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Microstructure Progress in Pressureless Sintered AlN Polytypes

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Aluminum nitride (AlN) is known to have a high thermal conductivity and is one of the valid candidates as substrate material for integrated circuits [1]. The material also has a potential in metal production and handling [2]. However, AlN has only a moderate flexural strength and fracture toughness. It has been reported that the presence of elongated grains gives rise to mechanisms such as crack deflection, crack bridging and grain pullout, which improve fracture toughness with a good combination of mechanical properties [3,4]. In the present work, we investigated the microstructure development in a series of AlN samples with different type of elongated AlN polytype grains.

The series of samples were prepared using AlN powder with Y_2O_3 (1.4-1.5 wt%) and different amounts of Al_2O_3 (14-33 wt%) as additives. The green bodies were sintered in nitrogen atmosphere in a graphite furnace at 1950°C for 4 h. Electron microscope observations were performed by using a Philips CM30 operated at an accelerating voltage of 300 kV.

During sintering different AlN polytypes with elongated grain shape develop dependent on the oxide addition. Figure 1(a) shows one such elongated AlN polytype grain in the sample with 15 wt% Al_2O_3-1.5 wt% Y_2O_3 additive. The elongated grain is tilted to 2H-AlN [110] orientation. From the tiny diffracted spots and streaks appearing in the corresponding SAED pattern of Fig. 1(b), it can be concluded that this elongated grain consists of a mixture of different polytypes. The grain grows along the hexagonal AlN a-axis. The detailed polytype structure of the same area as shown in Fig. 1(b) is shown in the HRTEM image of Fig. 2. The numbers represent the numbers of repeated modification layers, and polytype sub-lattice distances are also marked in the figure. From the repeated periods and crystallographic information, 24H-AlN polytype (with two hexagonally related blocks, each block with 12 AlN sub-lattices) can be identified inside the white square, but also 33R- and 39R-AlN polytypes (e.g. 39R with three rhombohedrally related blocks, each block with 13 AlN sub-lattices) are partly present in Fig. 2. As the Al_2O_3 content increases, AlN polytypes with smaller polytype index numbers begin to appear. Fig. 3 shows a HRTEM image of a part of a large 27R-AlN polytype grain in the sample with 33 wt% Al_2O_3-1.4 wt% Y_2O_3 additive.

The present investigation demonstrates that the main trend of the phase development in the present series of samples is in agreement with the phase diagram [5]. It also shows the possibility to improve the mechanical properties of AlN based ceramics by controlling the development of elongated AlN polytype grains in the AlN matrix [6].

References

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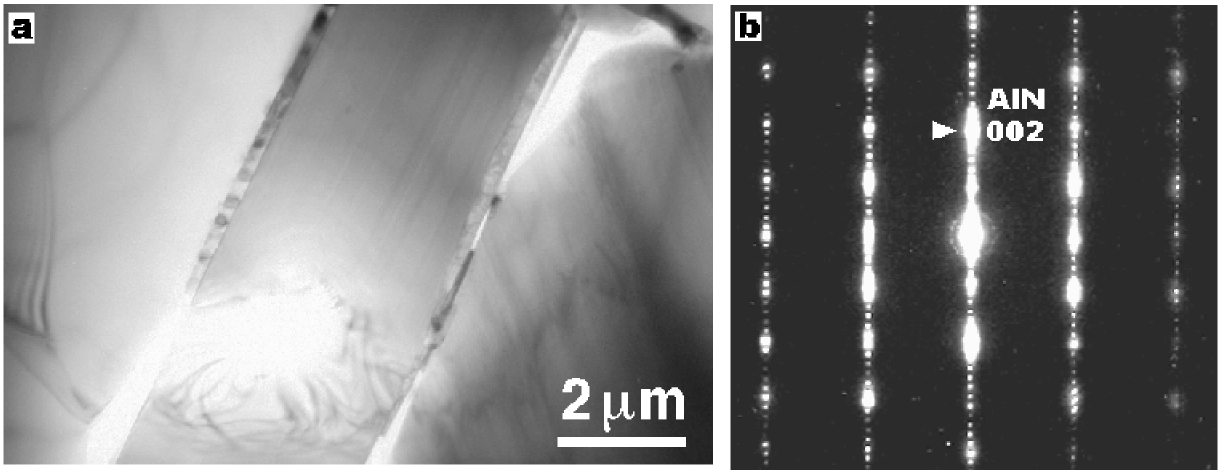

Fig. 1. (a) Low magnification TEM micrograph showing AlN polytype elongated grain in the sample with 15 wt%Al_2O_3-1.5 wt% Y_2O_3 in the staring powders. (b) corresponding SAED pattern.

