Induction Heating of Magnetically Susceptible Nanoparticles for Enhanced Hydrogenation of Oleic Acid

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Fatty acid hydrogenation has greatly improved reactor and catalysts design, but all processes use conventional reactor heating[1]. Radiofrequency (RF) induction heating has emerged as a potential replacement candidate as the heat is dependent on the magnetic moment of magnetic materials [2,3] and is localized at the surface of a magnetic susceptor. This can lessen the surface-substrate interface temperature gradient, limiting unwanted side reactions[2]. An active and magnetically susceptible catalyst needs to be designed and evaluated to take advantage of this mechanism. Therefore, Pd/Fe_3O_4 and Pt/Fe_3O_4 catalysts were synthesized, and the improved activity and selectivity of RF heating was demonstrated by comparing the RF heating to conventional thermal heating through the hydrogenation of oleic acid.

Hollow mesoporous microspheres composed of 28-32 nm Fe_3O_4 nanoparticles (Figure 1) were decorated with 1 wt.% Pd ($1Pd-Fe_3O_4$) and 3 wt.% Pt ($3Pt-Fe_3O_4$). Using a glass semi-batch reactor, three bulk temperatures of 50, 110, and 150 °C under 1.01 bar of H_2 were used. For $1Pd-Fe_3O_4$, the conversion of oleic acid was 28% higher 70 °C, but the conversions converged and reached an equilibrium limit of ~85% for the two higher temperatures. Both methods demonstrated similar selectivities across all temperatures. While $3Pt-Fe_3O_4$ was significantly less active and produced more cracked and heavy acids as products, the RF heating increased conversion by 5-6% over conventional across the temperature range. Furthermore, RF systematically increased selectivity to stearic acid (the expected primary product) 15 % at the two higher temperatures.

TPO was performed on the high temperature, used catalysts (150 °C) to quantify the coke deposition (Figure 2). The conventional heating of the Pd catalyst resulted in 6.5 wt.% coke as expected based on literature. However, no coke was found after the RF-driven reaction. In contrast, both RF and conventional heating generated coke on the Pt decorated samples. The increased coking of the RF $3Pt-Fe_3O_4$ (11% compared to 6.3%) is attributed to the suppression of cracking and increased acid condensation reaction[4] that is suppressed upon RF-heating of the Pd catalyst, implying better long-term stability. Overall, RF has shown improved selectivity that cannot be explained solely by temperature.
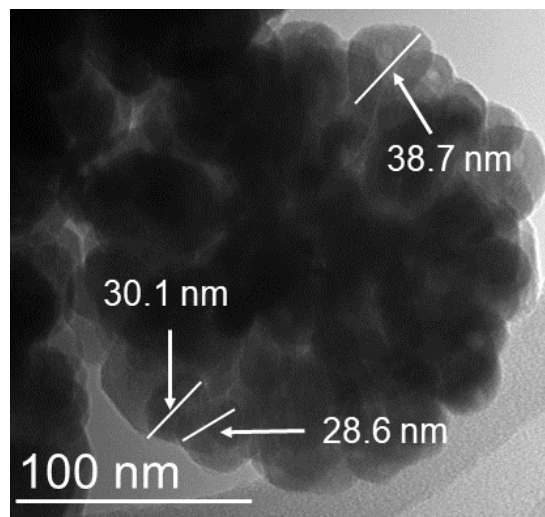
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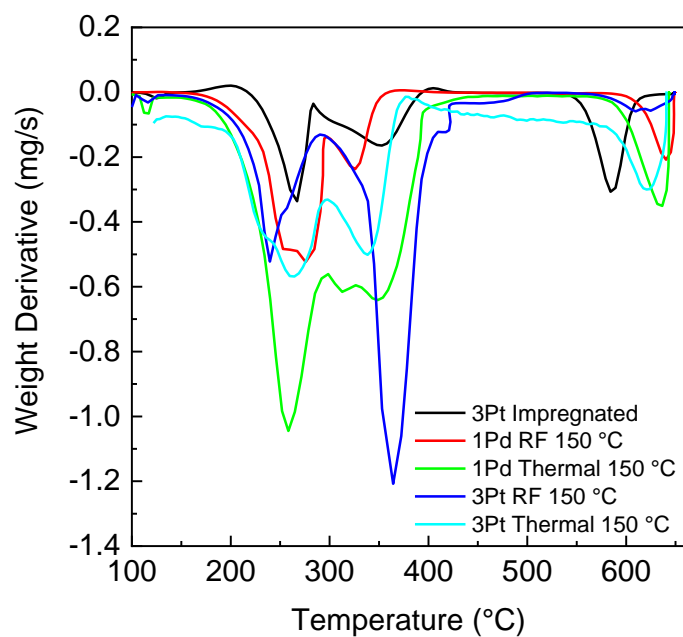
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Figure 1: TEM of the hollow mesoporous Fe_3O_4 support highlighting the diameter of the Fe_3O_4 nanoparticles.

Figure 2: Weight derivatives from TPO (air, 10 °C/min) for stearic acid-impregnated fresh 3Pt-Fe_3O_4 catalyst and spent RF and thermal catalysts (150°C).