

Supplementary material

Ultrasonic assisted biodiesel production from waste cooking oil over synthesis of novel sulfonic functionalized carbon spheres derived from cyclodextrin via one-step: A way to produce biodiesel at short reaction time

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Table S1 Properties of waste cooking oil.

Description	Unit	Value
Free fatty acid	wt. %	19.7
Water	wt. %	0.9
Unsaponifiable matter	wt. %	2.2
Density@40 °C	kg/m ³	890
Viscosity@40 °C	cSt	32.8
Flash point	°C	201
Color	MJ/kg	30.3
Total metal content (Na, K, Ca and Mg)	ppm	178
Fatty acid composition	Unit	Value
Palmitic acid (C16:0)	wt. %	23.4
Stearic acid (C18:0)	wt. %	8.8
Oleic acid (18:1)	wt. %	53.1
Linoleic acid (18:2)	wt. %	12.4
Linolenic acid (18:3)	wt. %	2.3

Table S2 Analysis of variance for 2⁴ factorial design.

Source of variation	Sum of square	Degree of freedom	Mean square	F _{value}	F _{critical}
X_1	532.46	1	532.46	268.65	
X_2	1012.83	1	1012.83	511.03	
X_3	4973.78	1	4973.78	2509.53	
X_1X_2	425.39	1	425.39	214.63	5.32
X_1X_3	112.89	1	112.89	56.96	
X_2X_3	187.01	1	187.01	94.35	
$X_1X_2X_3$	11.39	1	11.39	5.75	
Error	15.86	8	1.98		
Total	7260.20	15			

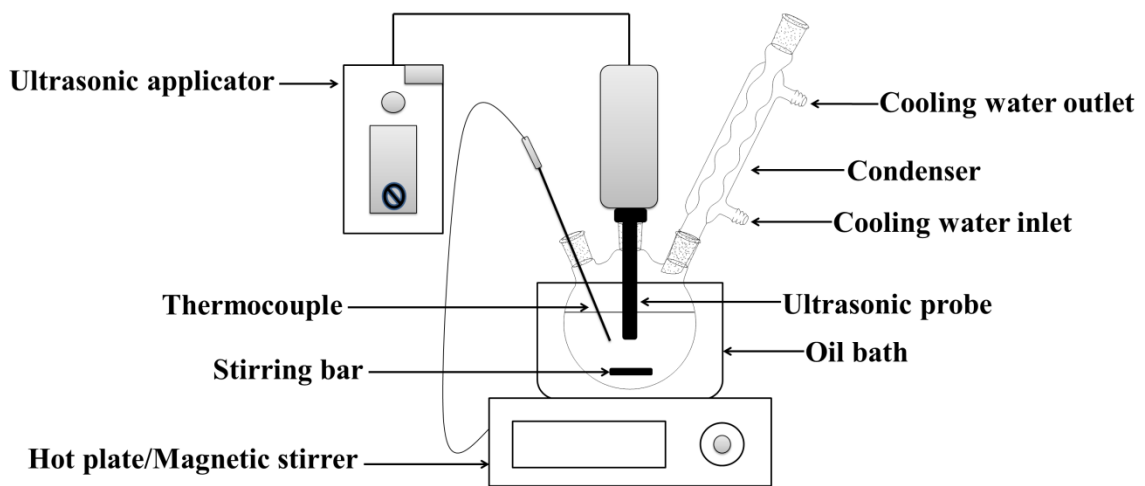


Fig. S1. Schematic diagram of the experimental set up for the ultrasonic assisted biodiesel production.

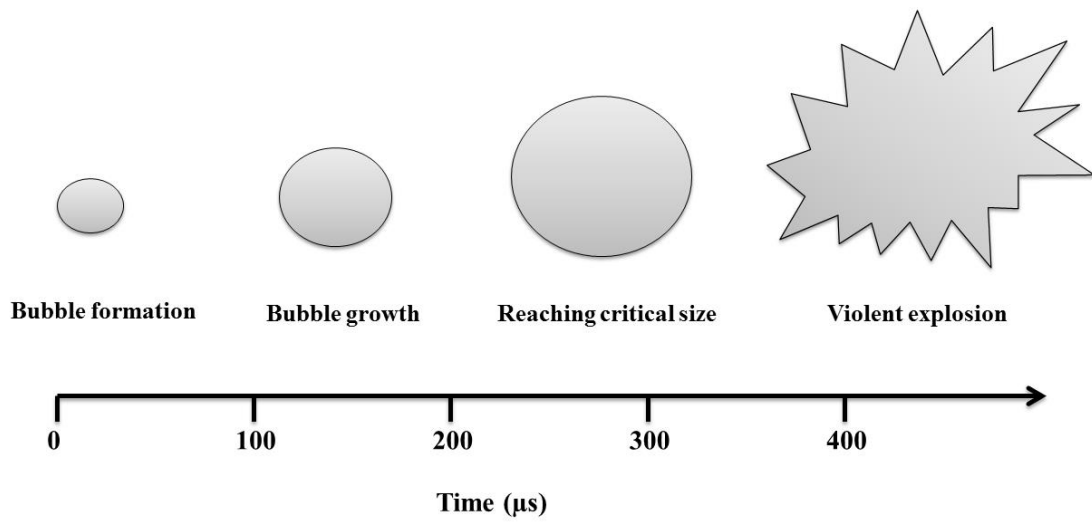


Fig. S2. Formation and growth of a cavitation bubble.

