Utilization of Dielectric Properties Assessment to Evaluate the Catalytic Activity and Rate of Deactivation of Heterogeneous Catalysts

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ESI Section 1. Thermogravimetric analysis

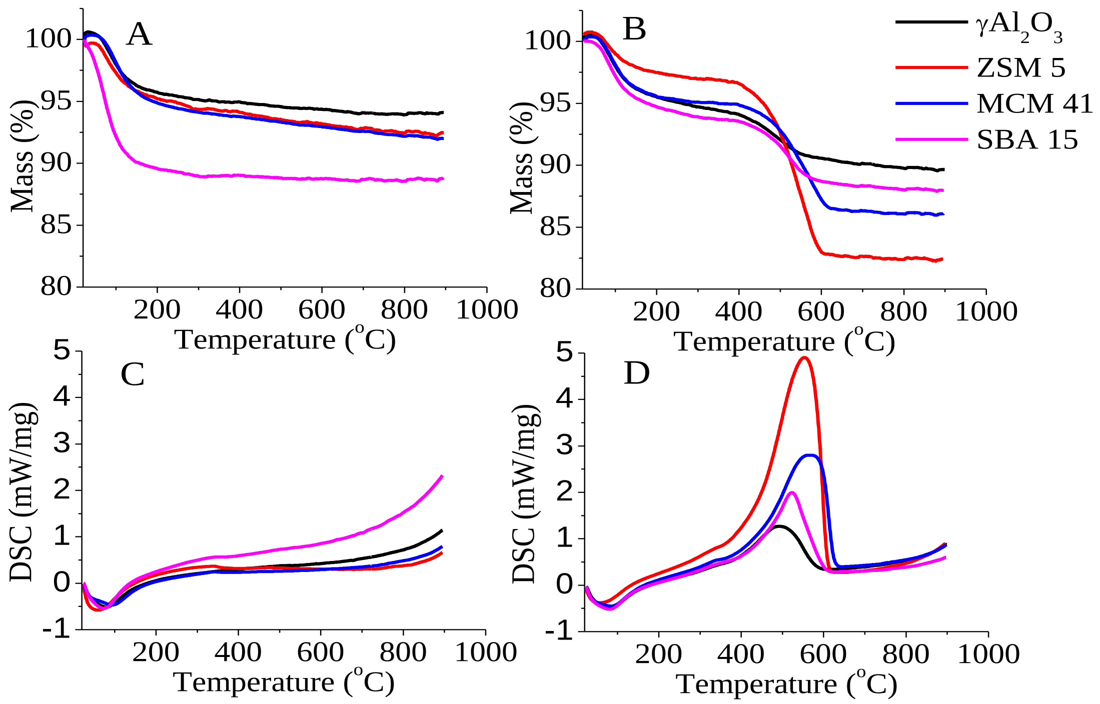

Figure S1. TGA mass loss from fresh catalyst (A) & used catalyst (B). The mass derivative for fresh catalyst (C) & used catalyst (D).

ESI Section 2. X-ray diffraction

The fresh and used catalysts were analyzed by XRD performed on a PANalytical Empyrean X-ray diffractometer with a Cu Kα radiation, data collected with a 0.02° step at 4 second acquisition time. Wide-angle (Figure. SI1) and small-angle (Figure. SI2) XRD measurements were performed in the 2ϴ range 10 - 80° and 0.5 - 10°, respectively.

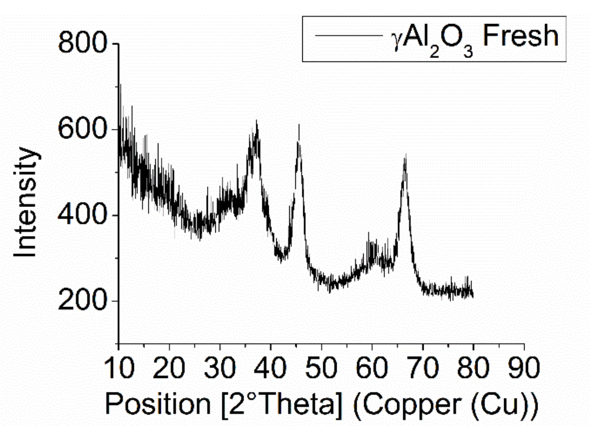

Figure S2.A. XRD for γ-Al_2O_3-based fresh catalyst.

