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ARTICLE

Supporting Information

Potassium modified layered $Ln_2O_2CO_3$ (Ln: La, Nd, Sm, Eu) materials: Efficient and stable heterogeneous catalysts for biofuel production

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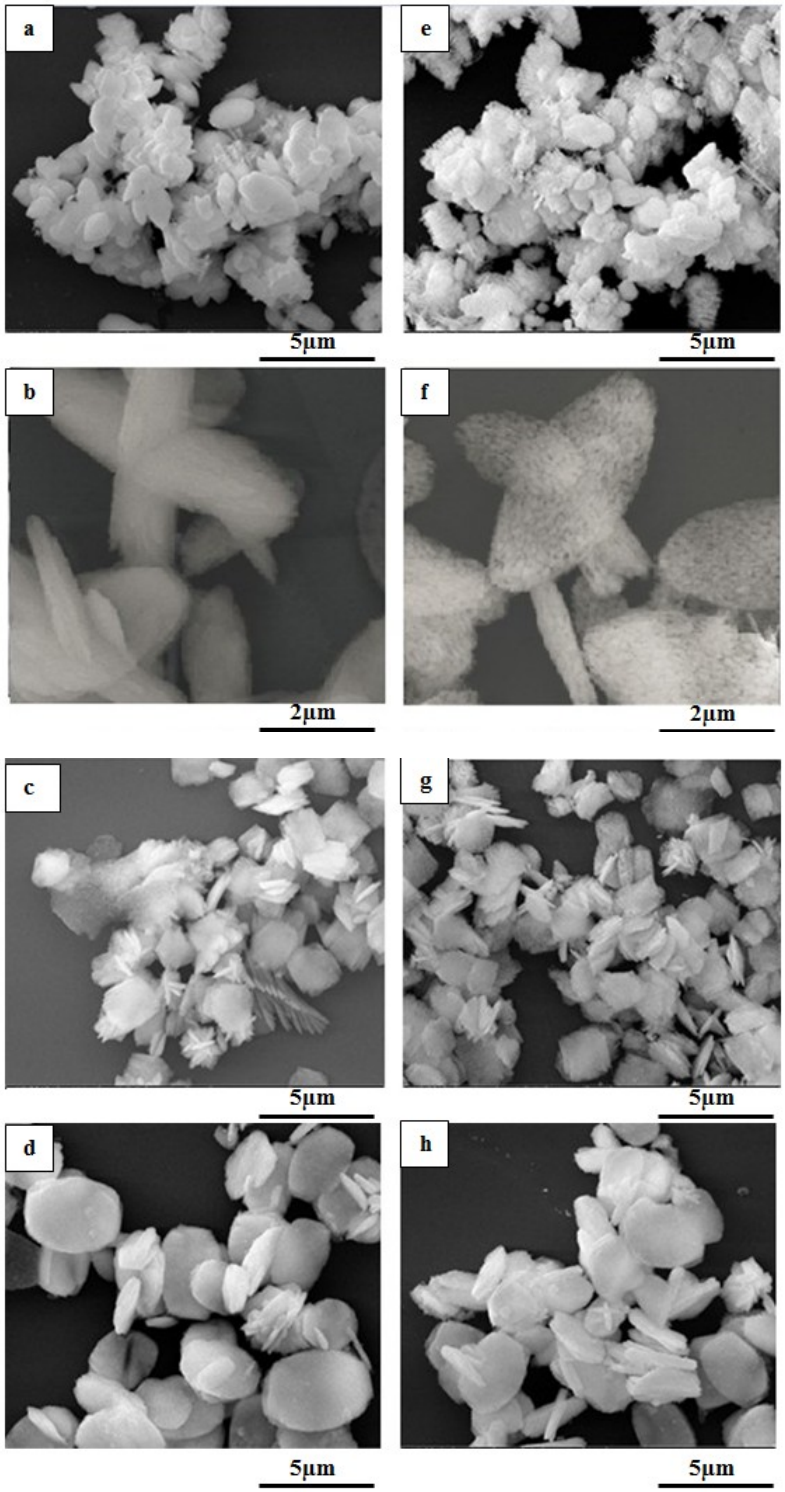

Fig. S1. SEM images of $Ln_2O(CO_3)_2$ (before calcination), Ln: (a) La, (b): Nd, (c) Sm, and (d) Eu, and $Ln_2O_2CO_3$ (after calcination), Ln : (e) La, (f) Nd, (g) Sm, and (h) Eu.

