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Hydroxyapatite Humidifier Vibrator Housing Fabrication and Characteristics

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Abstract: The humidifier vibrator housing is difficult to clean and prone to contamination due to its metallic material. To overcome these shortcomings, the humidifier vibrator housing was manufactured using Hydroxyapatite as a raw material. Although hydroxyapatite has excellent antibacterial properties and biocompatibility, it is difficult to manufacture a sintered body due to its weak fracture toughness. Therefore, hydroxyapatite sintered compacts were prepared according to the amount of plasticizer added and their physical properties were compared. The average compressive strength was 395.1 N·mm-2 at 8 % of the amount of added plasticizer, and the average bending strength was 61.8 N·mm-2 at 6 % of the amount of added plasticizer. The hydroxyapatite sintered compact showed the effect of inhibiting the production of bacteria regardless of the amount of plasticizer added. As a result of this physical property study, it was possible to develop a humidifier vibrator housing with excellent antibacterial properties and maintaining mechanical strength.
Keywords: Hydroxyapatite; Bio-active ceramic; Biomaterials; Antifungal; Antibacterial properties.

1. Introduction

To change the climate and the environment, and to improve the quality of life, many convenient devices are used for living. Among them, one of the house-hold goods used for improving the living environment is a humidifier. In the past, to control the humidity of a dry living environment, natural or direct moisture spraying, and fiber drying were used, but the development of electronic devices enabled more precise humidity control [1]. When the indoor air is higher than about 40 % humidity, it can create a pleasant indoor atmosphere, such as preventing respiratory diseases and diseases [2]. Such humidifiers are widely used in hospitals, public facilities, and businesses, as well as general homes, and are classified into three types of ultrasonic, heated, and mixed types. The core components of the humidifier are the vibrator and vibrator housing that exchange electrical energy with mechanical energy. It consists of a vibrator and a housing, and the role of the housing is to hold the part of the water supplied from the water tank as well as to fix the vibrator and to keep it humidified. The housing is usually made of metal and is an important place where direct humidification occurs in contact with moisture for 24 hours. Among the biomaterials, Hydroxyapatite (HAp), a bio-active ceramic, is a ceramic composed of a compound composed of Ca and P as its main component. Biomaterials existing in the body have two characteristics: biofunctionality, which is a property that must be able to perform the desired function perfectly, and biocompatibility, which is a property of a material that is compatible with living tissues [3, 4]. However, despite these biocompatible properties, Hydroxyapatite is not widely used. One of the reasons is that Hydroxyapatite is not only hard to obtain Hydroxyapatite itself, but also a ceramic, which is difficult to process, form and sinter compared to metal materials. Hydroxyapatite belongs to ceramics and has strong mechanical strength [5, 6]. It is known that the compressive strength of hydroxyapatite sintered at 1300 °C is about 500 MPa and the bending strength is about 110 MPa [7–9]. However, due to their weak fracture toughness, it is difficult to manufacture a sintered body. In this study, the sinterability was enhanced by adding a plasticizer, an organic material that facilitates molding at high temperature to Hydroxyapatite. A plasticizer is a low-volatile organic compound added to plastics or rubber to weaken the intermolecular forces and lowering the glass transition temperature to impart flow properties including flexibility, extension, elasticity, adhesion, and processability. This serves as a softener. Currently, most of them plasticizers are added to synthetic resins. To explain the action of plasticizers briefly, plastics are made up of long stringlike molecules, and the harder the force pulling them between the molecules, the harder it becomes. At this time, if the plasticizer is sandwiched between the molecules, the direct pulling force between the plastic molecules is weakened, which leads to good bending. In this study, the sinterability was enhanced by adding a plasticizer, an organic material that facilitates molding at high temperature to Hydroxyapatite. A plasticizer is a low-volatile organic compound added to plastics or rubber to weaken the intermolecular forces and lowering the glass transition temperature to impart flow properties including flexibility, extension, elasticity, adhesion, and processability. This serves as a softener. The plasticizer used in this experiment is polyethylene glycol, which has various characteristics, and its boiling point is lower than the sintering temperature of Hydroxyapatite at 1350 °C, so that the plasticizer disappears during sintering, so it does not affect Hydroxyapatite. Therefore, the physical and biological properties of the humidifier vibrator housing were directly molded using Hydroxyapatite. To measure the physical properties of the material, strength (MPa), hardness (Hv) and shrinkage (%) were measured.

