Strength Evaluation of Y_2O_3-stabilized Tetragonal ZrO_2 Polycrystals with Scanning Laser Acoustic Microscopy

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ABSTRACT

A scanning laser acoustic microscope, SLAM, was applied to measure an ultrasonic attenuation coefficient and detect the internal defects of Y_2O_3-stabilized tetragonal zirconia polycrystals(Y-TZP). Bend and tensile strength of the Y-TZP materials decreased with the increase of the attenuation coefficient and the number of macro-defects which were detected by SLAM, respectively, although a claer relation between bulk density and strength of Y-TZP materials was not given. SLAM can be the useful technique for nondestructive evaluation of the strength of Y-TZP .

INTRODUCTION

Nondestructive inspection using the ultrasonic wave is drawing much attention[1-5]. Quantitative ultrasonic measurements give the information on microstructure of materials[6,7]. A scanning laser acoustic microscope, SLAM, using the high-frequency ultrasonic wave through the material is the useful instrument to detect the internal defects and characterize the internal microstructure of ceramic materials. In this study, the ultrasonic attenuation coefficient of Y-TZP materials is measured and also macro-defects are detected by SLAM. Relation between the bulk density and the bend or tensile strength, the ultrasonic attenuation coefficient and the bend strength, number of the macro-defects detected by SLAM and the tensile strength of the materials is investigated, respectively.

EXPERIMENTAL PROCEDURE

Y-TZP materials examined are shown in Table I. Powders of materials A, B, and C, and materials D, E, and F were prepared by thermal decomposition[8] and hydrolysis[9], respectively. Materials A, C, D, and F were pressurelessly sintered at 1450°C for 2h. Materials B and E were presintered at 1400°C for 2h and then hot-isostatically sintered at 1400°C for 1.5h under 200MPa argon gas pressure. Sintered materials were cut into specimens by a diamond saw and were ground with a diamond wheel. The rectangular specimens for tensile test were inspected by 100 MHz SLAM to characterize the distribution of macro-defects in the specimens, and then fractured with 0.5 mm/min cross-head speed[10]. Ultrasonic attenuation coefficient of the materials was measured by 100 MHz SLAM[11]. The detail of principle of SLAM is discribed in Ref. 12. Three-point bend test for the specimens with dimensions of 3 by 4 by 36 mm was conducted under the condition of 30 mm span length with 0.5 mm/min cross-head speed. The bulk density of the material was measured by Archimedes' method.

RESULTS AND DISCUSSION

The average values of the bulk density, ultrasonic

Table I. Y-TZP materials examined in this study

Material	Powder Process*	Composition of Y_2O_3/mol%	Sintering Method**	Sintering Temp. and Time
A	TD(T-1)	2.75	PS	1400° C,2h
B	TD(T-1)	2.75	HIP	1400° C,2h/1400° C,2h
C	TD(T-2)	2.75	PS	1400° C,2h
D	H (H-1)	3.00	PS	1400° C,2h
E	H (H-1)	3.00	HIP	1400° C,2h/1400° C,2h
F	H (H-2)	3.00	PS	1400° C,2h

*)TD:Thermal Decomposition H:Hydrolysis
T-1, T-2, H-1, H-2:Different Lot Number
**)PS:Presureless Sintering HIP:Hot Isostatic Pressing

Table II. Average values of the bulk density, ultrasonic attenuation coefficient, number of macro-defects detected by SLAM, tensile strength, and bend strength of the Y-TZP materials

Material	Bulk Density g/cm^3	Attenuation Coefficient dB/mm	Average number of macro-defects detected by SLAM	Strength Tensile MPa	Bend MPa
A	5.99	1.9	---*	432	707
B	6.07	0.7	3.9 [504MPa]**	572	1400
C	5.99	1.0	4.5 [533MPa]**	513	960
D	5.92	1.1	6.1 [482MPa]**	503	825
E	6.06	0.8	0.8 [768MPa]**	743	1440
F	6.00	6.1	---*	324	550

*)There were too many defects to count in the test specimens.
**)The value in brackets shows the average tensile strength of the specimens inspected by SLAM.

attenuation coefficient, number of macro-defects detected by SLAM, and strength of the materials are summarized in Table II. Fig. 1 shows the plot of the bulk density vs. average strength for each material. A clear relation beween bulk density and strength is not given. On the other hand, the obvious relation between the attenuation coefficient and the bend strength is shown in Fig. 2 which indicates that the bend strength decreases with the increase of the attenuation coefficient. In addition, a good correlation between the average number of macro-defects detected by SLAM and the tensile strength is presented in Fig. 3. SEM observation shows that the pressurelessly sintered materials A, C, D, and F contain many pores, cracks and inclusions with the size of 1 to 30 μm distributed widely in the materials. Tensile fracture will start from the relatively large pore or inclusion. Hot-isostatically sintered materials B and E contain some inclusions with a very small amount of pores. Tensile fracture origin can be the relatively large inclusion such as Al_2O_3 and SiO_2. The bulk density will depend on the amount of volumes of internal pores and inclusions of the material. It will not reflect the distribution of the size and number of pores and inclusions. On the other hand, the ultrasonic attenuation would be attributed to pores, cracks, and inclusions which are the scatterer and scattering intensity would depend on the distribution of the size and number of the scatterers. Therefore, the attenuation coefficients of the materials would reflect the distributions of the scatterers and be the effective parameter to evaluate the bend strength of the materials. The number of macro-defecs detected by SLAM indicates the feature of the distribution