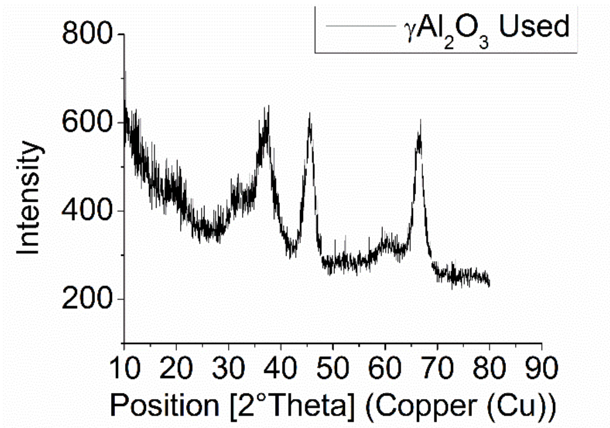

Figure S2.B. XRD γ-Al_2O_3-based used catalyst.

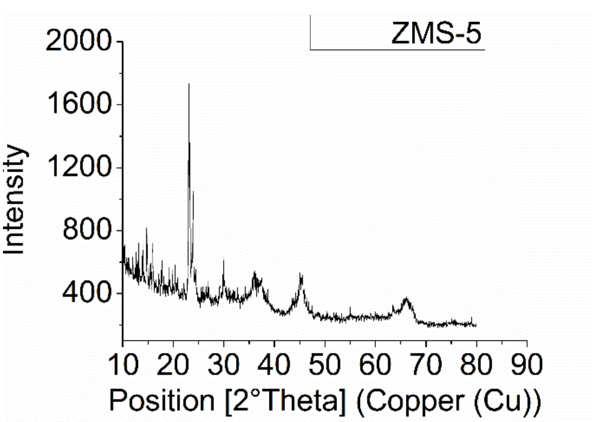

Figure S2.C. XRD for ZSM-5-based fresh catalyst.

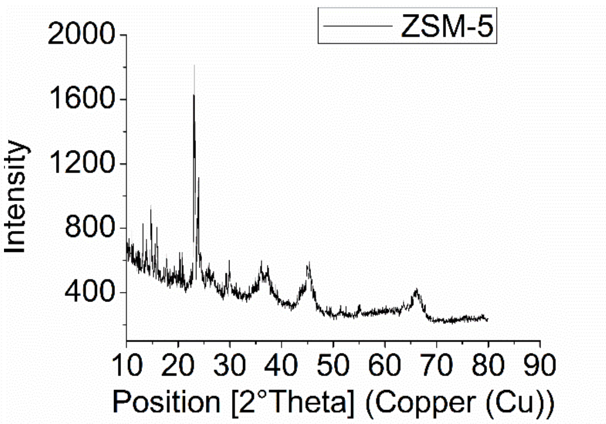

Figure S2.D. XRD ZSM-5-based used catalyst.

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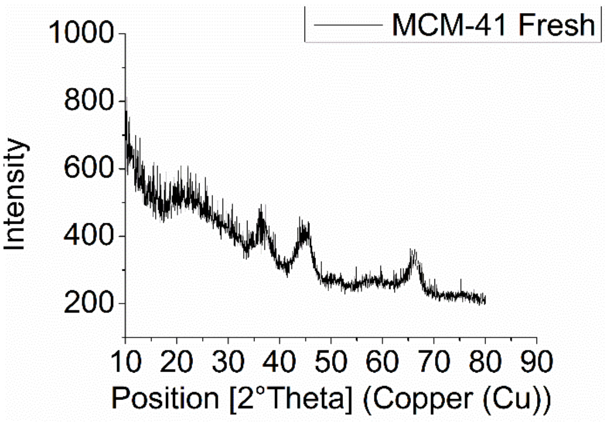


