

Supplementary Materials

# Catalytic Hydrogenation of Carbon Dioxide over Magnetic Nanoparticles: Modification in Fixed-Bed Reactor

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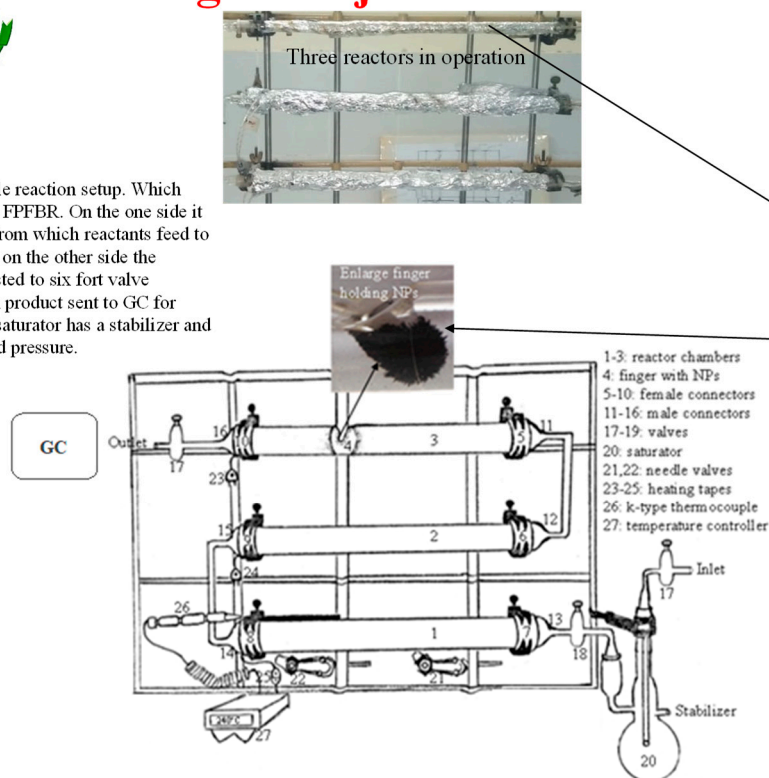
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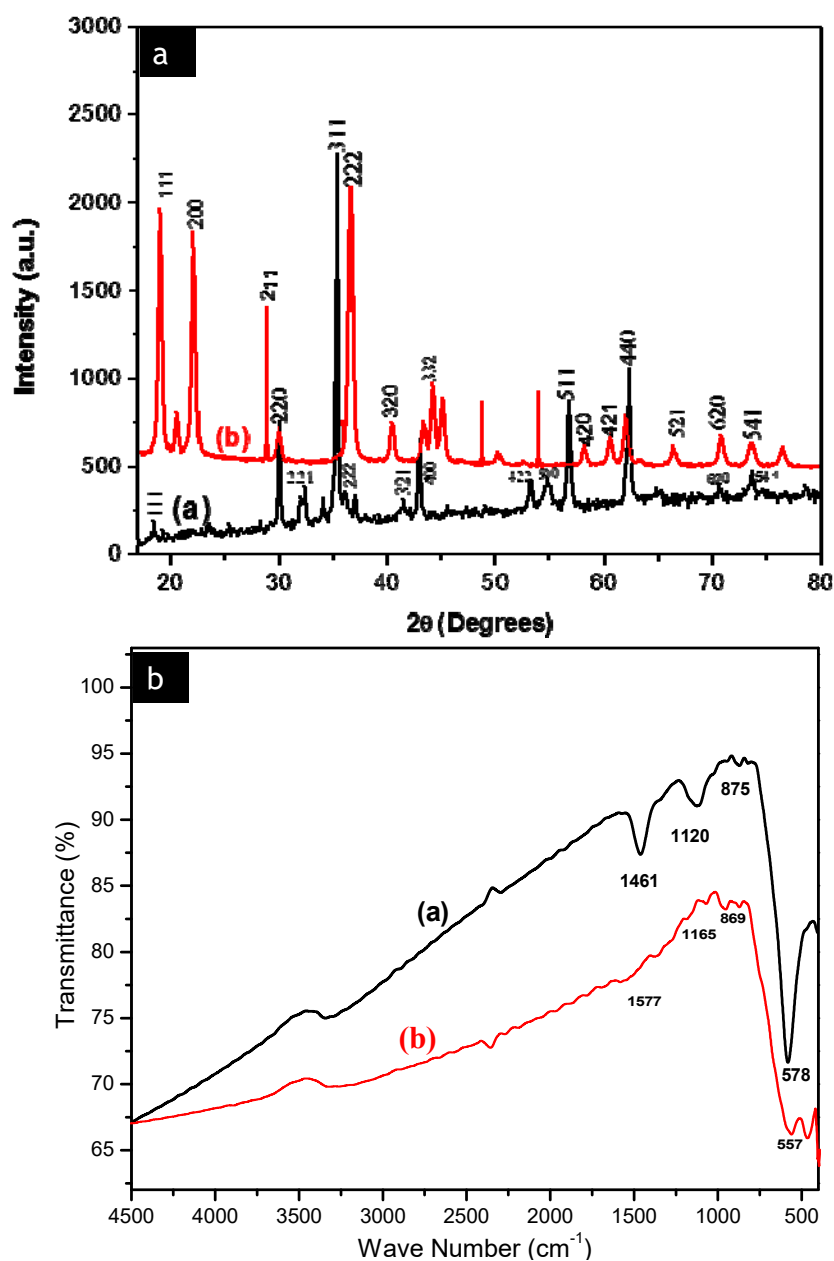
## Finger Projected Fixed-Fed Reactor