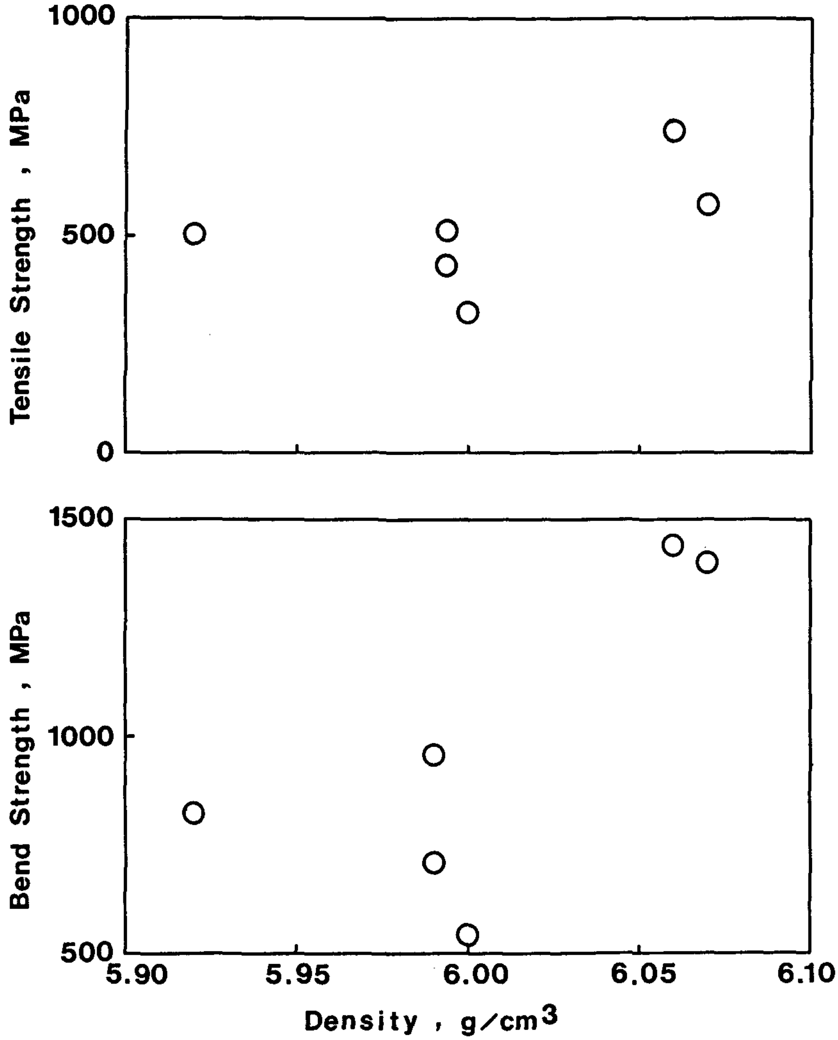

Figure 1. Plot of bulk density vs. strength of Y-TZP

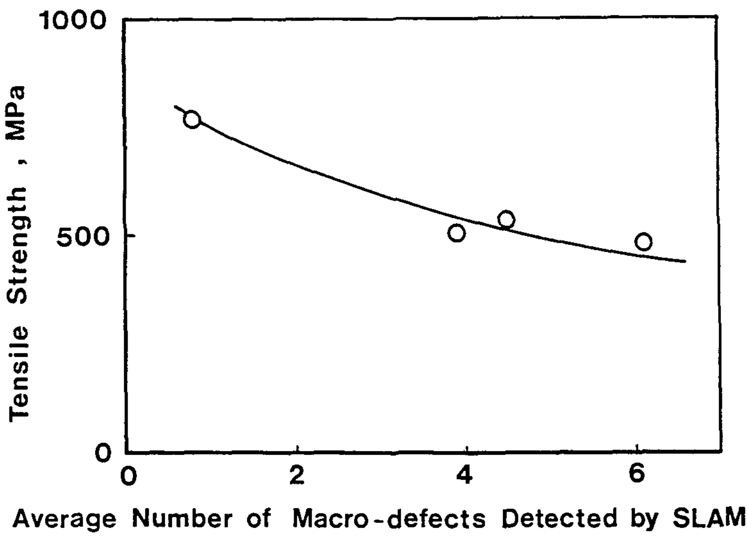

Figure 2. Plot of ultrasonic attenuation coefficient vs. bend strength of Y-TZP

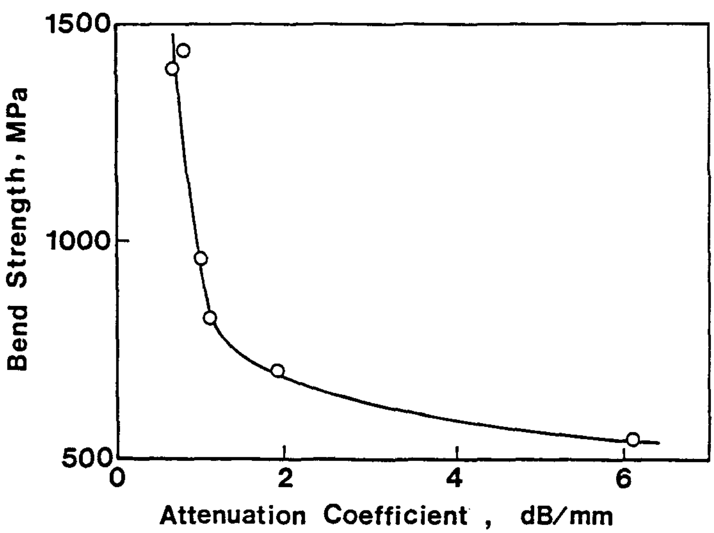

Figure 3. Plot of average number of macro-defects detected by SLAM vs. tensile strength of Y-TZP

of the macro-defects which effect on the tensile strength. Therefore, a good correlation between the average number of macro-defects detected by SLAM and the tensile strength is presented.

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