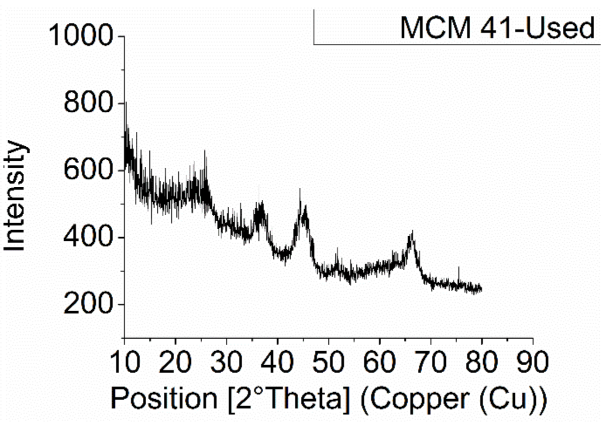
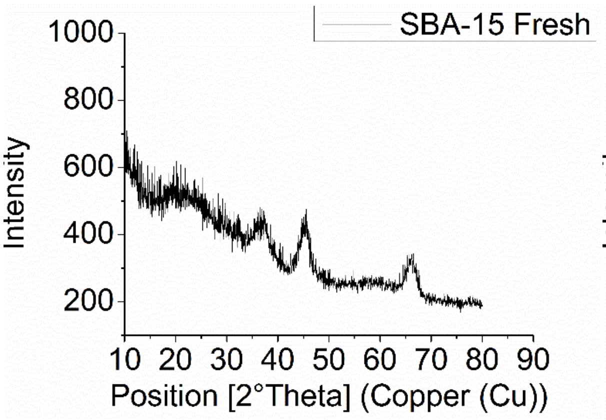


Figure S2.E. XRD for MCM-41-based fresh catalyst.

Figure S2.F. XRD MCM-41-based used catalyst.



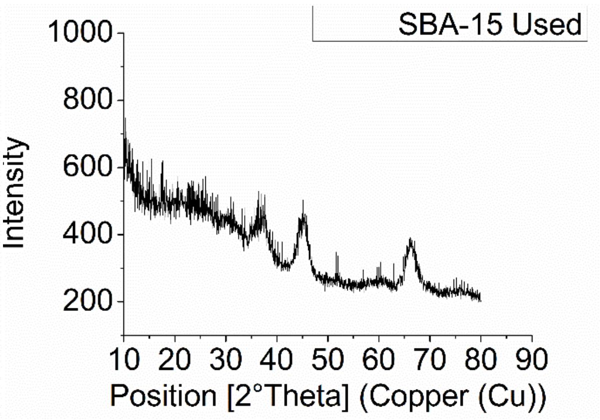


Figure S2.G. XRD for SBA-15-based fresh catalyst.

Figure S2.H. XRD SBA-15-based used catalyst.

