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Recession behavior of $Lu_2Si_2O_7$/mullite eutectic in steam jet at high temperature

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In this note, a recession behavior of $Lu_2Si_2O_7$/mullite eutectic bulk was examined in high velocity steam jet at 1200 °C and the recession mechanism of this eutectic was discussed. The preparation of $Lu_2Si_2O_7$/mullite eutectic bulk was referred to in our previous report [1]. High purity Lu_2O_3 (99.99% purity, Shin-Etsu Chemical Co. Ltd., 4 μm particle size), SiO_2 (99.99% purity, High Purity Chemicals Co. Ltd., 0.8 μm particle size), and Al_2O_3 (99.99% purity, High Purity Chemicals Co. Ltd., 0.8 μm particle size) were used as starting materials. These powders were mixed in an agate mortal according to Al_2O_3:SiO_2:Lu_2O_3 = 27.3:54.6:18.1 in molar ratios that are given in [2]. The mixed powder was packed into a platinum crucible and heated at 1550 °C for 12 hr in air. The sintered bulk was cooled down to 1000 °C with a cooling rate 0.8 Kmin^{-1}, and then cooled down to room temperature in the furnace.

The recession test of this sample was performed at 1200 °C for 500 hr using water injection equipment at Oak Ridge National Laboratory [3]. Heated high purity water was directly sprayed on the middle section of sample surface through a hollow alumina tube via a water pump. The estimated linear velocity of the steam jet was 35 m/s.

Fig. 1 shows the microstructure of $Lu_2Si_2O_7$/mullite eutectic before the test. Because the sample was not prepared by uni-directional solidification, the microstructure of this sample exhibited a colony morphology. However, the microstructure of this eutectic can be confirmed as an irregular lamella type that is found in Al_2O_3/YAG eutectic.

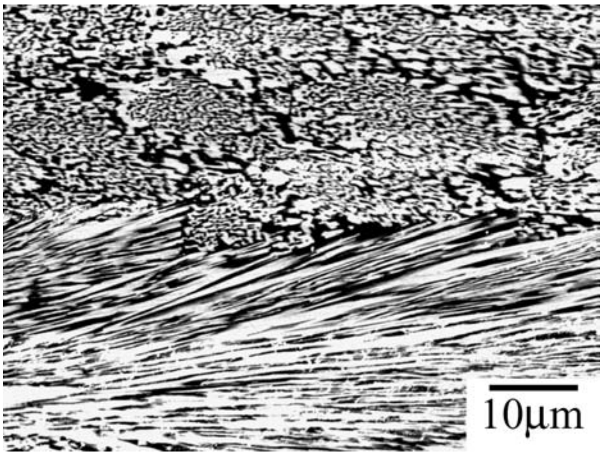

Figure 1 The microstructure of $Lu_2Si_2O_7$/mullite bulk before the test.

Figs 2a and b show the sample surface after the steam jet test, where (a) is the direct-steam exposed surface

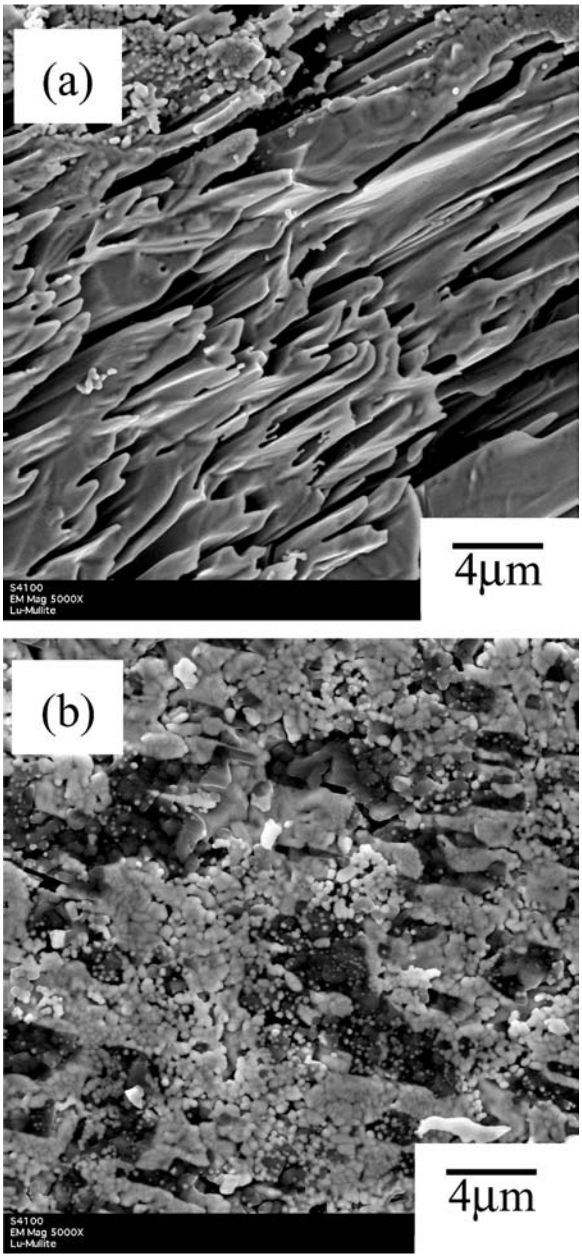

Figure 2 SEM images of the sample surface after the test, (a) the exposed region and (b) outside of the exposed region.

and (b) is the outside of the exposed region. It is clearly seen in steam-exposed region that one phase was completely recessed by the steam jet. The X-ray diffraction pattern from the sample after the test indicated that only mullite phase was removed from the bulk surface, namely, the micro honeycomb-like structure found in exposed region only consisted of $Lu_2Si_2O_7$ phase. On the other hand, at the outside of the exposed region, both mullite and $Lu_2Si_2O_7$ phases can be observed, where bright phase denotes $Lu_2Si_2O_7$ and the dark phase denotes mullite phase, as confirmed by X-ray analysis. In our previous report, it was suggested that mullite bulk surface decomposed by water vapor attack according to Equation 1 and the bulk surface covered with alumina phase [4]. It is also reported that alumina phase easily recessed by high velocity water vapor gas flow at elevated temperatures above 1300 °C [5]. Thus, it is considered that mullite phase easily recessed by the present experiment.

$$Al_6Si_2O_{13}(s) + 4H_2O(g) = 3Al_2O_3(s) + 2Si(OH)_4(g) \tag{1}$$

On the other hand, $Lu_2Si_2O_7$ phase was well sustained during the 500 hr steam jet test. The polycrystallization of $Lu_2Si_2O_7$ after exposure in static state water vapor environment was also observed in our previous work [1]. More detailed consideration of the recession mechanism of $Lu_2Si_2O_7$ phase in the actual combustion field suggested that $Lu_2Si_2O_7$ bulk surface decompose to Lu_2SiO_5 by water vapor attack according to Equation 2 [6].

$$Lu_2Si_2O_7(s) + 2H_2O(g) = Lu_2SiO_5(s) + Si(OH)_4(g) \tag{2}$$

From these results, one can conclude that $Lu_2Si_2O_7$ phase well sustain in the steam jet, however, mullite phase get easily recessed by the steam jet at 1200 °C.

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