Electronic Supplementary Material (ESI) for Environmental Science: Nano.

Reusable Piezo-catalytic Water Disinfection Activity of CVD Grown WS_2 Few-layer on Sapphire Substrate

Deepa Thakur[1], Moolchand Sharma[1], Viswanath Balakrishnan[1]* and Rahul Vaish[1]*

School of Engineering, Indian Institute of Technology Mandi, Mandi, Himachal Pradesh, India 175075

***Corresponding author E-mail address: viswa@iitmandi.ac.in, rahul@iitmandi.ac.in**

[1]Both authors contributed equally.

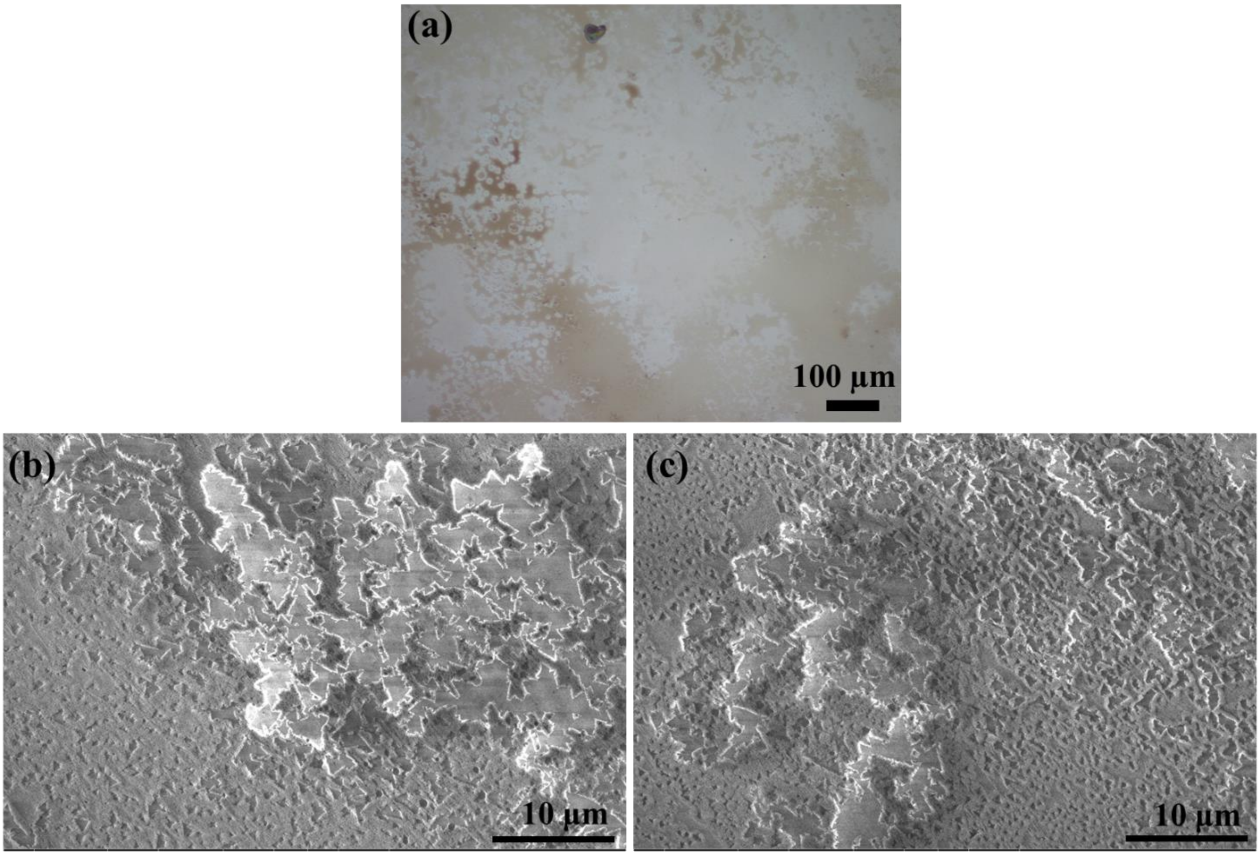

Figure S1: (a) Optical image of large area growth of few layer WS_2 is shown. (b) and (c) FESEM image to show coalescence and multilayer formation.