ESI Section 3. Catalytic Activity

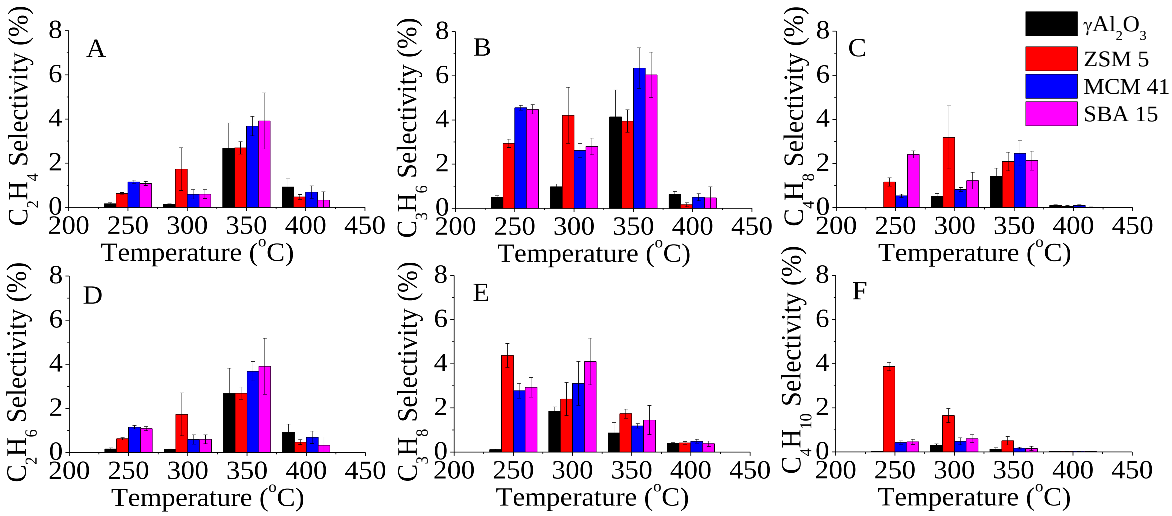


Figure S3. Plots of the selectivity's toward ethylene (A), propylene (B), butylenes (C), ethane (D), propane(E) and butanes (F) for each catalyst over the temperature range 250 – 400 °C.

ESI Section 4. Cavity Perturbation Theory and Dielectric Property Data

The cavity perturbation technique consists in the use of a resonant cavity to determine the dielectric properties of a sample. The resonant cavity produces a series of stationary waves which are modified when a sample is inserted in the cavity[6]. The modifications in the stationary wave pattern are related to the dielectric properties of a material and the dielectric constant and loss can be calculated. The dielectric constant is calculated by using the frequency of the wave used in the cavity while the dielectric loss is calculated by using the Quality factor of the resonant cavity. The Quality factor of a cavity represents the amount of wave oscillations that are lost through the cavity walls. A high quality factor results in a low number of oscillations lost to the number of oscillations used in the cavity while a low quality factor would result from a higher number of lost oscillations with respect to the number of oscillations present in the cavity.