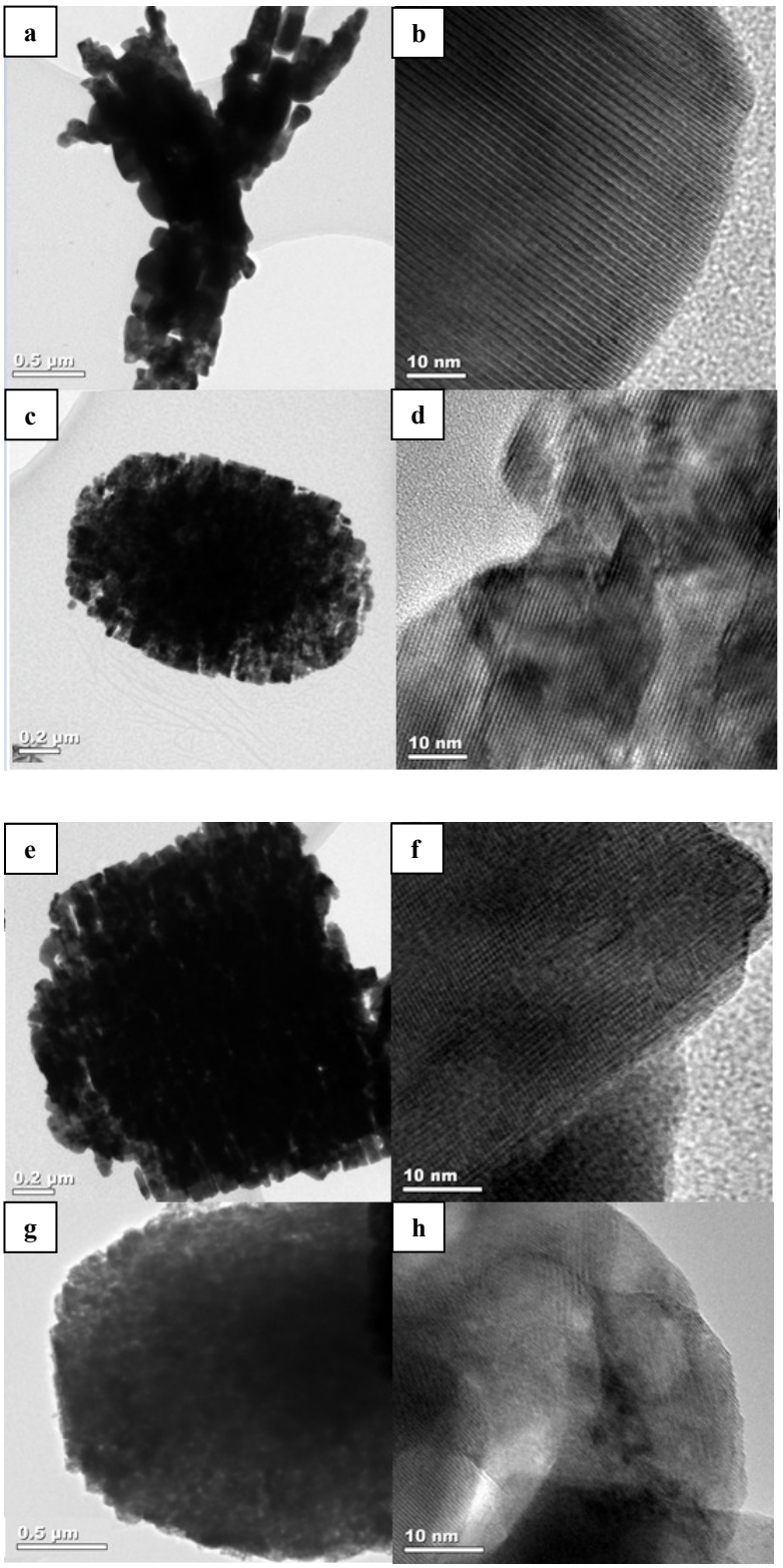

Fig. S2 TEM images of $Ln_2O_2CO_3$, Ln: (a) (b) La, (c) (d) Nd, (e) (f) Sm, and (g) (h) Eu.