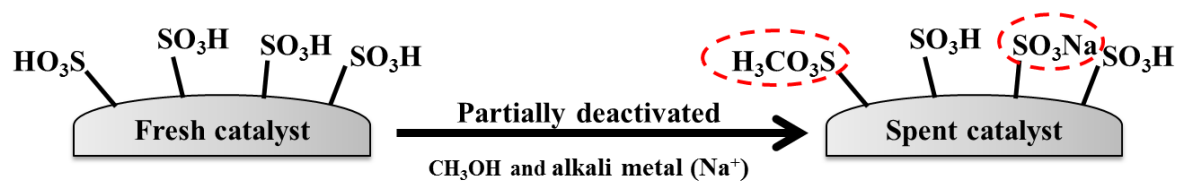


Fig. S3. The effects of the deactivation of active sites on catalyst.

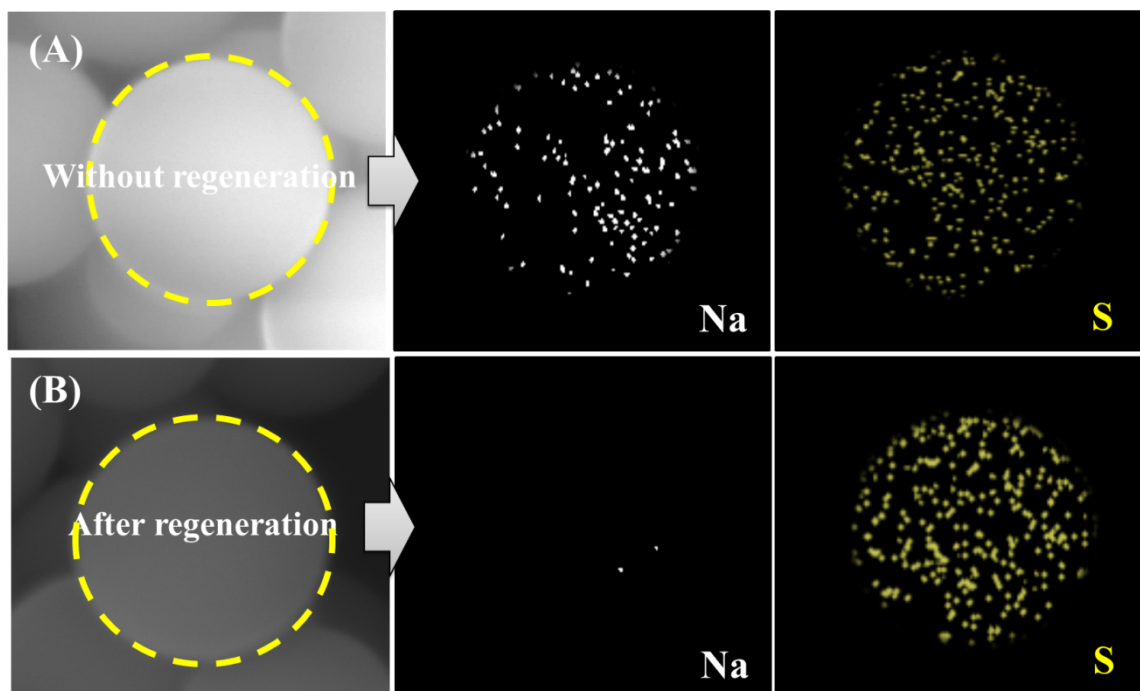


Fig. S4. SEM-EDS images of (A) spent catalyst without regeneration (4th reuse) and (B) spent catalyst after regeneration (4th reuse).