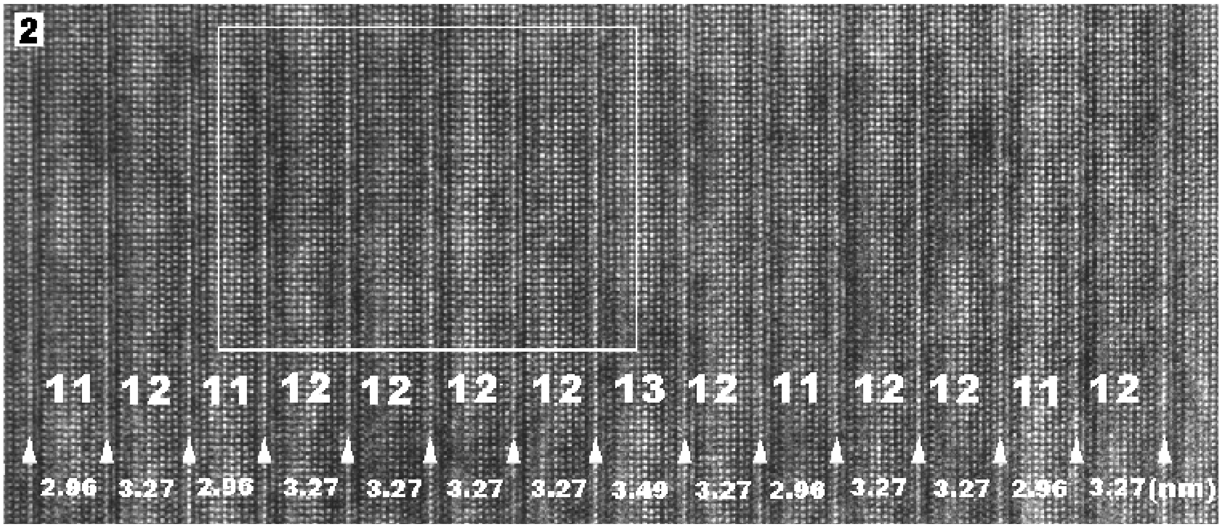

Fig. 2. HRTEM image of the mixed AlN polytypes (24H, 33R and 39R) in the sample with 15 wt% Al_2O_3-1.5 wt% Y_2O_3 as additive.

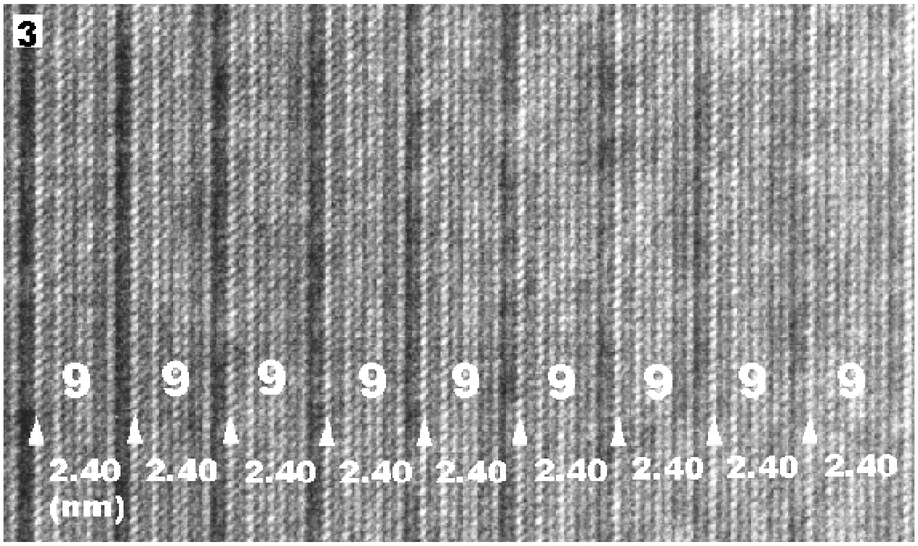

Fig. 3. HRTEM image from part of a large 27R-AlN polytype grain in the sample with 33 wt% Al_2O_3-1.4 wt% Y_2O_3 as additive.