2. Experimental procedure

2.1 Synthesis of Hydroxyapatite

Hydroxyapatite (Ca:P ratio = 1.67) powder was synthesized with CaCo3 and H3PO4 using liquid state methods. First, CaCo3 was mixed with distilled water, and stirred for 5 hours. H3PO4 was slowly dropped into the CaCo3 solution and stirring was continued for 12 hours. After reaction the solution was dried at 100 °C, and the obtained dry powder was sintered at 1350 °C.

2.2 Compressive strength measurement according to the amount of plasticizer added

First, the plasticizer was added in 2 %, 4 %, 6 %, 8 %, 10 % weight ratio with respect to the hydroxyapatite to determine the titration amount of the plasticizer. To measure the compressive strength, a 1 cm diameter mold was used to form a cylindrical sHApe and sintered at 1350 °C, for 4 hours. Cylinder area: 0.5 cm * 0.5 cm * 3.14 = 0.785 cm^2 pressurized ton: 1 ton. At this time, the plasticizer used was polyethylene glycol.

2.3 Bending strength measurement according to the amount of plasticizer added

Plasticizers were added in 2 %, 4 %, 6 %, 8 %, 10 % weight ratios relative to hydroxyapatite. To measure the bending strength, a rectangular mold was formed using a width (horizontal) * space (length) 4.70 mm * 25.0 mm mold and sintered at 1350 °C for 4 hours. And because the area of cylinder and rectangle is different, 1.5 ton was applied by calculating the number of pressurized tons per unit area. The total sample amount was 1.00 g as shown in Table 1.

Table 1. The ratio of HAp and plasticizer in mold of 1 g specimen.

Sample	HAp	Plasticizer	Remark
A	0.98 g	0.02 g	HAp 98 % + Plasticizer 2 %
B	0.96 g	0.04 g	HAp 96 % + Plasticizer 4 %
C	0.94 g	0.06 g	HAp 94 % + Plasticizer 6 %
D	0.92 g	0.08 g	HAp 92 % + Plasticizer 8 %
E	0.90 g	0.10 g	HAp 90 % + Plasticizer 10 %

2.4 Shrinkage rate measurement

Based on the compressive strength and flexural strength measurement results, the shrinkage of straight lines and cross-sectional areas after molding and heat treatment was calculated for each specimen to which 6 % and 8 % plasticizers were added using a cylindrical mode. Currently, the molding pressure was 1.5-3 tons.

2.5 Hydroxyapatite ceramics antibacterial

To measure the antibacterial properties of hydroxyapatite, first, samples sintered according to the amount of added plasticizer in the bulk state are put in tap water, and then separated and left at room temperature for 24 hours. After that, the supernatant is extracted, spread on a solid medium, and the presence or absence of bacteria is measured after incubation at 30 °C. for 48 hours. As a control group, normal tap water was tested with the experimental groups under the following conditions.

1) Make a solid medium
2) Prepare a sample of 0.4 g of sample + 3.6 g of water (total: 4.0 g).
3) Separately prepare samples left for 24 hours.
4) Centrifuge the sample at 1000 rpm for 10 minutes.
5) Separate the supernatant of each sample and incubate in a solid medium for 48 hours.

2.6 Modeling of Hydroxyapatite vibrator bousing

To manufacture a housing made of carbon steel with reference to the shrinkage rate, a mold was designed as shown in the Fig. 1 and a hydroxyapatite housing was manufactured. A is the outer frame, B is the inner frame, C is the upper presser, and D, E are the housing separation parts.