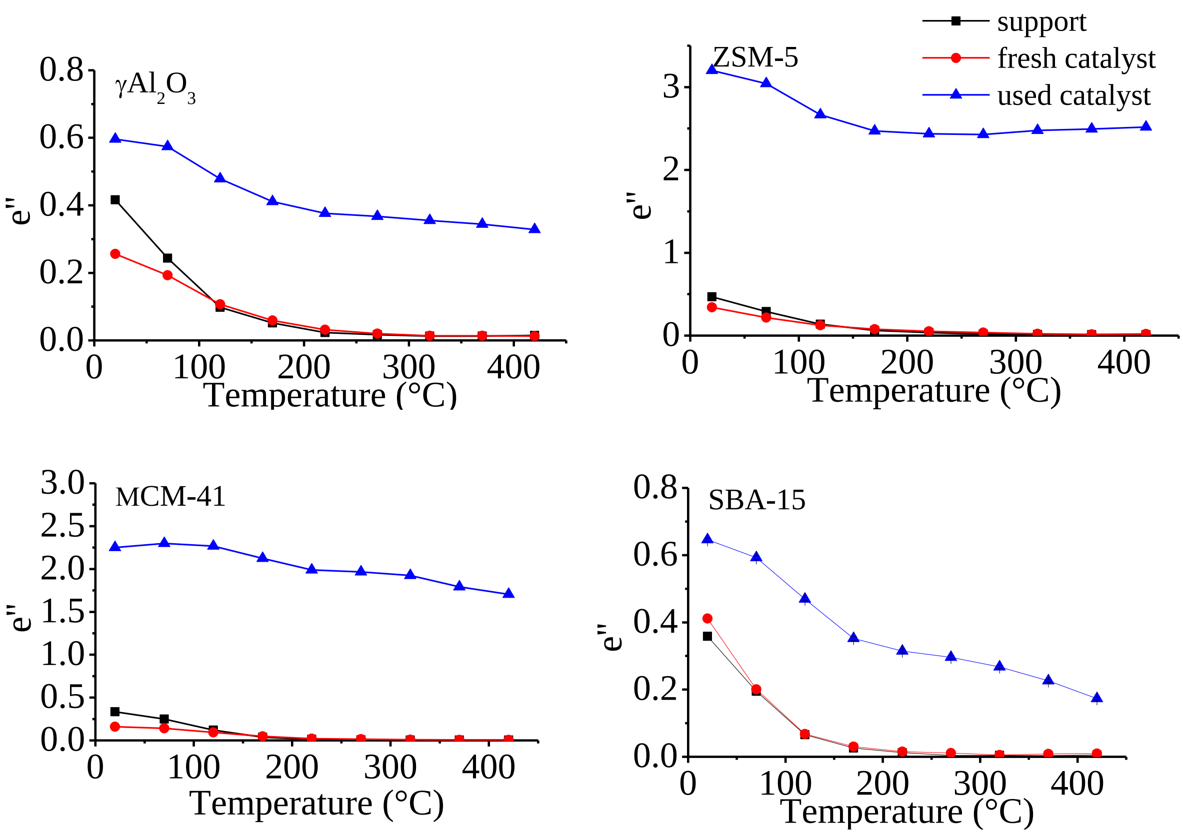


Figure S4. Variation in Dielectric Loss with temperature for the F-T catalysts measured at 2470 MHz (standard deviation ~ 0 .05).

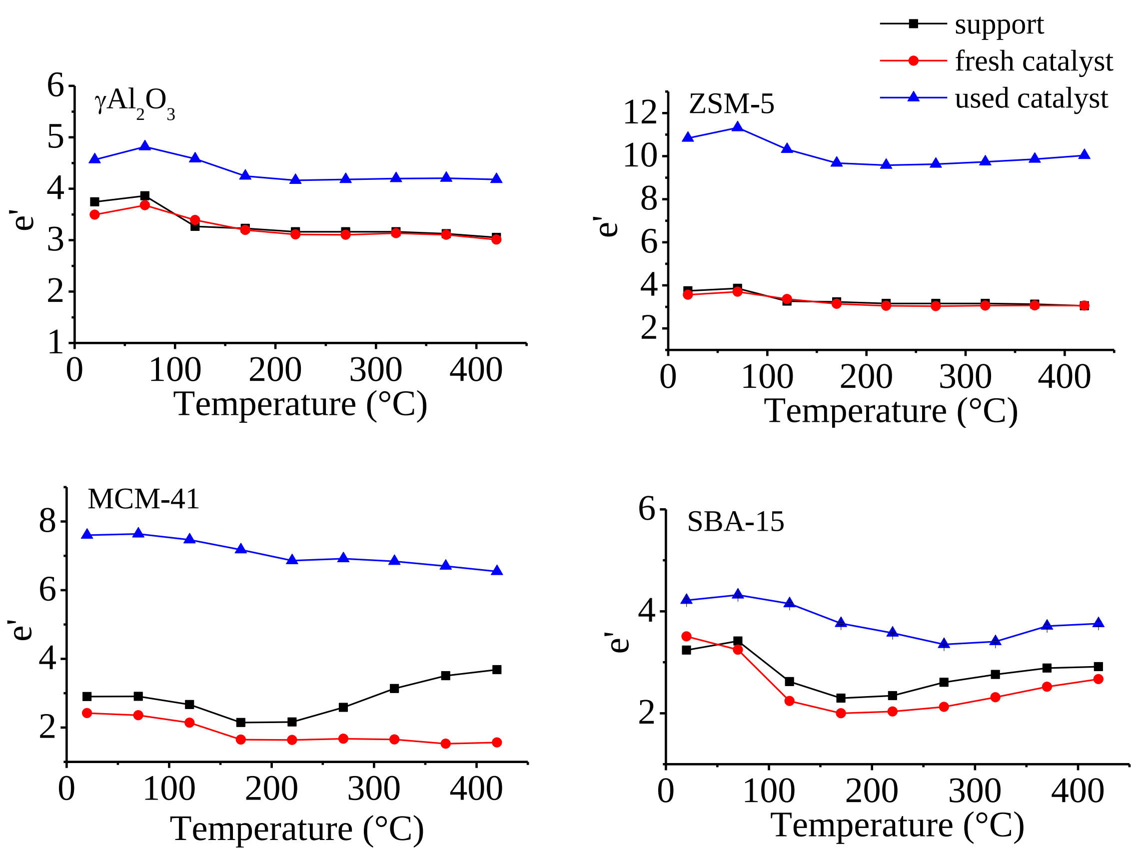


Figure S5. Dielectric constant with temperature for the different catalyst samples at 912 MHz (standard deviation ~ 0.26).

