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Tunable Fe-based nanoparticles heating properties for magnetically induced sustainable catalysis

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PURPOSE OF THE ABSTRACT

The increase of greenhouse gas emissions along with the depletion of fossil fuels impose the development of technologies that make use of renewable energy sources. These sources being intermittent, an efficient way to store them appears as an absolute necessity. In this context, iron-based nanoparticles used as magnetically stimulated heating agents activate catalytic reactions that store energy chemically [1]. Indeed products of added value such as methane could be efficiently obtained using CO2 as a source through the Sabatier exothermic reaction [2].

Tuning the Curie temperature of iron-based nanoparticles used as heating agent is of major importance in order to perform catalysis [3]. Thus, controlled amount of cobalt has been added to iron nanoparticles in order to achieve high heating capacities under moderate magnetic field frequency (Figure 1). As a result, and following our previous published results, CO2 conversion into methane has been achieved at low field frequency (97kHz) while maintaining catalytic performances (more than 80% CO2 conversion) (Figure 2). This result is of big interest in terms of the global energy efficiency of the system.

Moreover, increasing the Curie temperature of the heating agent enables to activate catalytic reactions that demand higher temperatures. Synthetic gas (CO, H2 mixture) production and catalytic dehydrogenation of alkanes such as propane have both received much attention because of the growing demand of light olefins and of the price increase of fossil resources. In this context, FeCo nanoparticles have been used to perform these endothermic reactions taking place at high temperatures (>500°C and >700°C respectively). As a result, propane dry reforming has been achieved with more than 90% conversion of propane to CO. Propane could also be successfully dehydrogenated with nearly 20% conversion with 80% selectivity toward propylene (Figure 2).

Still looking toward more sustainable and adaptable catalysis for fuels production and renewable energy integration [4], methanol production using CO2-CO-H2 mixture catalyzed by a Cu-ZnO catalyst will be studied using FeCo nanoparticles as heating agent.

As a whole, this work demonstrates that magnetic induction is a tunable, adaptable and dynamic way to perform catalysis, even at high temperatures. This can be coupled with energy production from renewable sources despite their intermittency thus, to efficiently respond to the need of sustainable fuels production.

FIGURES

Nanoalloy Composition	Curie Temperature (°C)	SAR (W/g) 47mT, 100kHz
$Fe_{0,5}Co_{0,5}$	1000	1650
$Fe_{0,7}Co_{0,3}$	900	1260
$Fe_{0,8}Co_{0,2}$	850	1140
$Fe_{0,9}Co_{0,1}$	800	1000
Fe	750	820
FeC	450	2000

Reaction $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

Heating Agent (HA)	HA loading (%wt)	Catalyst nature	Catalyst loading (%wt)	Field frequency (kHz)	Field amplitude (mT)	$X(CO_2)$	$S(CH_4)$	$Y(CH_4)$
FeCo	4,3	Ni	10	300	47	83,5	92,2	77
				100	47	92,5	90	83

Reaction $C_3H_8 \rightarrow C_3H_6 + H_2$

Heating Agent (HA)	HA loading (%wt)	Catalyst nature	Catalyst loading (%wt)	Field frequency (kHz)	Field amplitude (mT)	$X(C_3H_8)$	$S(CH_4) + S(C_2H_4)$	$S(C_3H_6)$
FeCo	10	Pt Sn	0,5 0,75	300	32	17,5	22,7	77,3

FIGURE 1
Increase with Curie temperature of the heating capacity (SAR) of Fe-based nanoparticles under magnetic induction

FIGURE 2
Magnetically induced catalysis performances for Sabatier reaction (top) and propane dehydrogenation (down)

KEYWORDS
CO2 hydrogenation | Magnetically induced catalysis | High temperature catalysis | Propane dehydrogenation

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