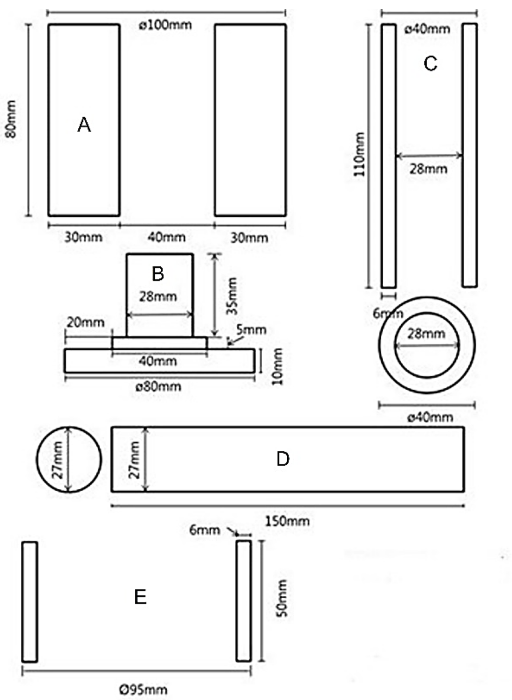

Fig. 1. The mold design for manufacture a housing

3. Result and discussion

3.1 XRD and EDS of Hydroxyapatite

Fig. 2 and Table.2 show XRD and EDS results of synthesized HAp. The main peak of the hydroxyapatite powder was found at 31.8, and all peaks were found to be hydroxyapatite crystals by JCPDS card number 9-432(Fig. 2). The EDS results for quantitative analysis of Ca and P also revealed that the molar ratio of Ca / P is 1.67 (Table 2).

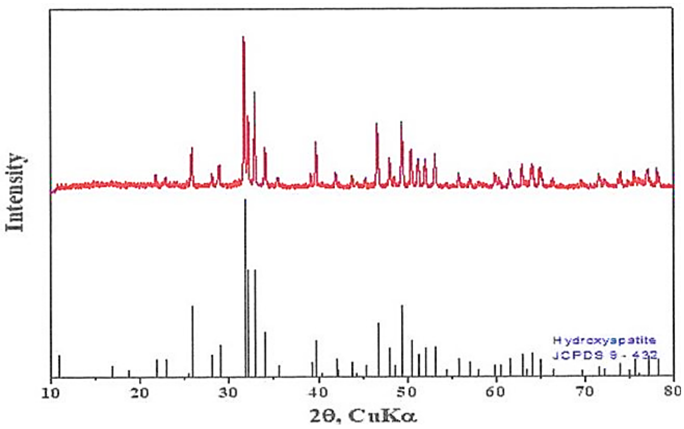

Fig. 2. XRD results of synthesized Hap

Table 2. EDS results of synthesized HAp

Element	Atomic (%)
O	69.56
P	11.41
Ca	19.03
Total	100.00
Ca/P	1.668

3.2. Compressive strength measurement

Fig. 3 shows the results of measuring the compressive strength of a specimen molded to 1 ton and heat treated according to the amount of plasticizer added. In the test for measuring compressive strength according to the amount of plasticizer added, a high measured value of compressive strength of 395.1 N·mm-2 was shown in the specimen with 8 % plasticizer added. Based on this result, four samples with 8 % added plasticizer were prepared in pressurized tonnage of 1 ton, 1.5 ton, 2 ton, and 3 ton, and the compressive strength was measured. When the pressurized tonnage was 1 ton and 1.5 ton, the results were similar. As the tonnage increased to 2 tons, the compressive strength was expected to increase, but the measured compressive strength showed a tendency to decrease.

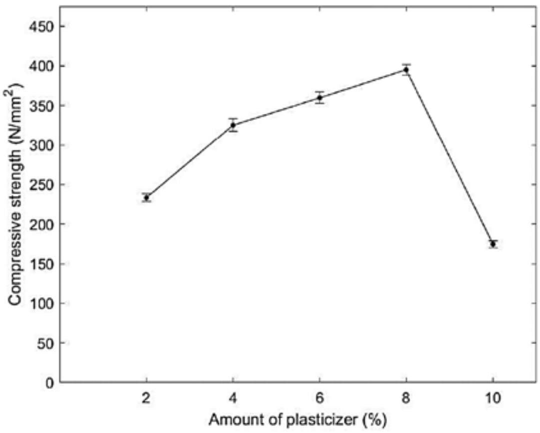

Fig. 3. Compressive strength results according to the amount of plasticizer added

