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(54) PROCESS FOR PRODUCING ARTICLES FROM CERAMIC OR METAL BY ELECTROPHORETIC FREE FORMING

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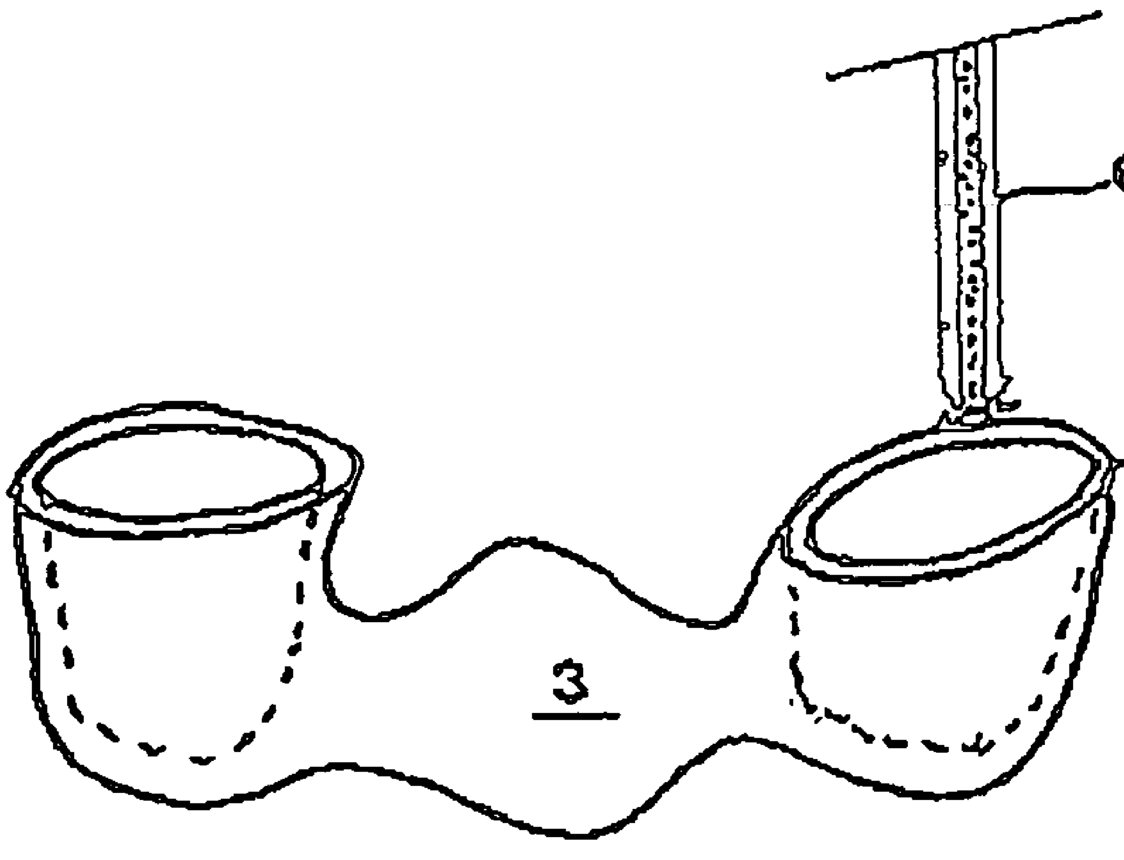
(57) **ABSTRACT**

The invention relates to an electrophoretic free forming process, by which both metallic and ceramic formed parts can be produced. In this process, a slip (suspension of water and metal powder or ceramic powder) is fed via a hollow needle (**6**) to the substrate (**3**) to be produced. By applying a voltage between the slip (**7**) and the substrate (**3**) a material deposit is produced. To build up a three-dimensional form scanned into a computer, the substrate is moved past the tip of the hollow needle (**6**) in a controlled manner. The control is performed on the basis of known CAD/CAM methods. With this process it is possible in particular to produce all formed parts known in dental technology on one machine. It is suitable in particular for producing reinforcing structures and for coating reinforcing structures with dentine or incisal material. Equally possible is the production of non-dental formed parts of dimensions comparable to those of dental formed parts.