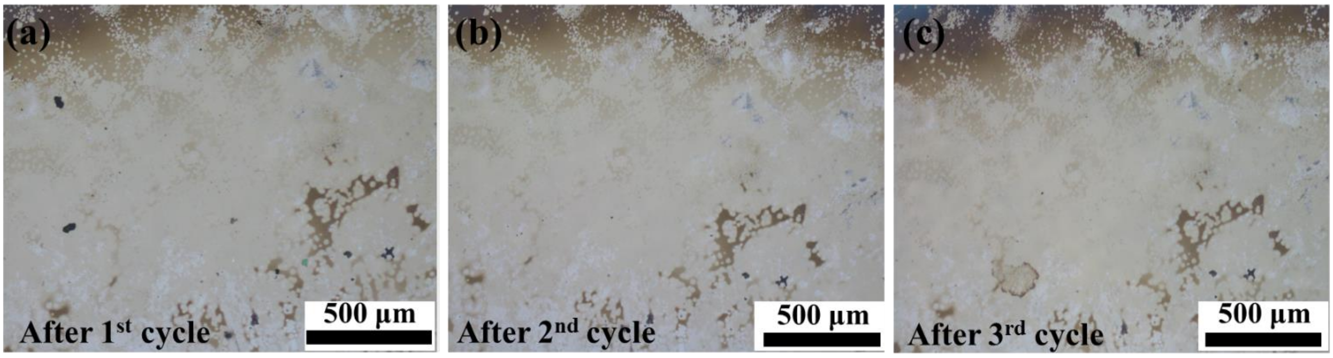

Figure S2: Optical images shows recovery of catalyst after three piezocatalytic cycles.

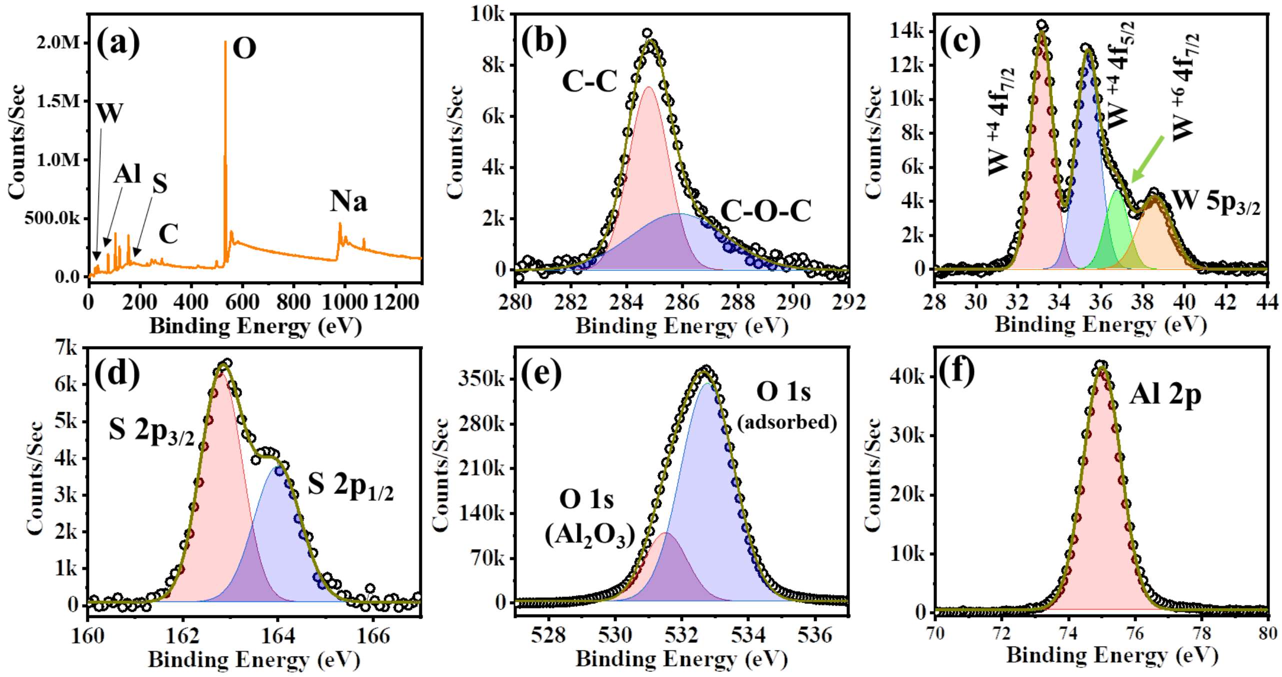

Figure S3: Surface analysis of catalyst after five cycles. (a) XPS Survey scan. Individual high-resolution (b) C scan, (c) W scan, (d) S scan, (e) O scan and (f) Al scan.