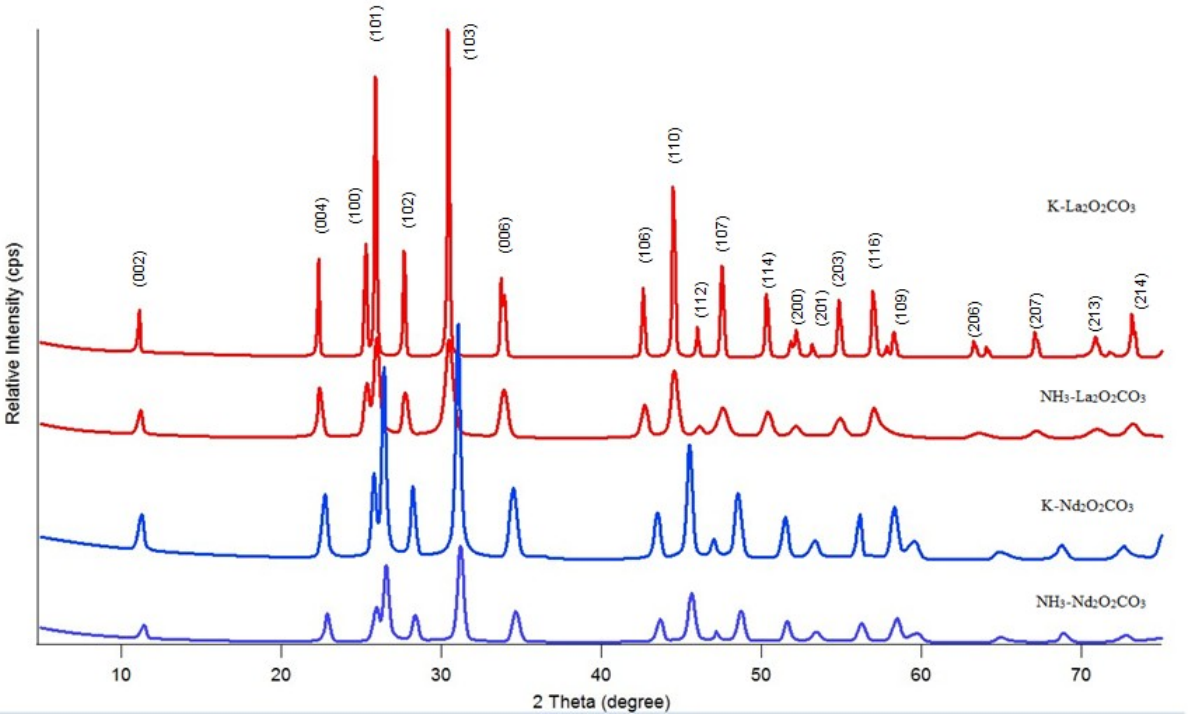

Fig. S3 XRD patterns of synthesized layered $Ln_2O_2CO_3$ (Ln: La and Nd) materials by using NH_3 and $(NH_4)_2CO_3$ (labeled as NH_3-$Ln_2O_2CO_3$) and KOH and K_2CO_3 (labeled as K-$Ln_2O_2CO_3$) as basic starting materials.