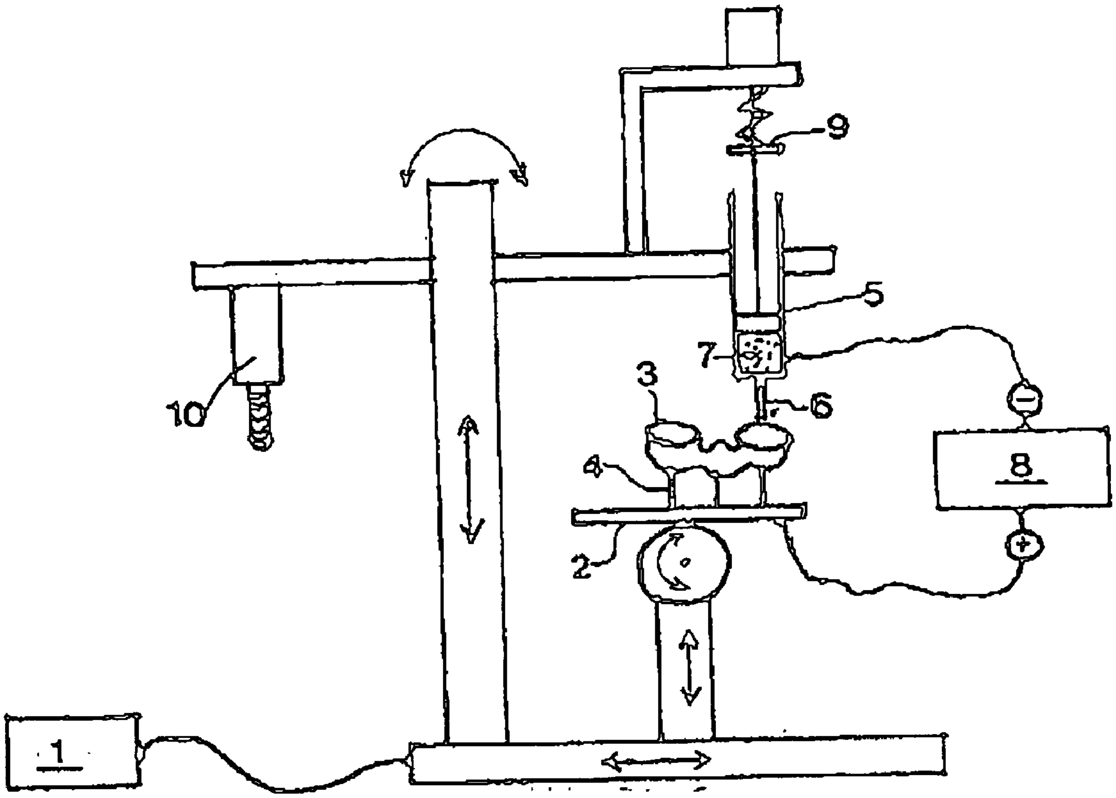


Fig. 1

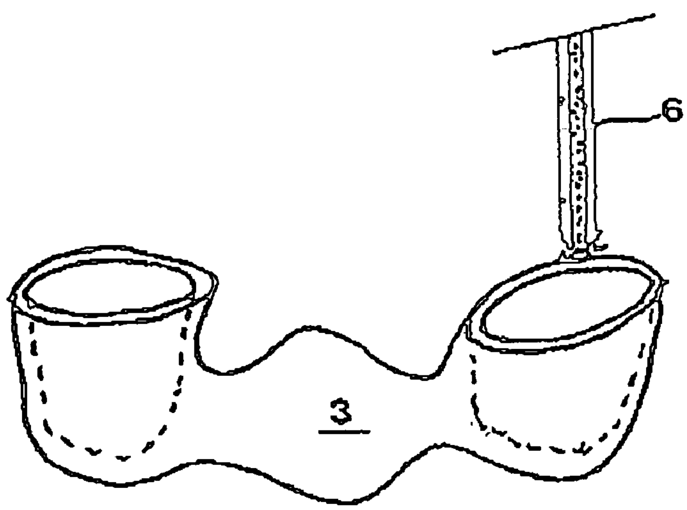


Fig. 2

PROCESS FOR PRODUCING ARTICLES FROM CERAMIC OR METAL BY ELECTROPHORETIC FREE FORMING

[0001] This invention relates to a process for producing articles from ceramic or metal by electrophoretic free forming. The invention relates in particular to producing dental parts. Dental parts in the context of the invention are all dental parts that can be used in the prosthetic or conservative treatment of a patient, including frames for bridges, crowns for individual teeth, inlays, or dental prostheses coated with dentine and/or with incisal material.

[0002] Non-dental articles in the context of the invention mean all products that can reasonably be produced by electrophoresis based on their dimensions and weight. As the term "free forming" itself implies, these articles are products that have a three-dimensional form. Not intended are simple coatings that already have always been produced by electrophoresis. Therefore, this process is particularly suitable for producing components for precision mechanics that up to now have been produced by machining or casting.

[0003] Also, as far as the inventor knows, there is as yet no "electrophoretic free forming process" in the sense of the invention.

[0004] The process according to the invention is based on the electrophoretic deposition of solid particles from a slip. "Slip" in the context of the invention means any suitable suspension of ceramic or metal powder in a liquid suspending medium.

[0005] Electrophoresis has gained sharply in importance in recent years for the production of wholly ceramic crowns and bridges. As representatives of this technology, the following publications are mentioned: WO 99/50 480 A1, DE 100 21 437 A1, DE 101 27 144 A1, DE 103 39 603 A1, and WO 2004/04 1113 A1. Since one of the goals of these inventions is to produce wholly ceramic dental prostheses, metals are intrinsically excluded as frame materials, especially since it could not be expected that metal powder can be applied by electrophoresis, inasmuch as short circuits would probably occur in the electrophoresis cell because of the conductivity of metals.

