Exceptional capability of nanosized CeO$_2$ materials to “dissolve“ lanthanide oxides established by time-gated excitation and emission spectroscopy

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Supporting Information
**Figure S1.** HRTEM images and their corresponding SAED pattern. (a) and (b) CZ-750, corresponding d-spacings: 3.03, 2.64, 1.87, 1.58 and 1.06 Å, which may be consistent with hkl 111, 200, 220, 311 and 422 of cubic Ce$_{0.6}$Zr$_{0.4}$O$_2$, card number 00-038-1439; or with hkl 101, 110, 112, 211 and 312 of tetragonal Ce$_{0.6}$Zr$_{0.4}$O$_2$ (centrosymmetric), card number 00-038-1436; (c) and (d) CZE-750, corresponding d-spacings: 3.03, 2.7, 1.9, and 1.6 Å, which may be consistent with hkl 111, 200, 220, and 311 of cubic Ce$_{0.6}$Zr$_{0.4}$O$_2$, card number 00-038-1439; or with hkl 101, 002, 112 and 103 of tetragonal Ce$_{0.6}$Zr$_{0.4}$O$_2$ (centrosymmetric), card number 00-038-1436; (e) and (f) CZE-1000, corresponding d-spacings: 3.04, 2.69, 2.64, 1.86, 1.6, 1.58, 1.32, 1.21, 1.17, and 1.06 Å, which may be consistent with hkl 111, 200, 200, 220, 311, 311, 400, 331, 420, and 422 of cubic Ce$_{0.6}$Zr$_{0.4}$O$_2$, card number 00-038-1439; or with hkl 101, 002, 110, 200, 103, 211, 220, 213, 310 and 312 of tetragonal Ce$_{0.6}$Zr$_{0.4}$O$_2$ (centrosymmetric), card number 00-038-1436.
Figure S2. HRTEM images of CZ-750 and the corresponding FFT analysis of the area indicated by the red square.

(a) and (b) corresponding d-spacings: 3.12, 2.7, 1.91, 1.56 and 1.07 Å, consistent with hkl 111, 200, 220, 222 and 422 of cubic CeO$_2$, card number 81-0792 (2002 JCPDS); (c) and (d) corresponding d-spacings: 3.14, 2.6 and 1.9 Å, consistent with hkl 111, 200 and 220 of of cubic CeO$_2$, card number 81-0792 (2002 JCPDS); (e) and (f) corresponding d-spacings: 3.05, 2.69, 1.86, 1.6, 1.55, and 1.1 Å, which may be consistent with hkl 111, 200, 220, 311, 222 and 422 of cubic Ce$_{0.6}$Zr$_{0.4}$O$_2$, card number 00-038-1439; or with hkl 101, 002, 200, 103, 202, and 204 of tetragonal Ce$_{0.6}$Zr$_{0.4}$O$_2$ (centrosymmetric), card number 00-038-1436.
Figure S3. HRTEM images of CZE-750 and the corresponding FFT analysis of the area indicated by the red square. (a) and (b) corresponding d-spacings: 3.05, 2.6, 1.87, 1.54 and 1.06 Å, consistent with hkl 111, 200, 220, 222 and 422 of cubic Ce$_{0.6}$Zr$_{0.4}$O$_2$, card number 00-038-1439; or with hkl 101, 110, 112, 202 and 312 of tetragonal Ce$_{0.6}$Zr$_{0.4}$O$_2$ (centrosymmetric), card number 00-038-1436; (c) and (d) corresponding d-spacings: 3.065 and 1.53 Å, consistent with hkl 111 and 222 of cubic Ce$_{0.6}$Zr$_{0.4}$O$_2$, card number 00-038-1439; or with hkl 101 and 202 of tetragonal Ce$_{0.6}$Zr$_{0.4}$O$_2$ (centrosymmetric), card number 00-038-1436; (e) and (f) corresponding d-spacings: 3.03 Å, which may be consistent with hkl 111 of cubic Ce$_{0.6}$Zr$_{0.4}$O$_2$, card number 00-038-1439; or with hkl 101 of tetragonal Ce$_{0.6}$Zr$_{0.4}$O$_2$ (centrosymmetric), card number 00-038-1436.
Figure S4. HRTEM images of CZE-1000 and the corresponding FFT analysis of the area indicated by the red square. (a) and (b) corresponding d-spacings: 3.05 Å, consistent with hkl 111 of cubic $\text{Ce}_{0.6}\text{Zr}_{0.4}\text{O}_2$, card number 00-038-1439; or with hkl 101 of tetragonal $\text{Ce}_{0.6}\text{Zr}_{0.4}\text{O}_2$ (centrosymmetric), card number 00-038-1436; (c) and (d) corresponding d-spacings: 3.05 and 1.58 Å, consistent with hkl 111 and 311 of cubic $\text{Ce}_{0.6}\text{Zr}_{0.4}\text{O}_2$, card number 00-038-1439; or with hkl 101 and 211 of tetragonal $\text{Ce}_{0.6}\text{Zr}_{0.4}\text{O}_2$ (centrosymmetric), card number 00-038-1436; (e) and (f) corresponding d-spacings: 3.04 and 1.52 Å, which may be consistent with hkl 111 and 222 of cubic $\text{Ce}_{0.6}\text{Zr}_{0.4}\text{O}_2$, card number 00-038-1439; or with hkl 101 and 202 of tetragonal $\text{Ce}_{0.6}\text{Zr}_{0.4}\text{O}_2$ (centrosymmetric), card number 00-038-1436.
Figure S5. Raman spectra of 10% Eu$^{3+}$ - CeO$_2$ - ZrO$_2$ which show besides the phonon modes (below 800 cm$^{-1}$), the luminescence transitions of Eu$^{3+}$ (2000 to 4000 cm$^{-1}$). The peak values were obtained following cm$^{-1}$ to nm conversion (excitation wavelength is 514 nm).

Figure S6. Luminescence spectra of 10% Eu$^{3+}$ - CeO$_2$ - ZrO$_2$ -750 normalized at 590 nm peak intensity. Table S1 summarizes the peak values and widths of emission lines illustrated in Figure S6.
**Figure S7.** Luminescence spectra of 10%Eu$^{3+}$-CeO$_2$-ZrO$_2$-1000 normalized at 590 nm peak intensity. **Table S2** summarizes the peak values and widths of emission lines illustrated in **Figure S7**.