Electronic supplementary information

Preparation of BZY powders

BZY powders were prepared by conventional solid state reaction method as follows. $BaCO_3$ (Wako Pure Chemical Industries, Ltd., Japan, 99.9 %), ZrO_2 (Tosoh Corporation, Japan, 97.031 %), Y_2O_3 (Shin-Etsu Chemical Co, Ltd., Japan, 97.86 %) were used as raw materials and mixed at the desired ratios. The mixtures were ball-milled for more than 50 hours and calcined at 1000 °C for 10 hours. They were ball-milled again for about 40 hours, pressed into pellets under 9.8 MPa and synthesized at 1300 °C for 10 hours. After the heat-treatment, they were ball-milled for about 100 hours to pulverize.

Data of phase diagram of BaO-ZrO_2-Y_2O_3-NiO system at 1500 °C for *Tetraplot*

Tetraplot is a software to view a quaternary phase diagram programmed by Naoyuki Hatada (Kyoto University). *Tetraplot* can be downloaded at the following URL (http://www.aqua.mtl.kyoto-u.ac.jp/tetraplot.html). We prepared the data of partial phase diagram of BaO-ZrO_2-Y_2O_3-NiO system at 1500 °C revealed in this study.