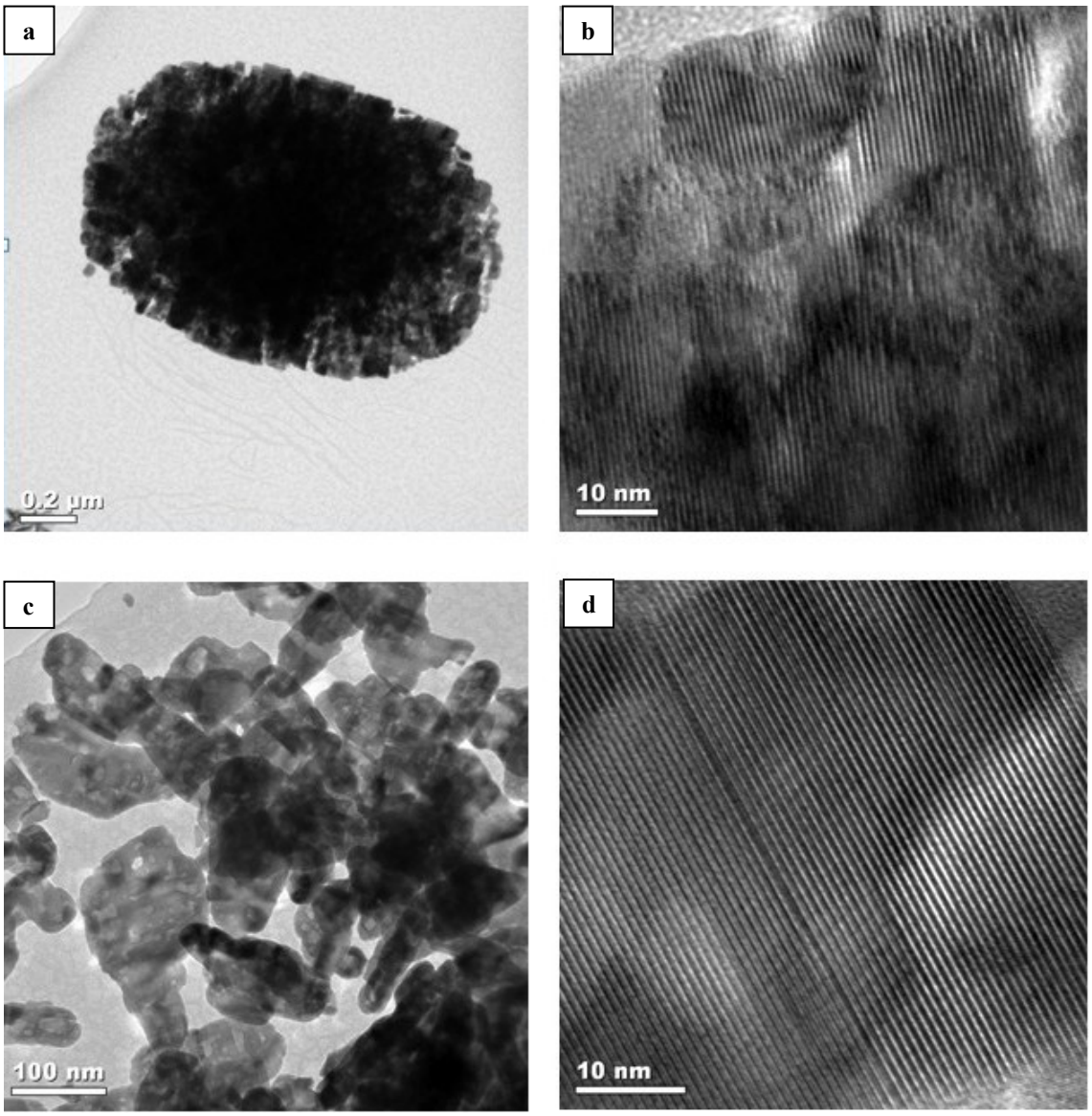

Fig. S4 TEM pictures of (a), (b) potassium contained base synthesized $Nd_2O_2CO_3$ material and (c), (d) ammonium contained base synthesized $Nd_2O_2CO_3$ material.

