

Supplementary Information

## Microflow chemistry and its electrification for sustainable chemical manufacturing

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### Performance Summary of HMF Production

Table S1: Summary of the space-time yield of HMF from fructose dehydration using homogeneous and heterogeneous catalysts and their specific reaction conditions.

Reactor Type	Catalyst Type	Catalyst	Heating Type	Phases	Solvent	Temp (°C)	Conv. (%)	Yield (%)	Space time yield (mol mL <sup>-1</sup> hr <sup>-1</sup> )	Ref
Batch	Homo	HCl	Conv.	Single	Water	180	50	25	9.99E-03	1
Batch	Homo	HCl	Conv.	Single	Water	180	75	55	2.20E-02	1
Batch	Homo	Acetic Acid	Conv.	Single	Water	200	92	52	9.53E-04	2
Batch	Homo	Formic Acid	Conv.	Single	Water	200	96	58	2.12E-03	2
Batch	Homo	HCl	Conv.	Single	Water	130	99	28	5.04E-03	3
Batch	Homo	HCl	MW	Single	Water	200	95	53	4.77E-02	3
Batch	Homo	AlCl <sub>3</sub>	MW	Single	Water	120	-	50	1.67E-03	4
Batch	Homo	H <sub>2</sub> SO <sub>4</sub>	MW	Single	Water	200	97	47	1.50E-02	5
Batch	Homo	AlCl <sub>3</sub>	MW	Biphasic	Water/MIBK	130	-	61	2.03E-03	4
Batch	Homo	HCl	Conv.	Biphasic	1:1 water/DMSO / 7:3 MIBK/2-BuOH	180	86	69	2.76E-02	1
Batch	Homo	H <sub>3</sub> BO <sub>3</sub>	Conv.	Biphasic	Water (0.87M NaCl)/7:3 MIBK/2- BuOH	150	72	50	1.11E-03	6
Batch	Homo	Phosphoric acid	Conv.	Biphasic	Phosphate buffer saline/2-sec-butyl- phenol	180	-	62.5	3.47E-04	7
Batch	Homo	H <sub>2</sub> SO <sub>4</sub>	Conv.	Biphasic	Water/MIBK	155	100	75	1.50E-04	8
Continuous	Homo	HCl	MW Stop-flow	Single	Water	150	-	85.6	1.43E-02	9
Continuous	Homo	HCl	Conv.	Single	Water	200	100	54	1.35E-01	10
Continuous	Homo	H <sub>3</sub> PO <sub>4</sub>	Conv.	Single	Water	240	-	40	2.00E-03	11
Continuous	Homo	H <sub>2</sub> SO <sub>4</sub>	Conv.	Single	Water	180	80	28	9.33E-05	12
Continuous	Homo	HCl	Conv.	Single	Water	185	71	53.25	1.77E-02	13

Continuous	Homo	HCl	Conv.	Biphasic	Water/MIBK	140	-	74	1.64E-03	14
Continuous	Homo	HCl	Conv.	Biphasic	Water/DMSO/ MIBK/2-butanol	185	96.47	82	8.19E-02	13
Continuous	Homo	HCl	Conv.	Biphasic	Water/MIBK	180	93.5	94.7	6.31E-03	15
Continuous	Homo	H <sub>3</sub> PO <sub>4</sub>	Conv.	Biphasic	Phosphate buffer saline/2-sec-butyl phenol	180	-	66.4	3.69E-04	7
Continuous	Homo	HCl	Conv.	Biphasic	Water/MIBK	150	-	93	4.80E-02	16
Continuous	Homo	HCl	Conv.	Biphasic+ Membrane	Water/Membrane/ MIBK	180	99.9	93	7.74E-03	17
Continuous	Homo	H <sub>2</sub> SO <sub>4</sub>	Conv.	Biphasic	Water/MIBK	155	96	81	3.04E-04	8
Continuous	Homo	HCl	Conv.	Biphasic	Water/MIBK	200	-	93	4.65E-01	18
Batch	Hetero	H <sub>3</sub> PO <sub>4</sub> - treated niobic acid	Conv.	Single	Water	100	28.5	27.9	1.86E-04	19
Batch	Hetero	3.75%-wt FeVOP	Conv.	Single	Water	80	70.8	59.6	9.92E-04	20
Batch	Hetero	TiO <sub>2</sub>	Conv.	Single	Water	200	98	22	1.32E-03	21
Batch	Hetero	TiO <sub>2</sub>	MW	Single	Water	200	84	38	5.06E-04	5
Batch	Hetero	Dowex 50wx8-100	MW	Single	70wt% Acetone as Co Solvent	150	95.1	73.4	3.26E-04	22
Batch	Hetero	SiO <sub>2</sub> -SO <sub>3</sub> H	MW	Single- Organic	DMSO	150	100	91	8.97E-04	23
Batch	Hetero	$\gamma$ -TiP	Conv.	Biphasic	Water w/ intermittent MIBK extraction	100	70.7	67.3	2.24E-04	24
Batch	Hetero	Diaion PK216	Conv.	Biphasic	Water/DMSO / MIBK	90	87	73	1.01E-04	25
Batch	Hetero	Al-TUD-1	Conv.	Biphasic	Water / Toluene	170	76	20	5.00E-05	26
Batch	Hetero	TP-A380	Conv.	Biphasic	Water / 7:3 MIBK/2-BuOH	180	67	43	3.58E-04	27
Batch	Hetero	Taa-SBA-15	Conv.	Biphasic	Water / 7:3 MIBK/2-BuOH	180	66	49	1.63E-03	27
Batch	Hetero	Ag <sub>3</sub> PW <sub>12</sub> O <sub>40</sub>	Conv.	Biphasic	Water / MIBK	120	83	78	9.96E-04	28
Batch	Hetero	Cs <sub>2.5</sub> H <sub>0.5</sub> PW <sub>12</sub> O <sub>40</sub>	Conv.	Biphasic	Water / MIBK	115	78	74	9.45E-04	29
Batch	Hetero	NA-p	Conv.	Biphasic	Water / 2-BuOH	160	90	89	3.56E-04	30
Batch	Hetero	TA-p	Conv.	Biphasic	Water / 2-BuOH	160	94	90	1.80E-04	30
Batch	Hetero	NA-p	Conv.	Biphasic	Water/2-butanol	160	70	58	5.79E-04	31
Batch	Hetero	H-form Zeolite Si/Al = 11.7	Conv.	Biphasic	Water / MIBK	165	64	42	2.39E-05	32
Batch	Hetero	Amberlyst- 15	Conv.	Biphasic	1,4-dioxane with 10 vol% DMSO	100	-	75	7.50E-05	33
Continuous	Hetero	Amberlyst- 15	Conv.	Biphasic	1,4-dioxane with 10 vol% DMSO	110	98	92	5.52E-03	33
Continuous	Hetero	TiO <sub>2</sub>	Conv.	Biphasic	Water / n-BuOH	200	-	18	4.60E-03	34
Continuous	Hetero	TiO <sub>2</sub>	Conv.	Biphasic	Water / n-BuOH	200	-	11	2.81E-03	34