[0006] The presumed drawback also exists with this process, that ceramics such as zirconium oxide, for example, which are subject to shrinkage upon sintering, are not satisfactorily processed since the ceramic composition is deposited on the working model. In the case of zirconium oxide, therefore, a duplicate of the working model has to be made in this process with expansion plaster. However, duplication implies an additional source of error with regard to accuracy of form. With alumina, on the other hand, best qualities are produced with the above process, including with respect to strength.

[0007] A process for producing dental parts from dental metal powder is disclosed in the prior application DE 10 2005 052 113.4-23. The teaching given there with regard to slip composition and the sintering process is fully applicable to the present invention, so that both dental metal and dental ceramic can be processed with the present invention.

[0008] A generally known process for producing dental frames consists of milling out a frame from an isostatically prepressed block of ceramic, particularly zirconium oxide, using CAD/CAM technology. In this case, the dentition of the patient or a working model is scanned and the frame is milled on the basis of the scanned three-dimensional molding. This process makes it possible to compensate for the sintering shrinkage in the case of zirconium oxide, but involves considerable milling expense. Another drawback consists of the fact that the accuracy of hollow cavities achieved from an impression on a working model cannot be obtained by milling. This is because the accuracy in internal milling is limited by the dimensions of the milling head. This process has the further drawback that an esthetically satisfactory dental prosthesis cannot be produced because of the uniformity of the ceramic block.

[0009] Therefore, it is the aim of the invention specified in Claim **1** to describe a process for producing articles from ceramic or metal based on scanning technology that is substantially simpler than known scanning processes that is suitable for any material, and that has high dimensional accuracy.

[0010] Advantageous embodiments of the invention are described in the dependent claims **1** to **10**.

[0011] The invention is described below with reference to the production of dental parts. However, it is obvious that non-dental articles can also be produced with the invention.

[0012] The Figures show:

[0013] FIG. **1** the principle of a machine for implementing the process;

[0014] FIG. **2** an enlarged section from FIG. **1**.