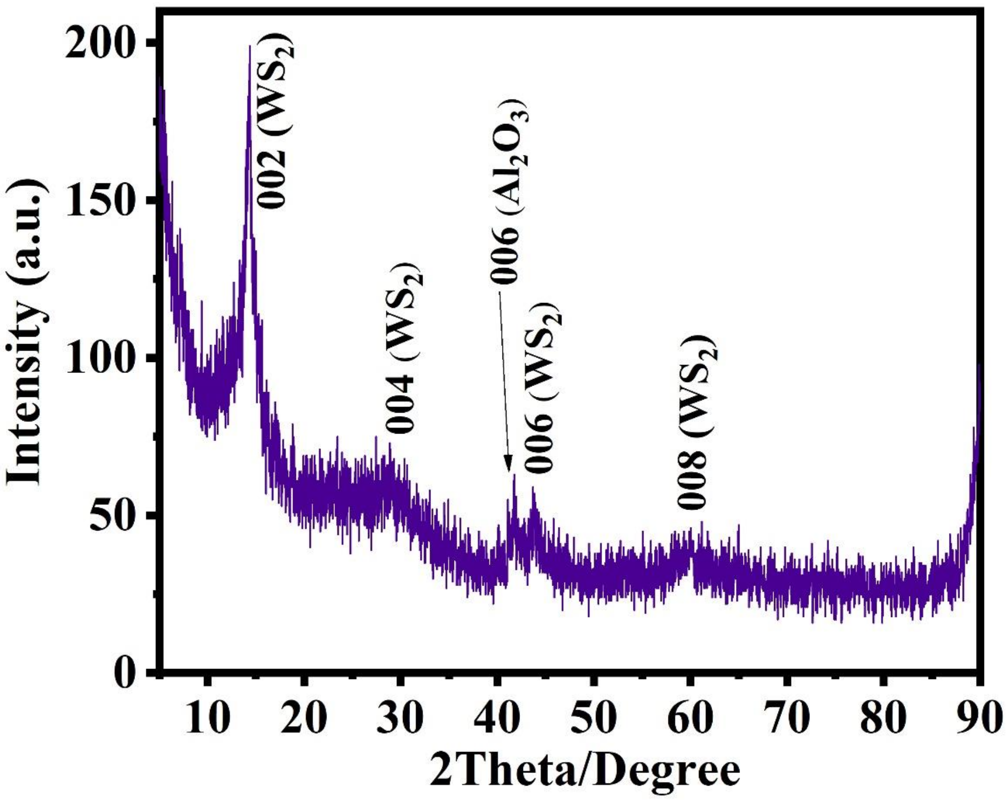

Figure S4: XRD analysis of WS_2 grown over sapphire substrate.

A comparative summary of piezocatalysis by other researchers is presented in table shown below:

Sr. No.	**Materials**	**Application**	**Reaction rate**	**sonicator conditions**	**Dye/pollutant**	**Catalyst amount**	**Ref.**
1	Single and few layer WS_2	dye degradation	99.7% in 60 min	300 W	MB 40 mg/L	10 mg	[1]

2	MoS_2 Few layer	H_2 evolution	29.1 μ mol g^{-1} h^{-1}	110 W and 40 kHz	RB (100 mL, 10 mg/L)	20 mg catalyst for H_2 evolution and 10 mg for RB dye degradation	[2]
		Dye degradation	96% in 60 min				
	WS_2 Few layer	H_2 evolution	15.4 μ mol g^{-1} h^{-1}				
		Dye degradation	65.7% in 60 min				
	WSe_2 Few layer	H_2 evolution	11.3 μ mol g^{-1} h^{-1}				
		Dye degradation	43.5% in 60 min				
3	PDMS embedded monolayer WS_2 nanoflowers	dye degradation and antibacterial	0.13 ($ppms^{-1}$) degradation rate: ~6624 ppm L $mole^{-1}s^{-1}$ Antibacterial: 99.99% in 60 min.	300 W, 40 kHz	RB (10 mg/L) And E coli (2×10^8 bacteria/mL)	300 mg	[3]
4	Co doped	dye degradati	73.6% MB in 25 min	40 kHz, 100W	MB (30 mg/L)	10 mg	[4]

