Supporting Information

Co-based catalyst had good redox performance under low-temperature range but with low selectivity in high-temperature, while vanadium-based catalyst had good acidity with low activity in low-temperature condition. In order to obtain the superb activity of single layer, we optimized the CoCeO\textsubscript{x} catalyst series with oxidation ability and acidity. The characteristic results of CoCeO\textsubscript{x} series were shown in Fig. S1(a). With the increase of Ce doping, the catalytic propane oxidation activity decreased slightly. The overall catalytic activity was in order as followed: Co\textsubscript{0.9}Ce\textsubscript{0.1}O\textsubscript{x} > Co\textsubscript{0.8}Ce\textsubscript{0.2}O\textsubscript{x} > CoO\textsubscript{x} > CeO\textsubscript{x}. Moreover, we surveyed all samples to confirm the property including oxidation ability from H\textsubscript{2}-TPR and O\textsubscript{2} adsorption ability from O\textsubscript{2}-TPD, which was generally seen as the origin for catalytic oxidation. It could be found that all results indicated that Co\textsubscript{0.9}Ce\textsubscript{0.1}O\textsubscript{x} performed the most suitable property with highest peak in low temperature H\textsubscript{2} reduction and top peak area in O\textsubscript{2} desorption.

![Fig. S1](image)

**Fig. S1** (a) Catalytic activity of CoCeO\textsubscript{x} series catalysts for propane oxidation (Zhang et al., 2019). (b) H\textsubscript{2}-TPR of CoCeO\textsubscript{x} series catalysts, (c) O\textsubscript{2}-TPD of CoCeO\textsubscript{x} series catalysts
**Fig. S2** (a) TEM image of Co$_3$O$_4$; (b) TEM image of Co$_{0.9}$Ce$_{0.1}$O$_x$; The electron diffraction image (SAED) and fast Fourier transform image (FFT) of the selected area are on the right and upper right corners of (a) and (b), respectively.

**Fig. S3** (a) SEM image of Co$_3$O$_4$; (b) SEM image of Co$_{0.9}$Ce$_{0.1}$O$_x$;