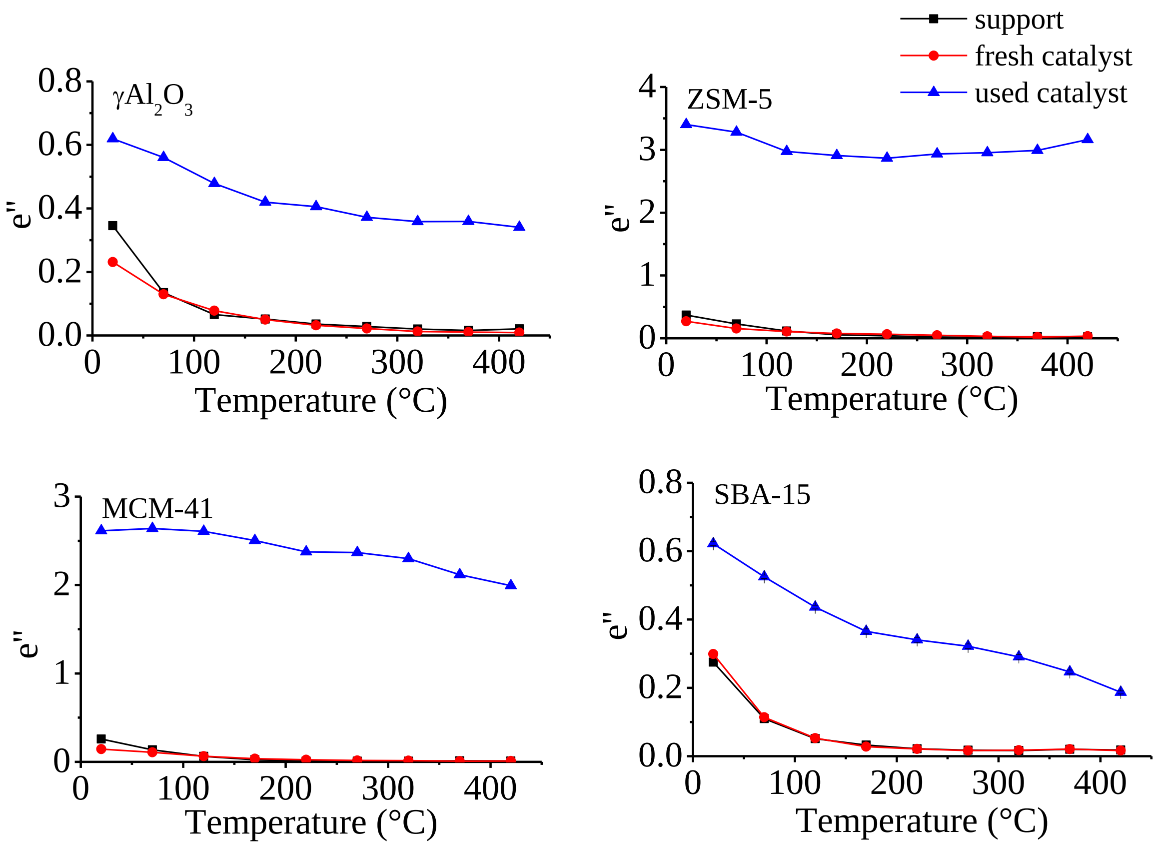


Figure S6. Variation in Dielectric loss with temperature for the F-T catalysts measured at 912MHz (standard deviation ~ 0.05).

ESI Section 5. Penetration depth:

The power density (P_d) can be calculated from the following equation:

$$P_d = 2\pi * f * \varepsilon_0 * \varepsilon^{"} * E^2 \qquad \text{(Equation SI1)}$$

Where f is the frequency used (in Hz), E is the electric Field intensity, ε_0 is the permittivity for vacuum and ε'' is the dielectric loss.