	MoS_2, 3.2 nm thick	on					
5	$MoSe_2$ NFs Single and few layer	dye degradation	90 % in 30 sec K_{obs}:0.3 ppm s^{-1} Degradation rate: 69,889 ppm L $mole^{-1}$ s^{-1}	250 W, 40 kHz	RhB [1 × 10^{-5} m]	10 mg	[5]
6	MoS_2 Nano Flowers	dye degradation	40336 ppm L mol^{-1} s^{-1} (93% in 60 s)	250 W, 40 kHz	RhB [10 mg L^{-1}]		[6]
7	Co-doped MoS_2	dye degradation	99.2% in 60 s		MB [5 mg L^{-1}]	10 mg	[7]
	MoS_2		36.5% in 60 s				
8	glutathione modified acidized-MoS_2	Piezo-photo Water splitting	H_2: 1250 μmol g^{-1} h^{-1}	280 W	200 mL water	0.05 g	[8]
9	Au-	Piezo-	99.999% in	Visible	E.Coli	2 mg	[9]

	MoS_2	photo Bacterial Sterilization	15 min (photo+piezo), 45 min for piezo, 60 min for photo	light and mechanical vibration	(2×10^6 CFU /mL)		
10	Fe@3D-WS_2	Levofloxacin and Dye degradation	99.6% in 12 min	40 kHz; 100 W	Levofloxacin (25 mg/L)	20 mg	[10]
			98% within 30 s		Rhodamine (1000 ppm, 20 mL)	0.01 g	
	3D-WS_2		63% in 12 min		Levofloxacin (25 mg/L)	20 mg	

The 2D TMDCs based catalyst shows high efficiency towards piezocatalytic dye degradation and other application like water splitting, antibacterial activity and H_2 evolution. But uptill now mostly catalyst in powder or solution form has been used. The use of thin-film catalyst is very rare. Thin film based catalyst have advantage of easy/good recovery and recyclability with negligible loss of catalyst. Powder or solution-based catalyst has difficult process for catalyst recovery and suffers catalyst loss. Hence recyclability which is one of the very important factors for practical industry-based requirement, becomes difficult. Hence the developed large area thin film based WS_2 grown on sapphire substrate with piezo catalyst behaviour opens up platform for developing reusable, low cost catalyst for dye degradation. There are very few reports on the use of thin-film based catalyst. The existing literature survey direct us towards the future directions which can be integration of WS_2 with other material which can increase its activity multiple times.

References:

1 R. Cao, R. Wu, D. Zhang and S. Xu, *Appl. Surf. Sci.*, 2021, **553**, 149557.

2 S. Li, Z. Zhao, D. Yu, J. Z. Zhao, Y. Su, Y. Liu, Y. Lin, W. Liu, H. Xu and Z. Zhang, *Nano Energy*, 2019, **66**, 104083.

3 S. Masimukku, Y. Hu, Z. Lin, S. Chan and T. Chou, *Nano Energy*, 2018, **46**, 338–346.

4 W. I. N. T. Yein, W. Qun, J. Jiahuang, L. I. Yang and W. U. Xiaohong, *Chem. Res. Chinese Univ.*, 2019, **35**, 892–900.

5 M. Wu, J. Lee, Y. J. Chung, M. Srinivaas and J. Wu, *Nano Energy*, 2017, **40**, 369–375.

6 J. M. Wu, W. E. Chang, Y. T. Chang and C. Chang, *Adv. Mater.*, 2016, **28**, 3718–3725.

7 W. T. Yein, Q. Wang, Y. Li and X. Wu, *Catal. Commun.*, 2019, **125**, 61–65.

8 Y. Sua, L. Zhang, W. Wang, X. Li, Y. Zhanga and D. Shao, *J. Mater. Chem. A*, 2018, **6**, 11909–11915.

9 T. Chou, S. Chan, Y. Lin, P. Yang, C. Liu, Y. Lin, J.-M. Wu, J. Lee and Z. Lin, *Nano Energy*, 2019, **57**, 14–21.

10 F. Meng, W. Ma, C. Duan, X. Liu, Z. Chen, M. Wang, J. Gao and Z. Zhang, *Appl. Catal. B Environ.*, 2019, **252**, 187–197.