Table S2: Summary of the space-time yield of HMF from tandem glucose dehydration using homogeneous and heterogeneous catalysts and their specific reaction conditions.

Reactor Type	Catalyst Type	Catalyst	Heating Type	Phases	Solvent	Temp (°C)	Conv. (%)	Yield (%)	Space time yield (mol mL <sup>-1</sup> hr <sup>-1</sup> )	Ref
Batch	Homo	DyCl <sub>3</sub>	Conv.	Single	Water	140	17	7	3.11E-05	35
Batch	Homo	H <sub>2</sub> SO <sub>4</sub>	Conv.	Single	Water	200	32	2	1.20E-04	21
Batch	Homo	H <sub>2</sub> SO <sub>4</sub>	MW	Single	Water	200	11	2	4.44E-05	5
Batch	Homo	AlCl <sub>3</sub>	MW	Single	Water	120	-	40	3.33E-04	4

Batch	Homo	CrCl <sub>3</sub> & HCl	Conv.	Single	Water	140	-	15	9.99E-05	36
Batch	Homo	H <sub>3</sub> PO <sub>4</sub> / Nb <sub>2</sub> O <sub>5</sub>	Conv.	Single	Water	120	92	52	9.62E-06	37
Batch	Homo	CrCl <sub>3</sub> & HCl	Conv.	Biphasic	Water/THF	140	-	59	1.09E-04	36
Continuous	Homo	H <sub>3</sub> PO <sub>4</sub>	Conv.	Biphasic	Phosphate buffer saline/2-sec-butyl- phenol	180	-	75.7	5.36E-05	7
Continuous	Homo	AlCl <sub>3</sub> & HCl	Conv.	Biphasic	Water/MIBK + 20wt% NaCl	160	-	66.2	2.48E-03	38
Batch	Hetero	TiO <sub>2</sub>	MW	Single	Water	200	64	19	2.53E-04	5
Batch	Hetero	ZrO <sub>2</sub>	MW	Single	Water	200	57	10	2.22E-04	5
Batch	Hetero	TiO <sub>2</sub>	Conv.	Single	Water	250	39	27	1.62E-03	39
Batch	Hetero	ZrO <sub>2</sub>	Conv.	Single	Water	250	38	17	1.02E-03	39
Batch	Hetero	TiO <sub>2</sub> -ZrO <sub>2</sub>	Conv.	Single	Water	250	44	29	1.74E-03	40
Batch	Hetero	ZrO <sub>2</sub>	Conv.	Single	Water	200	48	5	3.00E-04	21
Batch	Hetero	A-TiO <sub>2</sub>	Conv.	Single	Water	200	81	20	1.20E-03	21
Batch	Hetero	NA-p	Conv.	Biphasic	Water/2-BuOH	160	72	49	8.90E-05	31
Batch	Hetero	SBA-15- [PMIm] Cl/CrCl <sub>2</sub>	Conv.	Biphasic	water/DMSO/ MIBK/2-BuOH	150	50	35	6.48E-05	41
Batch	Hetero	Sn-β/HCl (pH =1)	Conv.	Biphasic	Water(26wt%NaC l)/n-BuOH	160	75	41	1.52E-04	42
Batch	Hetero	Sn-β/HCl (pH =1)	Conv.	Biphasic	Water(26wt%NaC l)/THF	180	79	57	2.71E-04	42
Batch	Hetero	Ti-β/HCl (pH=1)	Conv.	Biphasic	Water(26wt%NaC l)/THF	180	76	53	1.68E-04	42
Batch	Hetero	Nb(0.05)- Beta 18 Zeolite	Conv.	Biphasic	Water/MIBK + 20%NaCl	180	97.4	82.1	1.95E-05	43
Batch	Hetero	Al-TUD-1	Conv.	Biphasic	Water/toluene	170	76	18	2.25E-05	26
Continuous	Hetero	TiO <sub>2</sub>	Conv.	Biphasic	Water/MIBK	180	-	26	2.16E-02	34
Continuous	Hetero	TiO <sub>2</sub> /HCl	Conv.	Biphasic	Water(0.15M HCl co catalyst)/MIBK	180	-	37	3.08E-02	34
Continuous	Hetero	P-TiO <sub>2</sub>	Conv.	Biphasic	Water/2- methyltetrahydrof uran + 20wt% NaCl	150	93	66	6.60E-04	44

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