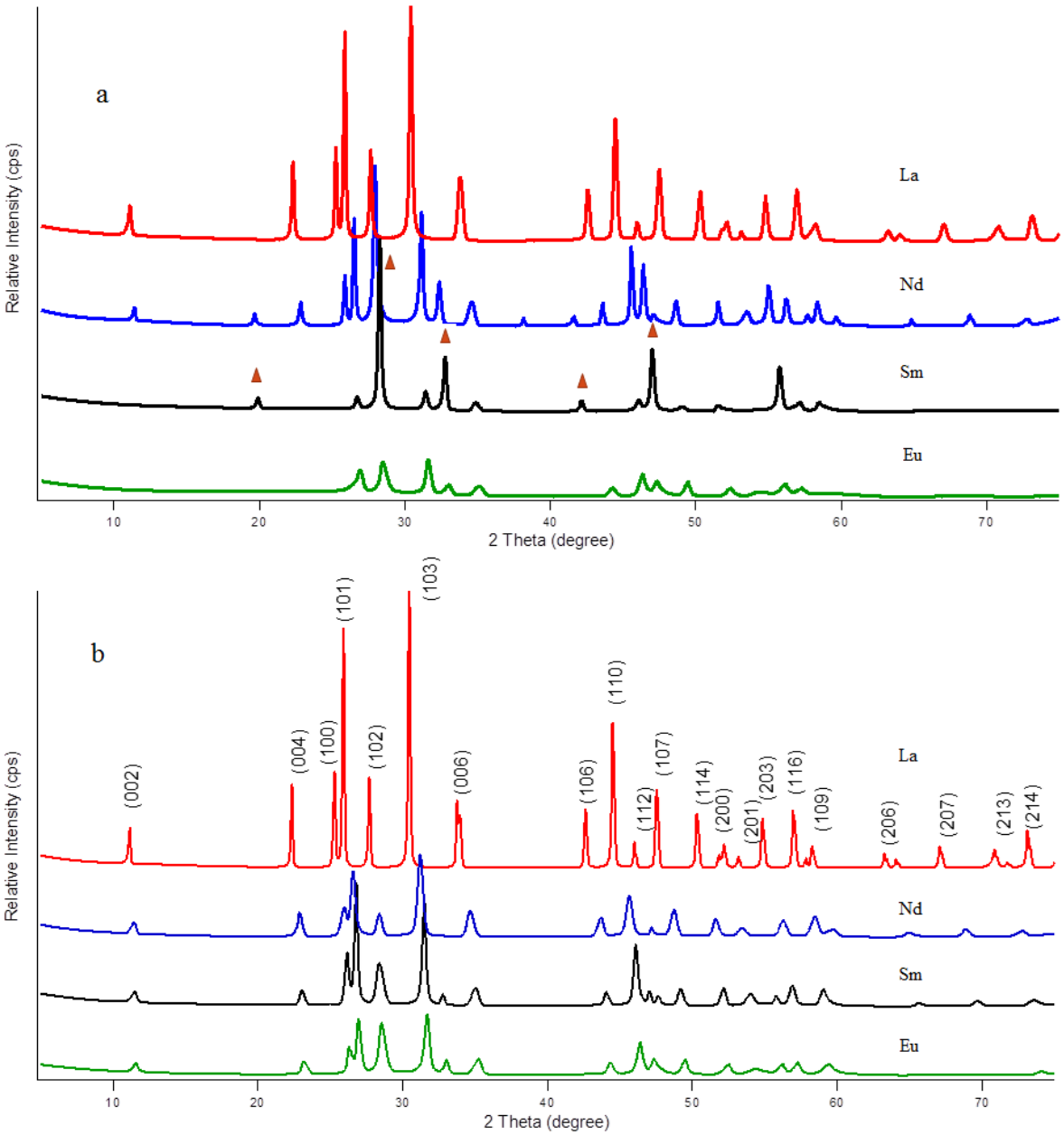

Fig. S5 XRD patterns of (a) synthesized $Ln_2O(CO_3)_2$ (Ln = La, Nd, Sm, Eu) solid materials after 4th cycle of biodiesel reactions, ▲ are the peaks from Ln_2O_3 (b) synthesized layered rare earth oxycarbonate materials $Ln_2O_2CO_3$ (Ln = La, Nd, Sm, Eu) before reactions.

