Enhanced Surface Hardness of Zirconia Toughened Alumina (ZTA)

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Introduction: For ball and lining applications in total hip replacement, strong and hard ceramics, such as alumina and zirconia, have been used. Alumina is very hard and resistant to wear, however, its relatively low strength and fracture toughness limit its wider applications. Zirconia is much stronger and tougher than the alumina, but it has a disadvantage of lower hardness [1]. In addition, the low-temperature environmental degradation (aging) hinders its stable applications in orthopedic area. Recently, zirconia toughened alumina (ZTA) [2] was developed and applied clinically. The strength and toughness of the ZTA is comparable to those of zirconia, but the hardness is remarkably lower than alumina as a result of the addition of less hard zirconia. In the present research, strong and, at the same time, hard ZTA was developed. The surface hardness of the ZTA containing 20 % zirconia was enhanced to the level of pure alumina by increasing the concentration of alumina at the surface of the specimen.

Methods: The ZTA with 5, 10, 15, 20 and 25 vol % of zirconia were sintered at 1650 °C to obtain fully densified body and their mechanical properties were investigated. Among the ZTA composites, the ZTA with 20 % of zirconia which has excellent mechanical properties was chosen to be surface treated and further investigated. For the surface treatment, the ZTA containing 20 % zirconia was firstly sintered at 1400 °C and dipped into AlO(OH) sol [3] for 2-min. After surface treatment, the samples were sintered again at 1650 °C and polished for measuring the hardness. The composition of treated surface as depth from the surface was evaluated by EDS analysis. Hardness of the samples was estimated by Vickers hardness test method.

Results and Discussion: The flexure strength and hardness of ZTA composites in relation to zirconia content are shown in Fig.1. Although the strength increased, lower hardness was observed in the sample containing more zirconia contents.

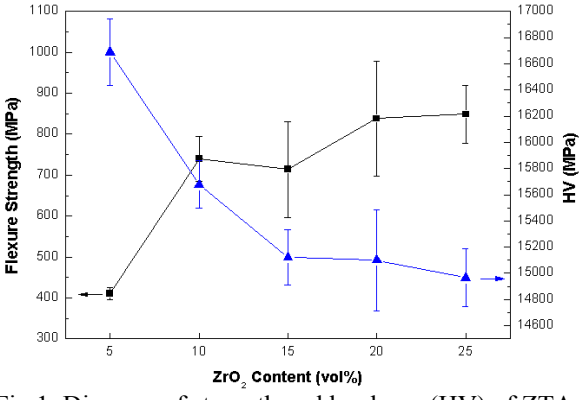

Fig.1. Diagram of strength and hardness (HV) of ZTA composites.

This result indicates that the alumina has strongly influenced hardness of ZTA composites. Fig. 2 presents the cross-section of the ZTA composites (20 vol % ZrO2) and distribution of alumina and zirconia analyzed by EDS. AlO(OH) sol was successfully infiltrated into the ZTA composites with depth of ≈300 μm . The percentage of alumina was decreased with increased penetration depth. The hardness of the surface modified ZTA as depth from the surface is illustrated in Fig. 3. The part having high ratio of the alumina showed relatively high hardness, especially in the range of 250μm from the surface. Hereby, it was confirmed the ZTA composite could have good hardness as well as flexure strength by the sol infiltration method.

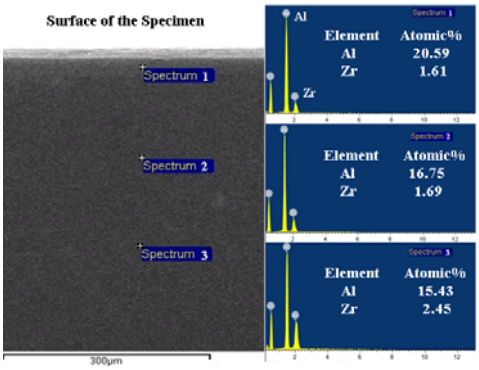

Fig.2. EDS analysis of surface treated sample.

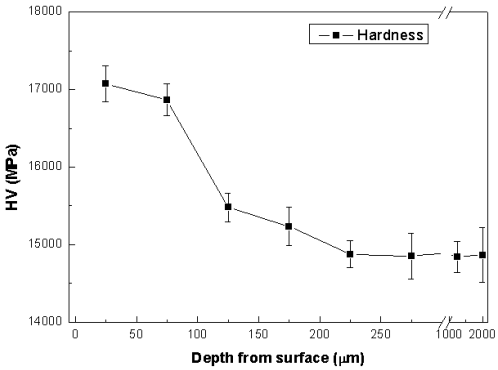

Fig.3. Vickers hardness (HV) changes of surface treated specimen by AlO(OH) sol depended on the distance from the surface.

Conclusions: The surface hardness of ZTA composites was successfully enhanced by AlO(OH) sol infiltration method. It concluded that we can fabricate the ZTA composite which has a good strength and wear-resistant and the surface modified ZTA has a great potential for use as a hip-joint replacement material.

References:

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