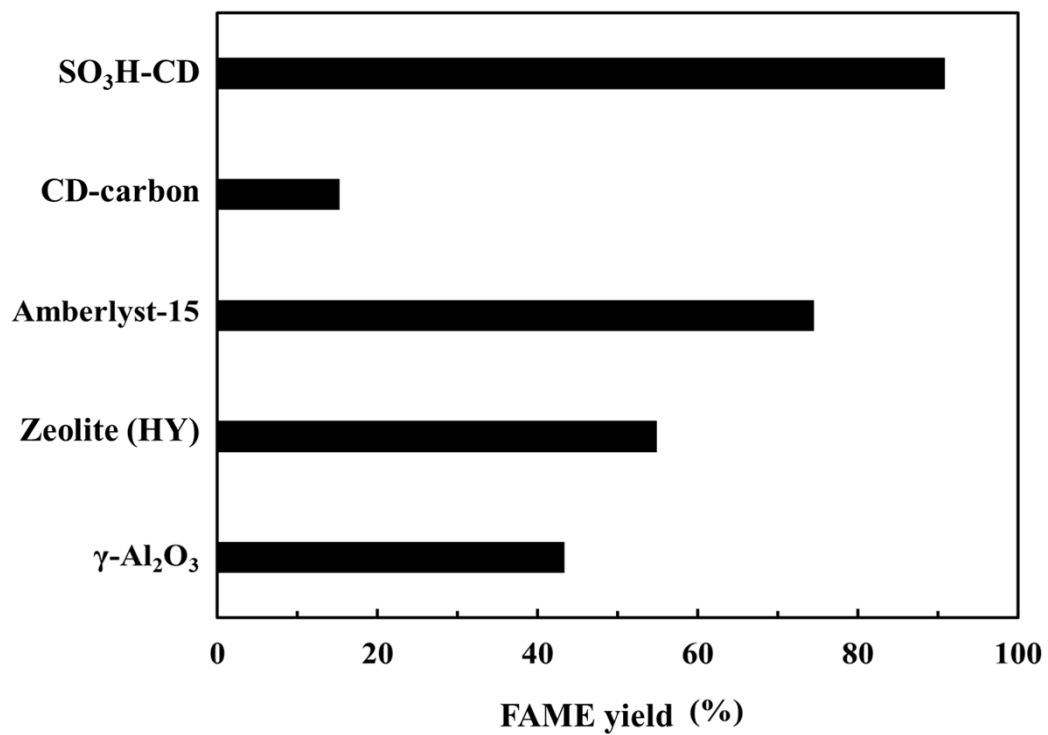


Fig. S5. The catalytic activity of different catalysts. Reaction condition: catalyst loading of 11.5 wt.%, reaction time of 8.8 min and reaction temperature of 117 °C.

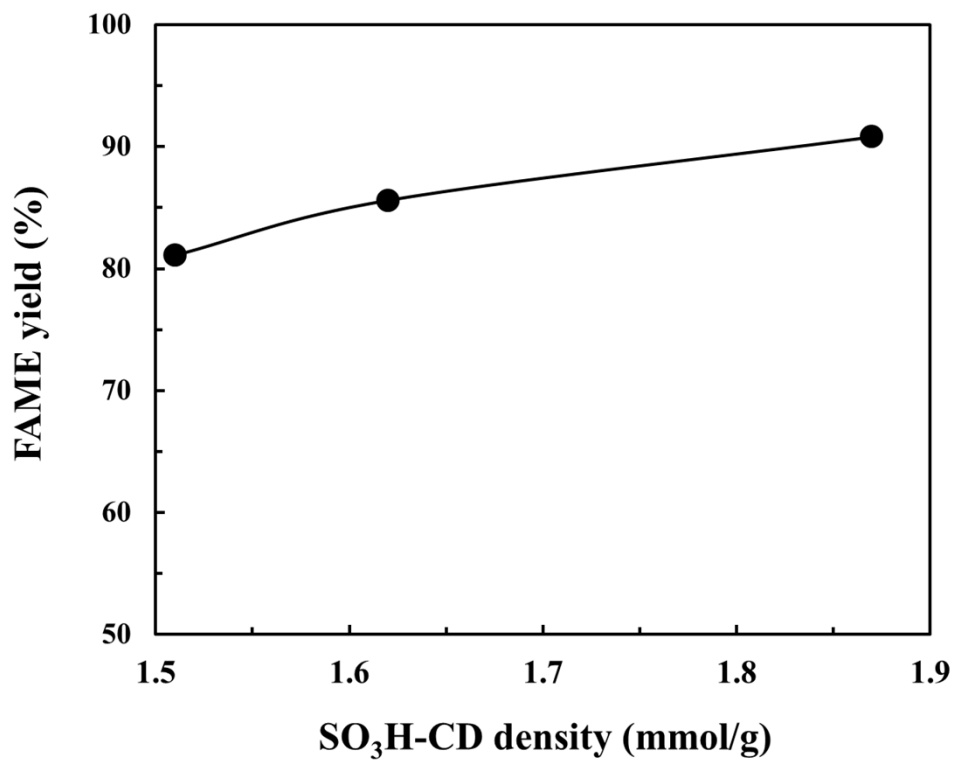


Fig. S6. Effect of SO₃H-CD with different acid densities. Reaction condition: catalyst loading of 11.5 wt.%, reaction time of 8.8 min and reaction temperature of 117 °C.