Sketch of whole reaction setup. Which consist of five FPFBR. On the one side it has saturator from which reactants feed to reactors while on the other side the reactor connected to six port valve through which product sent to GC for analysis. The saturator has a stabilizer and can maintained pressure.

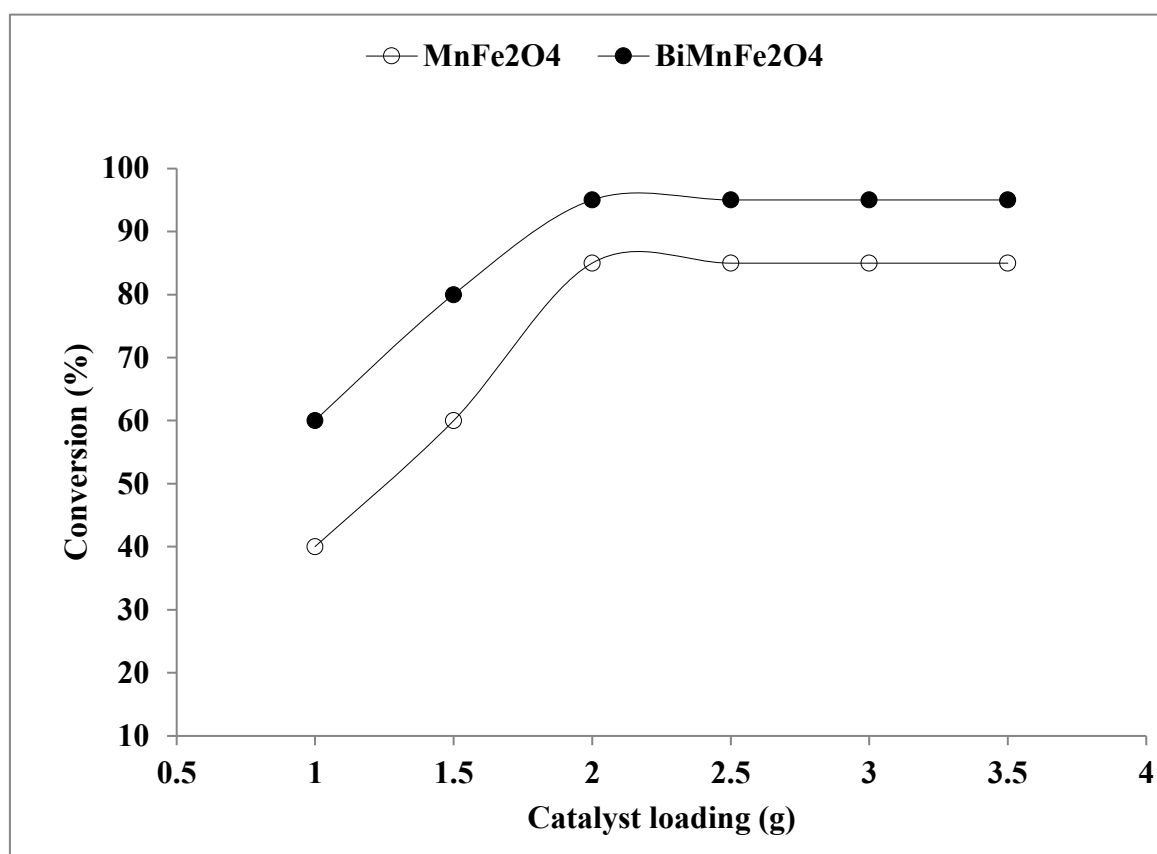


Modifies fixed bed reactor which is 80cm long quartz glass chamber with 20mm diameter consist of 18 fingers projected toward inside with a groove to out side. The groove has magnets which hold the magnetic NPs. Means we have 18 fixed beds in the reactor