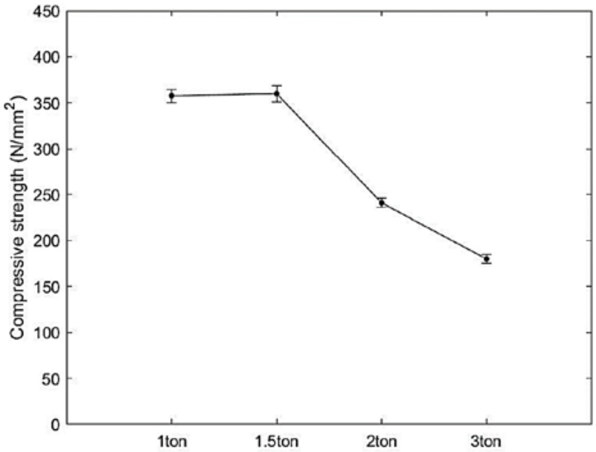

Fig. 4. Graph of compressive strength according to ton number at 8% of plasticizer addition.

The compressive strength of the specimen with 8 % plasticizer added according to the pressure change was 1.5 tons, which showed the highest compressive strength during compression molding. This is due to microcracks occurring in the sintering process as a small amount of plasticizer is released during molding due to high pressure as the pressurized tonnage increases. Therefore, when the amount of plasticizer added exceeds 8 %, the compressive strength is judged to be low [10, 11].

3.3 Bending strength measurement

Based on the compressive strength results, the measured values of the bending strength of the specimens molded at a pressure of 1,5 tons and then sintered on each specimen were 57-61.8 N·mm-2 on average, which was the highest at 6 % and 8 % of the amount of plasticizer added, the amount of plasticizer added was decreased at 10 %. The reason is thought to be due to microcracks that occur during the molding and processing of hydroxyapatite, as mentioned above. (Figure 5)

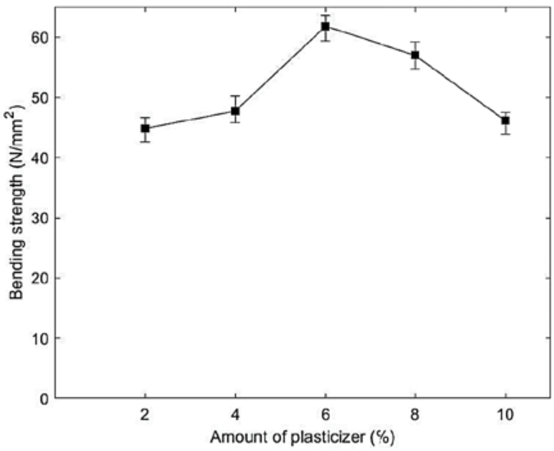

Fig. 5. Bending strength results according to the amount of plasticizer added.

3.4 Shrinkage rate measurement

In reflection of the compressive strength and bending strength results, three samples were subjected to different pressures into one group, and the average value of the shrinkage was measured. Fig. 6 is the calculated value of shrinkage of straight line and cross-sectional area when the amount of plasticizer added is 6 %. An average of 6.1-5.4 % reduction in area and an average of 5.85-4.95 % decrease in length are shown in Fig. 7 is a calculated value of shrinkage of straight lines and cross-sectional areas when the amount of plasticizer added is 8 %. The average area decreased by 6.1-5.4 %, the average length decreased by 7.4-5.9 %, and the shrinkage rate decreased as the molding pressure increased. However, based on the results in Fig. 4, it was judged that the mechanical properties were deteriorated due to microcracks in the sintered compact, so the housing was manufactured with a pressure of 1.5 tons based on an average area reduction of 5.48 % and an average length reduction of 5.65 %.

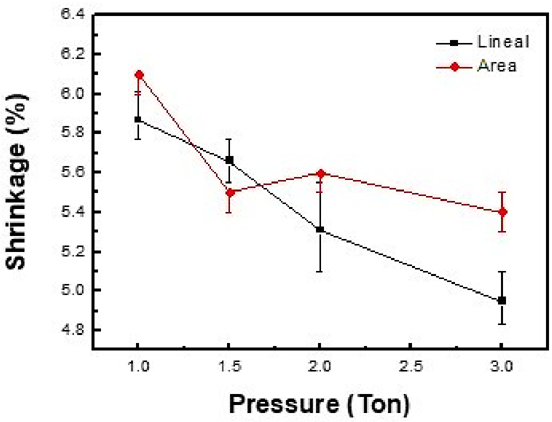

Fig. 6. The shrinkage of the straight line and cross-sectional area at 6 % of plasticizer addition.