[0015] In FIG. **1**, **1** designates a computer that controls a CAD/CAM machine in accordance with a scanned three-dimensional form. Corresponding machines that permit motion on 3 to 5 axes are already state of the art and need not be described here in detail.

[0016] A substrate **3**, in this case the frame of a three-membered bridge supported by three pins **4**, is shown on a bench **2**. These pins can be part of the bench or can be applied by electrophoresis. The bench **2** can be moved controllably around 5 axes.

[0017] Above the bench **2** is a slip feeder **5** that ends in a pointed feed element **6** for the slip **7**. A hollow needle such as those used in medicine as injection needles has proved to be suitable for this. The slip can also be fed over the surface of a pointed feed element **6**. With this procedure, it is recommended that the surface of the feed element be provided with lengthwise profiling. It is important for exact operation that the end of the feed element has no wide surface.

[0018] Another advantage could be produced by the feed element **6** rotating gently. At the same time, it can exert a material-leveling function if its end is designed like a mill.

[0019] The bench **2** is connected to the positive pole of an electrophoresis control system **8**, while the slip feeder **5** is at the negative pole. To facilitate the flow of slip in the needle **6**, pressure is exerted on the slip **7** by a pressure device **9**. In the embodiment shown, a piston is used for this purpose. A pressurized gas cushion would also be suitable.

[0020] As shown in particular in FIG. **2**, the frame **3**, already partially produced, is fed past the tip of the needle **6** in accordance with the scanned program. The corresponding kinematically opposite process would also be possible in principle by the needle **6** moving and the substrate standing still.

[0021] With a conventional slip, a voltage of about 40 V is applied, which leads to a current up to about 100 mA. An electrophoretic effect then occurs, whereby deposition of the solid is produced directly beneath the needle **6**. In principle, it can be said that low voltage is used for aqueous slips because of gas evolution, while a higher voltage range is indicated for nonaqueous slips.

[0022] At the end of the deposition process, the blank has sufficient strength to be sintered by known processes and infiltrated with glass if appropriate.

[0023] The process pursuant to the invention is suitable for applying dentine or incisal material to the frame. For this purpose, the frame just has to be fastened downward to the bench **2** with the recesses for the dental stumps.

[0024] The device shown also has a mill **10** that is used to finish the part produced if necessary. This is particularly the case when telescope crowns or conical crowns that must have a smooth surface are being made.

[0025] Consequently, an electrophoretic free-forming process is made available with the invention that satisfies all requirements.

1. Process for the electrophoretic production of ceramic and metallic articles, the process comprising the steps of providing a slip comprising a suspension of ceramic or metal powder in a liquid suspending medium, feeding the slip through a pointed feed element (**6**) onto a substrate (**3**) to effect a material deposition on the substrate, and applying a voltage between the slip (**7**) and the substrate (**3**), wherein the substrate (**3**) is moved past a tip of the feed element (**6**) in a controlled manner to construct a scanned three-dimensional form.

2. Process pursuant to claim **1**, wherein the pointed feed element (**6**) comprises a hollow needle.

3. Process pursuant to claim **1**, wherein the slip comprises a metallic slip.

4. Process pursuant to claim **1**, wherein the slip comprises a ceramic slip.

5. Process pursuant to claim **1**, wherein the substrate (**3**) is moved under control on the tip of the feed element (**6**).

6. Process pursuant to claim **1**, wherein the process further comprises the production of frames.

7. Process pursuant to claim **1**, wherein a computer program in a computer (**1**) is provided and adapted to compensate for sintering shrinkage.

8. Process pursuant to claim **7**, wherein the slip comprises a zirconium oxide slip.

9. Process pursuant to claim **1**, wherein dentine and/or incisal material is applied to the material deposition.

10. Process pursuant to claim **2**, wherein the slip is fed to the tip of the feed element (**6**) under pressure.

11. Process pursuant to claim **1**, wherein the feed element (**6**) comprises a pointed feed element that has lengthwise profiling on the outside thereof.

12. Process pursuant to claim **1**, wherein the feed element (**6**) rotates during the application of the slip.

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