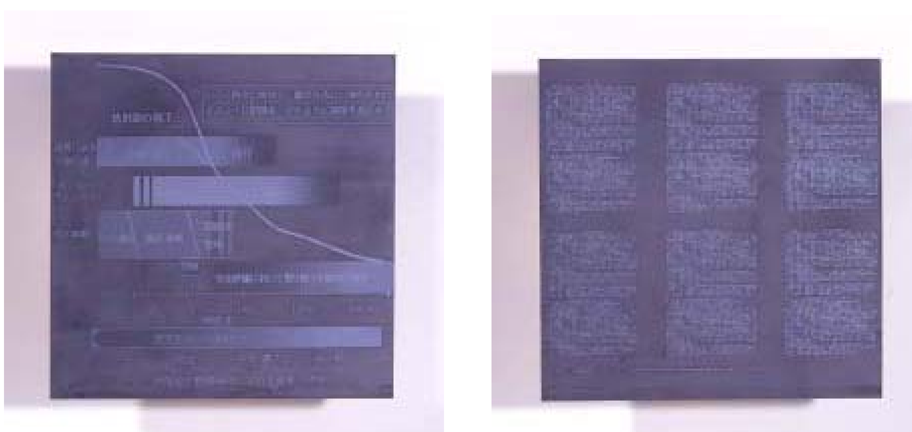

Fig. 6: Figures and Scaled Down Sentences Engraved on Silicon Carbide (Sintered Compact)

DISCUSSION

Engraving experiments on durable artificial materials were carried out by applying laser technologies. By selecting appropriate materials and engraving methods, characters and patterns can be expressed along with shading and gradation. These technologies can be applied to not only documentary records but also to markers and monuments. Among the materials, silicon carbide, which has strong resistance against heat wear and chemical impacts, corrosion resistance and wear resistance, showed satisfactory results in terms of accuracy. Thus, it is expected to be a promising material for the long-term record preservation.

With respect to the density of characters in written records in the case of dot printing, it was estimated that, with 2-point characters, information totaling 6 to 8 pages of A-4 size can be engraved on a 10 cm×10 cm plate. When a document that has 500 pages of A4 size paper is engraved on sintered silicon carbide plates, the total volume of recording media is evaluated as follows:

- Size of plate: 10cm × 10cm
- Size of character to be engraved: 2-points (≒ 0.7mm; of readable size by naked eye or using a magnifying glass)
- Number of pages of original document to be engraved on a plate: 8
- Number of pages of original document to be engraved on both sides of a plate: 16
- Number of plates needed for a series of document package: 500 / 16 = 32
- The thickness of a plate: 1mm
- The total thickness of recording media: 32mm
- Bulk of recording media preserving 500 pages of document: 10cm × 10cm × 32cm

The examination has shown the possibility of long-term preservation of documentation records as a permanent system. A further examination is suggested concerning the assessment of the durability of the sintered silicon carbide plate against wear and chemical impacts. Preserving color pictures and photographs for a long-term duration is also proposed. (3, 4)

CONCLUSION

We have proposed that the concept of a record preservation system is the combination of several different methods in order to impart redundancy to the communication function. The system should be robust that its overall function would not be influenced by partial damage, and also be flexible enough to adapt to the changes of background conditions in the future.

Records and information should be preserved by way of both Relay System and Permanent System. The former would maintain record preservation and communication functions in the framework of social systems whereas the latter would consist of durable storehouse facilities, recording media and markers/monuments and be independent of any social systems and human control. Silicon carbide is one of the most promising materials for the Permanent System of Records Preservation. It is expected to be the potential candidate for long-term recording media with its superior characteristics of resistance against heat, wear and chemical impacts, and of engraving accuracy.

REFERENCES

1. Radioactive Waste Management Funding And Research Center (RWMC) (2000): Research Report on the 2000 Research on High-Level Radioactive Waste Disposal Program (Third Series) - Research on the Improvement of Monitoring Apparatus and Technology – (2/2 Development of a Record Preservation System for Geological Disposal) (in Japanese)
2. Radioactive Waste Management Funding And Research Center (RWMC) (2001): Research Report on the 2001 Research on High-Level Radioactive Waste Disposal Program (Third Series) - Research on the Improvement of Monitoring Apparatus and Technology – (2/2 Development of a Record Preservation System for Geological Disposal) (in Japanese)
3. Radioactive Waste Management Funding And Research Center (RWMC) (2002): Research Report on the 2001 Research on High-Level Radioactive Waste Disposal Program (Third Series) - Research on the Improvement of Monitoring Apparatus and Technology – (Series No. 3) Development of a Record Preservation System for Geological Disposal) (in Japanese)
4. Radioactive Waste Management Funding And Research Center (RWMC) TECHNICAL REPORT RWMC-TRE-03001 －Record Preservation Study on Geological Disposal - Significance and Technical Feasibility –
5. Japan Nuclear Cycle Development Institute (1999) - H12: Project to Establish the Scientific and Technical Basis for HLW Disposal in Japan