

Supplementary Information

Potential mediated electrochemical recycling and sensing of cadmium ions in wastes water over ZnO/SA-g-PPy bio-composite

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Table S1. Observed physical parameters during polymerizations.

Composition	Time for the beginning of polymerization (min.)	Completion time for polymerization (min.)	Temperature change of reaction bath (°C)	pH	Yield of reaction (%)
PPy	3.5	20.0	0.5	2	67
ZnO/SA-g-PPy	2.0	15.0	2.0	2	78

Table S2. IR peaks for PPy, Sodium Alginate (SA), SA-g-PPy, and ZnO/SA-g-PPy.

Sr. No.	SA (cm ⁻¹)	PPy (cm ⁻¹)	SA-g-PPy (cm ⁻¹)	ZnO/SA-g-PPy (cm ⁻¹)	Assigned group
1.	--	--	793	793	C-H and N-H ring out-of-plane bending
2.	927	906	916	916	C-O-H and C-N-H stretching in SA and PPy ring in-plane bending
3.	1046	1043	1045	--	C-O-C glycosidic linkage of SA And C-N-C linkage in PPy
4.	1186	1187	1188	1182	C-C stretching
5.	--	1221	--	--	C-H and N-H in-plane deformation vibrations
6.	--	1361	--	--	C-N stretching in polypyrrole ring
7.	1413	--	1410	1401--	O-H and N-H bend vibration
8.	1556	1552	1546	1557	Strong hydrogen bonds between the pyrrole N-H groups and the hydroxyl groups and free COO ⁻ group of adjacent SA.
9.	1637	1706, 1723	1712	1712 weak	Interaction of Zn ²⁺ with polypyrrole and COO ⁻
10.	2950	3004	2804, 2881	2835	C-H sp ³

11.	3430	3406	3298	3644	N-H and O-H
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Table S3. XRD data and structural parameters

S. No.	Sample	Angle (2θ)	Plane (hkl)	<i>d</i> -value (Å)
1.	SA-g-PPy	25.10°	110	3.55
2.	ZnO	31.78°	100	2.41
		34.44°	002	2.09
		36.22°	101	1.47
		47.55°	102	1.90
		56.64°	110	1.60
		62.91°	103	1.46
		66.35°	200	1.40
		67.97°	112	1.37
		69.18°	201	1.35
3.	ZnO/SA-g-PPy	17.88°	110	4.96
		23.65°	110	3.85
		26.29°	110	3.39
		30.57°	100	2.96
		32.92°	100	2.25
		36.28°	101	1.46

Table S4. IR peaks and corresponding intensity of ZnO/SA-g-PPy electrode-based sensor, after sensing and before sensing of Cd²⁺ ions.

Before Sensing		After Sensing	
Peak Position (cm ⁻¹)	Intensity	Peak Position (cm ⁻¹)	Intensity
617	37.89	617	136.89
1041	42.18	1116	92.84
1413	24.44	1398	165.38
1557	16.86	1384	151.24
1648	39.78	1619	150.58
		1713	153.87