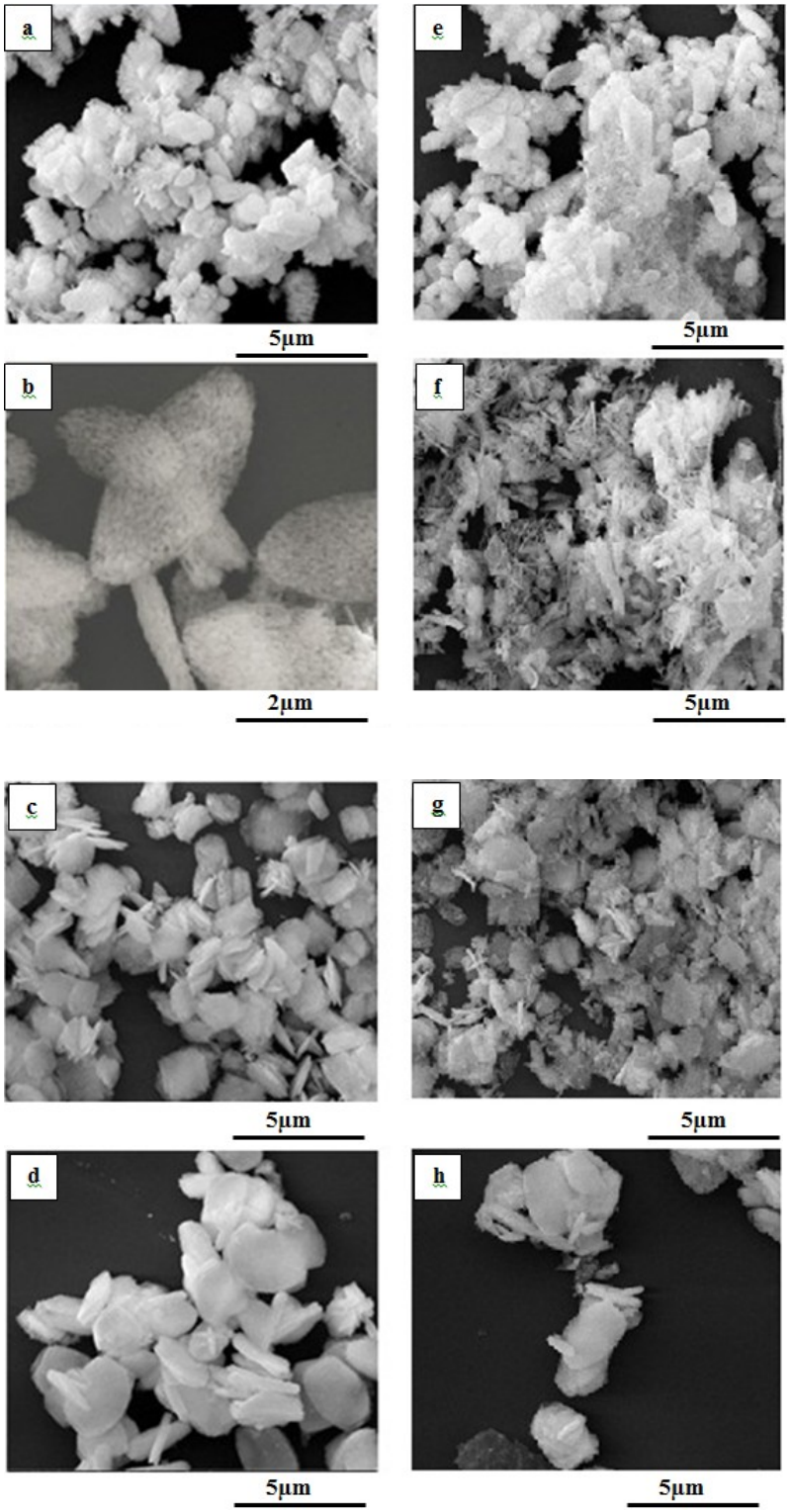

Fig. S6 SEM images of Ln_2O_2CO before reactions (a) La, (b): Nd, (c) Sm, and (d) Eu and after reactions, (e) La, (f) Nd, (g) Sm, and (h) Eu.

$$\text{Yield \% of FAME} = \frac{\text{FAME}}{\text{FAME} + \text{MG} + \text{DG} + \text{TG}} \times 100\%$$

Equation S1 The equation to calculate yield of FAME for biodiesel reactions. (FAME: fatty acid methyl esters; MG: monoglycerides; DG: diglycerides; TG: triglycerides.)

Table S1. BET surface area and basic strength tests by indicators and TPD-CO_2.

Sample	BET Surface Area (g/m^2)	Basic Strength (H_-)	Basic Sites Amount (< 200 °C mmol/g)
$La_2O_2CO_3$	11	+9.3	0.15
$Nd_2O_2CO_3$	19	+9.3	0.33
$Sm_2O_2CO_3$	15	+9.3	0.15
$Eu_2O_2CO_3$	13	+9.3	0.21

Table S2. Biodiesel yields of potassium and ammonium based $Ln_2O_2CO_3$ materials**.**

Sample	Starting Base Mixture	FAME Yield
$La_2O_2CO_3$	KOH and K_2CO_3	78 %
	NH_3 and $(NH_4)_2CO_3$	24 %
$Nd_2O_2CO_3$	KOH and K_2CO_3	99 %
	NH_3 and $(NH_4)_2CO_3$	25 %

Table S3. The potassium amount in fresh and recycled $Ln_2O_2CO_3$ materials.

Sample	K^+ Amount in $Ln_2O_2CO_3$ Materials (wt. %)	K^+ Amount in Recycled $Ln_2O_2CO_3$ Materials (wt. %)	K^+ Amount in $Ln_2O_2CO_3$ Materials (Mole. %)
$La_2O_2CO_3$	1.35	0.77	11.5
$Nd_2O_2CO_3$	1.45	1.12	12.5
$Sm_2O_2CO_3$	1.10	0.47	10.0
$Eu_2O_2CO_3$	1.03	0.42	9.5

Table S4. The potassium and rare earth metal amount in biodiesel.

Sample	K^+ Amount in Biodiesel Product (ppm)	Ln^{3+} Amount in Biodiesel Product (ppm)
$La_2O_2CO_3$	1.4	ND
$Nd_2O_2CO_3$	ND	ND
$Sm_2O_2CO_3$	2.5	ND
$Eu_2O_2CO_3$	4.5	ND

ND: Not Detected