CRYSTALLINE ALUMINA COMPOSITES

This is a division of application Ser. No. 602,874, filed Apr. 23, 1984 and now U.S. Pat. No. 4,595,598 issued 6/17/86.

The invention relates to composites comprising crystalline alumina bonded to a substrate, and to a method for making such composites.

BACKGROUND OF THE INVENTION

In application Ser. No. 602,876, now abandoned for "Crystalline Alumina Orthodontic Bracket", filed on the same day as this application and assigned to the same assignee as this application, there is disclosed orthodontic brackets comprising as a load bearing member crystalline alumina. As is disclosed in said application, one of the problems inherent in the use of crystalline alumina orthodontic brackets is bonding them to teeth (or to any other substrate) because of the high surface energy of crystalline alumina.

This invention relates to one means for enhancing the bond of crystalline alumina to substrates. While the invention is described chiefly in terms of its use in connection with orthodontic brackets, the invention is applicable to the bonding of crystalline alumina articles to any substrate.

BRIEF SUMMARY OF THE INVENTION

The invention provides composites comprising crystalline alumina adhesively bonded (i.e., by using an adhesive) to a substrate, wherein at least a portion of the surface of the alumina that is bonded to said substrate has a thin, adherent siliceous coating, said coating forming a strong adhesive bond to the adhesive bonding the crystalline alumina to the substrate. The invention also provides a method of producing a composite which comprises coating at least a portion of a surface of a crystalline alumina article with a thin, adherent coating of a siliceous material, and then bonding the resultant coated surface to a substrate with an adhesive that forms a strong adhesive bond to said siliceous material.

THE PRIOR ART

The semi-conductor art has disclosed articles made of single crystal alumina having a coating of silica. For instance, see McKinnon et al., U.S. Pat. No. 3,764,507.

Hurley, in U.S. Pat. No. 3,625,740, discloses a process for treating sapphire surface with a silane to enhance adhesion to an epoxy resin.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of an orthodontic bracket made of crystalline alpha-alumina;

FIG. **2** is a side view of the bracket of FIG. **1**;

FIG. **3** is a front view of the bracket of FIG. **1**;

FIG. **4** is a top view of the bracket of FIG. **1**;

FIG. **5** is a top view of a die that is used to produce a crystalline alpha-alumina rod having a cross-sectional configuration essentially identical to the configuration of the top of said die;

FIG. **6** is a schematic representation of apparatus for producing a crystalline alpha-alumina rod;

FIG. **7** is a perspective view of a crystalline alpha-alumina rod produced by the apparatus of FIG. **6**;

FIG. **8** is a perspective view of a bracket blank cut from the crystalline alpha-alumina rod of FIG. **7**;

FIG. **9** is a schematic representation of apparatus for sputter coating silica on a crystalline alpha-alumina article;

FIG. **10** is a perspective view of a plastic orthodontic bracket having a crystalline alpha-alumina liner in the archwire groove;

FIG. **11** is a perspective view of an orthodontic bracket having a plastic base, with the remainder of the bracket being crystalline alpha-alumina;

FIG. **12** is a view similar to FIG. **5**, showing an alternative configuration of the top of the die;

FIG. **13** is a perspective view of a crystalline alpha-alumina orthodontic bracket having a keyway in the base for the purpose of enhancing the bonding of the bracket to the tooth;

FIG. **14** is a side view of the orthodontic bracket of FIG. **13**; and

FIG. **15** is a perspective view of a "single-wing" orthodontic bracket made of crystalline alpha-alumina.

DETAILED DESCRIPTION OF THE INVENTION

As was mentioned above, the invention will be described in terms of bonding crystalline alumina, preferably crystalline alpha-alumina, orthodontic brackets to substrates, including teeth, although it is applicable to other crystalline alumina articles.

As used herein, the term "crystalline alumina" is intended to include only essentially monocrystalline alumina, that is, alumina comprised of a single crystal or two or more single crystals grown together longitudinally but separated by a relatively small angle (usually within 4°, determined with respect to the C-axes of the neighboring single crystals) grain boundary.

Preferably, the orthodontic bracket is entirely crystalline alpha-alumina. Such a bracket can be produced by first drawing a crystalline alpha-alumina rod from a melt, wherein the rod has a predetermined crross-sectional configuration, by slicing thr rod into individual blanks, and then machining the blanks to produce the bracket. A detailed description of this process follows.

The preferred procedure for producing a crystalline alpha-alumina rod having predetermined cross-sectional configuration is the EFG (for Edge-defined, Film-fed, Growth) modification of the Czochralski process for growing crystalline alpha-alumina. The EFG process is described by LaBelle in "EFG - The Invention and Application to Sapphire Growth", in Journal of Crystal Growth, 50, pages 8–17 (September 1980). See also LaBelle, U.S. Pat. No. 3,591,348, LaBelle et al., U.S. Pat. Nos. 3,701,636 and 3,915,662, and other patents and articles cited in the Journal of Crystal Growth article.

FIG. **6** is a schematic representation of apparatus for producing a sapphire rod having a predetermined cross-sectional configuration by the EFG process. The apparatus **20** includes a crucible **22** containing molten alumina **24**. A die **26** made from a suitable material such as molybdenum or iridium is positioned such that the bottom of the die **26** is immersed in the molten alumina **24**, and the top of the die **26** is above the surface of the melt **24**. A vertical distance above the melt **24** of up to 50 millimeters is permissible. FIG. **5** shows the top surface **28** of the die **26**. The top surface **28** is smooth, flat, and has the shape of the desired configuration of the cross-section of the crystalline alpha-alumina rod **30** (shown in FIG. **7**) from which the brackets are made. It is important that the side **32** of the die **26** and the top surface