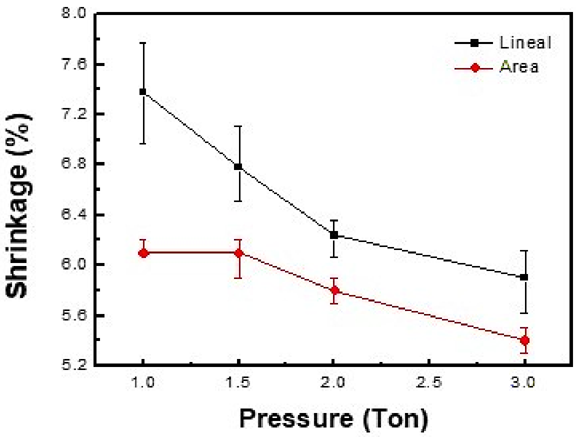

Fig. 7. The shrinkage of the straight line and cross-sectional area at 8 % of plasticizer addition.

3.5 Hydroxyapatite ceramics antibacterial

As shown in fig. 8, after 48 hours, the antibacterial properties of each sample were measured. As a result, no bacteria were detected regardless of the amount of plasticizer added (2 %, 4 %, 6 %, 8 %, 10 %). In the tap water used as a control, the proliferation of bacteria presumed to be Pseudomonas aeruginosa, a representative bacterium occurring in water, was observed compared to the sample immersed in hydroxyapatite [12-13].

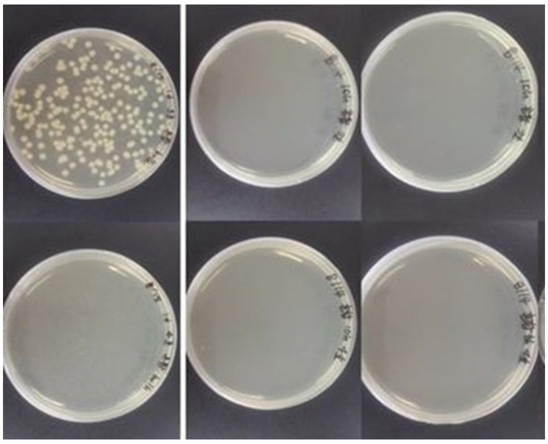

Fig. 8. The result of measuring antimicrobial activity by dividing each sample into 24 hours.
(Left upper: Control, Others are Hydroxyapatite samples)

3.6 Modeling of Hydroxyapatite vibrator housing

By referring to the structure and design of the existing housing, a basic mold as shown in Fig. 1 was manufactured for housing manufacturing. Based on the results of the above physical properties study, a hydroxyapatite sintered body with 8 % plasticizer added was fabricated and combined with a vibrator. As shown in Fig. 9, the vibrator housing with excellent mechanical strength and suppressing the generation of bacteria was able to be made into parts. Therefore, it is thought that it is possible to manufacture a vibrator housing for a humidifier without corrosion.

Fig. 9. Modeling of Hydroxyapatite vibrator housing.

4. Conclusion

In this study, the humidifier vibrator housing was made of Hydroxyapatite. In this case, the effect of the added plasticizer was investigated to prepare a sintered body most suitable for housing manufacturing. The compressive strength showed the highest compressive strength in the specimen that was heat-treated after adding 8 % of plasticizer and molding at a pressure of 1.5 tons, and the highest bending strength in the sintered body to which 6 % of plasticizer was added. In the sample in which the presence or absence of bacteria was measured after incubation at 30 °C for 48 hours, no bacteria were detected regardless of the amount of plasticizer added (2 %, 4 %, 6 %, 8 %, 10 %), and compared with the control group, the generation of bacteria showed the result of suppressing. Based on the above results, the humidifier vibrator housing can be made into parts by forming and heating hydroxyapatite powder with 8% plasticizer added at a pressure of 1.5 tons. Therefore, through this study, it is thought that it is possible to manufacture a hydroxyapatite vibrator housing that is not corroded by water and has antibacterial properties that suppress the generation of bacteria in water.

5. References

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