Structural peculiarities of silicon after ball milling in the presence of different materials

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HRTEM studies of silicon after treatment in a planetary mill have been performed. It is shown that along with the initial phase of silicon (Si-I), the sample also contains some high-pressure phases: Si-III (Kasper phase) and Si-IV (lonsdaleite). Samples of powdered Si were prepared in a Planetary Micro Mill with addition of 0.5%-5% B_4C or nanodiamond. The duration of milling in the experiments was 5 min, 20 min and 2 h. The powder after the treatment was examined in a JEM-2010 TEM with EDS and EELS attachments. We studied the orientation relationship between the particles of different phases, finding that there are, in general, two mechanisms of formation of Si-IV: (1) through the stacking faults formation; (2) through the transformation first to the Kasper phase (Si-III), and then from the Si-III to Si-IV [1]. Estimations of temperature and pressure conditions in the planetary ball mill made previously are in accordance with the conditions of formation of the above-mentioned phases. In the next step we have processed a mixture of silicon and boron carbide powders. When pure B_4C was subjected to ball milling [2], no twins, polytypes or other crystal lattice defects were observed. In the samples where Si concentration prevailed (about 95%), we observed both twins and stacking faults in B_4C. For comparison we processed Si in the presence of diamond powder in the same proportions as before for a mixture of Si and B_4C. It is shown that as a result of processing of Si both in pure form, and in the presence of additives of boron carbide and diamond in the planetary mill in Si and B_4C, twins are formed with the same twinning planes (fig.1,2) as in the case of traditional deformation. It is shown that different variants of phase transformations are realized in silicon.

Figures

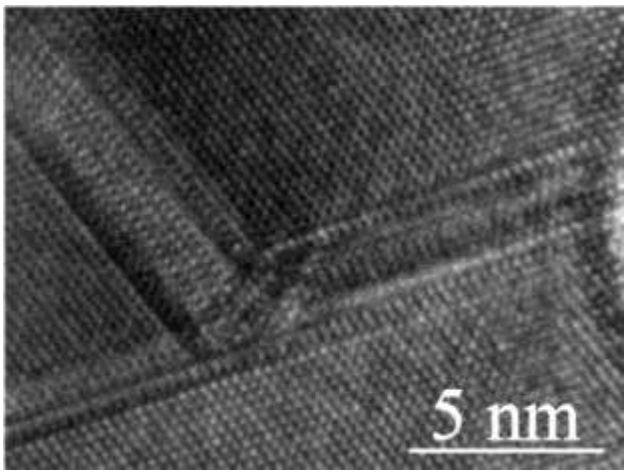

Figure 1. Two systems of {111} twins in silicon after ball milling. Twin boundaries compose a 70.53° angle.

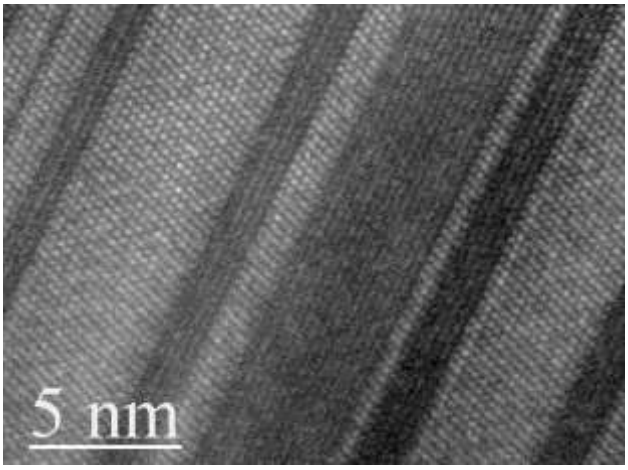

Figure 2. {10-11} twins in B_4C after ball milling.

References

[1] B.Kulnitskiy, D.Ovsyannikov, I. Perezhogin, M. Popov, et al, J. of the Eur. Ceram. Soc. 37 (2017) 1349–1353.
[2] V.Blank, B.Kulnitskiy, I.Perezhogin, M.Popov et al., Acta Cryst. (2016). B72, 733–737.