Also the dielectric properties determine the penetration depth of a material. The more absorbing is a material, the lower its penetration depth is[13]. The penetration depth can be calculated by the equation ESI2.

$$D_p = \frac{\lambda_0}{2\pi * \sqrt{2\varepsilon'}} * \frac{1}{\sqrt{\left(1 + \left(\frac{\varepsilon^{"}}{\varepsilon'}\right)^2\right)^{0.5} - 1}} \qquad \text{(Equation SI2)}$$

Where λ_0 is the radiation wavelength (m).

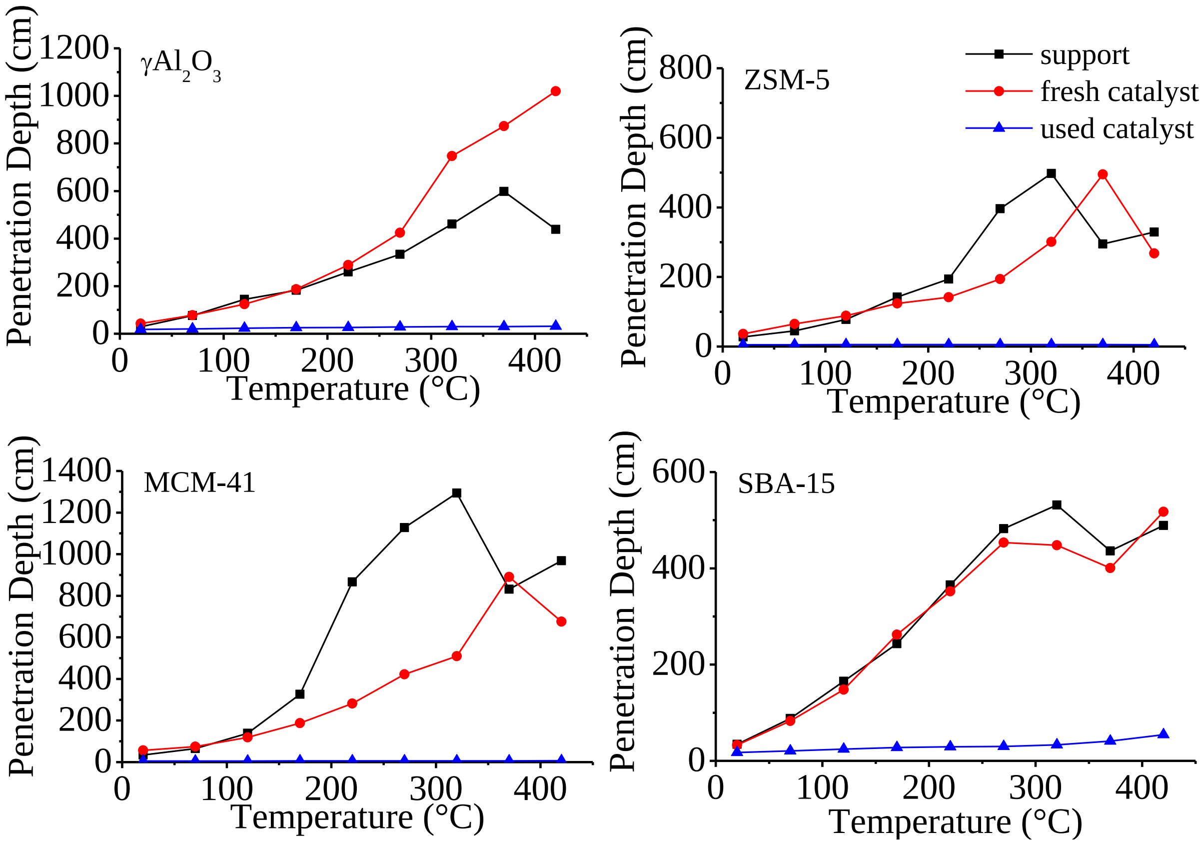


Figure S7. Variation in Penetration depth of Microwave energy with temperature for F-T catalysts at 912 MHz.