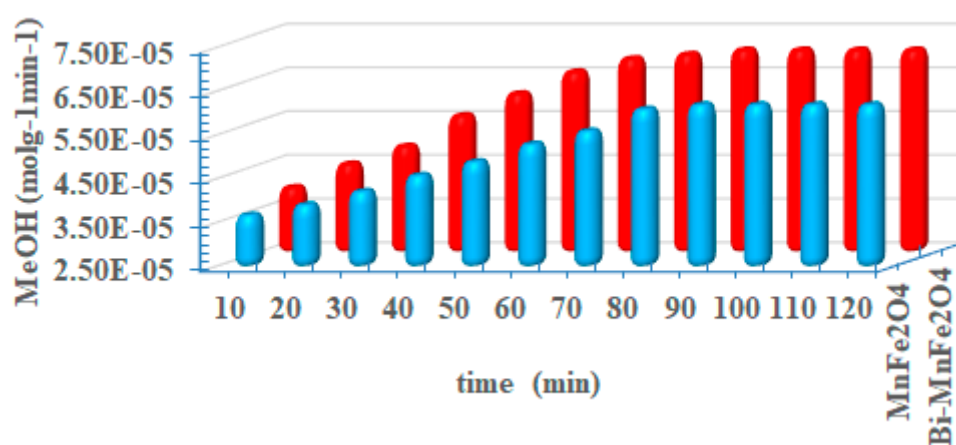
**Figure S1.** Schematic diagram of reaction setup and Finger Projected Fixed-Fed Reactor (FPFBR) used for hydrogenation of CO<sub>2</sub> to methanol.



**Figure S2.** (a) XRD pattern of MnFe<sub>2</sub>O<sub>4</sub> (pattern a), Bi-MnFe<sub>2</sub>O<sub>4</sub> (pattern b), (b); FTIR spectra of MnFe<sub>2</sub>O<sub>4</sub> (curve a), Bi-MnFe<sub>2</sub>O<sub>4</sub> (curve b).



**Figure S3.** Effect of catalyst loading per chamber on the rate of CO<sub>2</sub> hydrogenation to MeOH. Reaction conditions; pressure: 1 bar, Temp: 413–513K, data collected after 90 min, feed ratio 3/1: H<sub>2</sub>/CO<sub>2</sub>



**Figure S4.** Comparison of the catalytic activity of MnFe<sub>2</sub>O<sub>4</sub> and Bi-MnFe<sub>2</sub>O<sub>4</sub> for CO<sub>2</sub> conversion to MeOH. Reaction Conditions: Pressure: 1 bar, Temp: 220 °C, Catalyst: 2g/chamber, feed ratio 3/1: H<sub>2</sub>/CO<sub>2</sub>.

**Table S1.** Different types of reactors used for hydrogenation of CO<sub>2</sub> to MeOH under various reaction conditions.

Entry No	Catalyst	Reactor type	Temp (K)	Pressure (bar)	E <sub>a</sub> (kJ/mol)	Ref.
1	Cu/SiO <sub>2</sub>	*TKA	403 – 453	6	133	[1]
2	SiC QDs	Slurry	423	32	48.6	[2]
3	CeO <sub>x</sub> /Cu	Batch	500– 600	5	106.3	[3]
4	Cu/ZnO/Al <sub>2</sub> O <sub>3</sub>	Fixed bed	473 – 573	30	44	[4]
5	Cu/SiO <sub>2</sub> + ZnO/SiO <sub>2</sub>	Fixed bed	523 – 723	50	86-96	[5]
6	Cu/ZnO	Fixed bed	525 – 575	5	116.7	[6]
7	Cu/CeO <sub>x</sub> /TiO <sub>2</sub>	Batch	500 – 600	5	50.2	[7]
8	C/Pd–ZnO	Fixed bed	503 – 543	20	56.8	[8]
9	Cu/ZnO	**TQR	423– 573	1	-	[9]
10	Pd–CuZnO	Fixed bed	503– 543	45	31	[10]
11	MnFe <sub>2</sub> O <sub>4</sub>	***FPFBR	413 – 513	1	115.2	Recent
12	Bi–MnFe <sub>2</sub> O <sub>4</sub>	***FPFBR	413 – 513	1	100	Recent

\*Transient Kinetics Analysis (TKA) reactor system, \*\*Tubular Quartz Reactor (45 cm length and 1 cm diameter),

\*\*\*Finger projected fixed-bed reactor

## References

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