

Supporting Information

1. The synthesis process of Ho³⁺-doped LaNbTiO₆

Firstly, 0.5 mmol Nb₂O₅ was dissolved with excess hydrofluoric acid in a water bath at 90 °C, and the pH of the NbF₅ solution was regulated to 9.0 by adding ammonia aqueous solution. Then, the white precipitate of niobic acid obtained was filtered and washed with deionized water for several times to make sure that the F⁻ ions were completely removed. Afterward, the precipitate of niobic acid was dissolved with tetra-n-butyl titanate and citric acid with the mole ratio of 1:1:3 under heating at 80 °C. Then, tetra-n-butyl titanate, holmium nitrate, lanthanum nitrate, and ammonium nitrate were added into the solution. The mole ratio of tetra-n-butyl titanate and ammonium nitrate is 1:15. The doped concentration of Ho³⁺ in all metal ions M (La³⁺ and Ho³⁺) is 0.5, 1, 2, 3, 4 and 5 mol%, respectively. The doped concentration is the proportion of Ho³⁺. The obtained solution was mixed homogeneously under continuous stirring and heating at 80 °C for 4~5 hours until the sol formed. After the water evaporated, the transparent sol turned into gel with high viscosity. The gel was dried at 120 °C for 16 hours to form yellow xerogel. The obtained xerogels were then introduced into crucibles, then directly transferred into a muffle furnace annealed at 1100 °C for 1 h, respectively. Finally, all samples were ground into powder for characterization.

2. The synthesis process of Bi³⁺-doped LaNbTiO₆

Firstly, 0.5 mmol Nb₂O₅ was dissolved with excess hydrofluoric acid in a water bath at 90 °C, and the pH of the NbF₅ solution was regulated to 9.0 by adding

ammonia aqueous solution. Then, the white precipitate of niobic acid obtained was filtered and washed with deionized water for several times to make sure that the F⁻ ions were completely removed. Afterward, the precipitate of niobic acid was dissolved with tetra-n-butyl titanate and citric acid with the mole ratio of 1:1:3 under heating at 80 °C. Then, tetra-n-butyl titanate, bismuth nitrate, lanthanum nitrate, and ammonium nitrate were added into the solution. The mole ratio of tetra-n-butyl titanate and ammonium nitrate is 1:15. The doped concentration of Bi³⁺ in all metal ions M (La³⁺ and Bi³⁺) is 2 mol%. The obtained solution was mixed homogeneously under continuous stirring and heating at 80 °C for 4~5 hours until the sol formed. After the water evaporated, the transparent sol turned into gel with high viscosity. The gel was dried at 120 °C for 16 hours to form yellow xerogel. The obtained xerogels were then introduced into crucibles, then directly transferred into a muffle furnace annealed at 1100 °C for 1 h, respectively. Finally, all samples were ground into powder for characterization.

3. The synthesis process of Ho³⁺ and Bi³⁺co-doped LaNbTiO₆

Firstly, 0.5 mmol Nb₂O₅ was dissolved with excess hydrofluoric acid in a water bath at 90 °C, and the pH of the NbF₅ solution was regulated to 9.0 by adding ammonia aqueous solution. Then, the white precipitate of niobic acid obtained was filtered and washed with deionized water for several times to make sure that the F⁻ ions were completely removed. Afterward, the precipitate of niobic acid was dissolved with tetra-n-butyl titanate and citric acid with the mole ratio of 1:1:3 under heating at 80 °C. Then, tetra-n-butyl titanate, bismuth nitrate, lanthanum nitrate, and

ammonium nitrate were added into the solution. The mole ratio of tetra-n-butyl titanate and ammonium nitrate is 1:15. The doped concentration of Ho^{3+} is 4 mol% and the doped concentration of Bi^{3+} in all metal ions M (La^{3+} , Ho^{3+} and Bi^{3+}) is 0, 1, 2, 3, 4 and 5 mol%. The obtained solution was mixed homogeneously under continuous stirring and heating at 80 °C for 4~5 hours until the sol formed. After the water evaporated, the transparent sol turned into gel with high viscosity. The gel was dried at 120 °C for 16 hours to form yellow xerogel. The obtained xerogels were then introduced into crucibles, then directly transferred into a muffle furnace annealed at 1100 °C for 1 h, respectively. Finally, all samples were ground into powder for characterization.