Electronic Supplementary Material (ESI) for Analyst.

Supplementary Information

A Highly Sensitive Ion-Selective Chemiresistive Sensor for Online Monitoring of Lead Ions in Water

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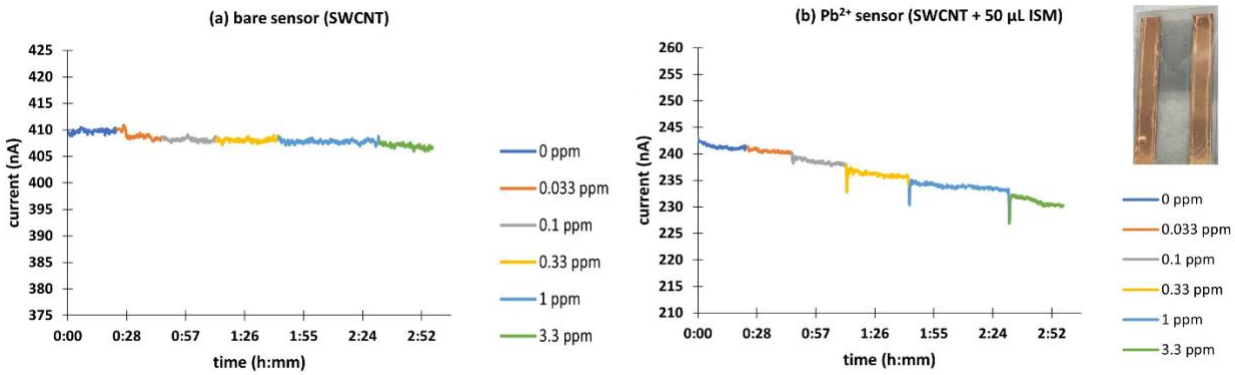

Fig. S1 Sensitivity comparison of a bare device and a Pb^{2+} sensor to lead ions in different concentrations (from 33 ppb to 3.3 ppm). (a) Resonse of a bare sensor made of SWCNT as a resistive film and (b) a Pb^{2+} sensor made of SWCNT as a resistive film and coated with ISM (Drop-casted 50 µL of ISM solution on the SWCNT at the circular opening (Image of the actual sensor on the top right of the figure).

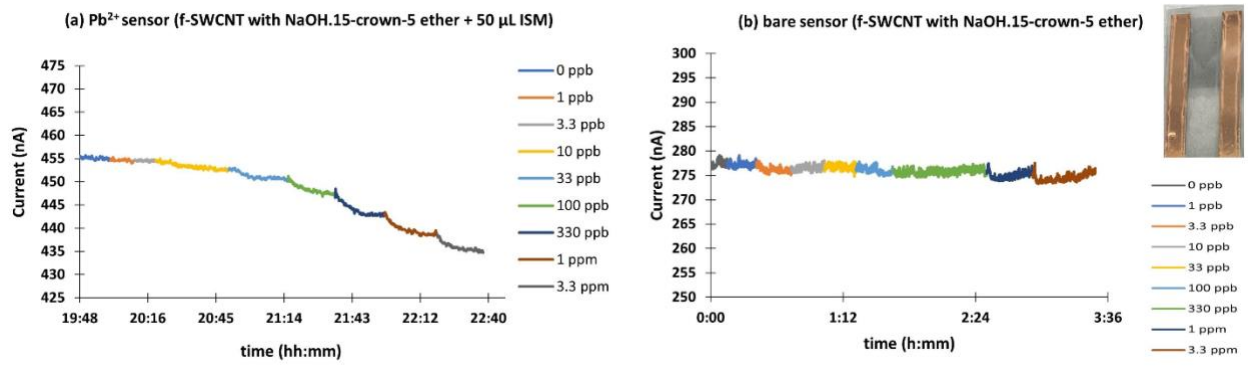

Fig. S2 Response comparison of a Pb^{2+} sensor and a bare sensor to lead ions in different concentrations (from 1 ppb to 3.3 ppm). (a) Resonse of a Pb^{2+} sensor made of f-SWCNT (with NaOH.15-crown-5 ether) as a resistive film coated with ISM (Drop-casted 50 µL of ISM solution on the SWCNT film at the circular opening) and (b) a bare sensor made of f-SWCNT (with NaOH.15-crown-5 ether) as a resistive film (Image of the actual sensor on the top right of the figure).

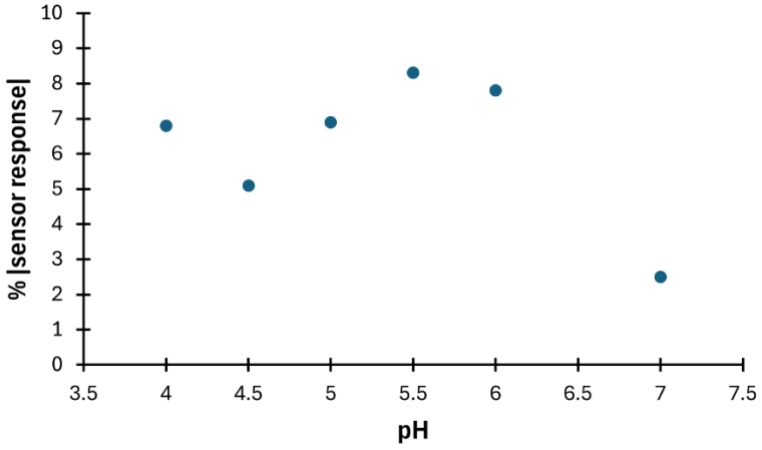

Fig. S3 Pb^{2+} sensor responses in a range of pH 4-7 in 200 mg/L tris-acetate buffer solution.

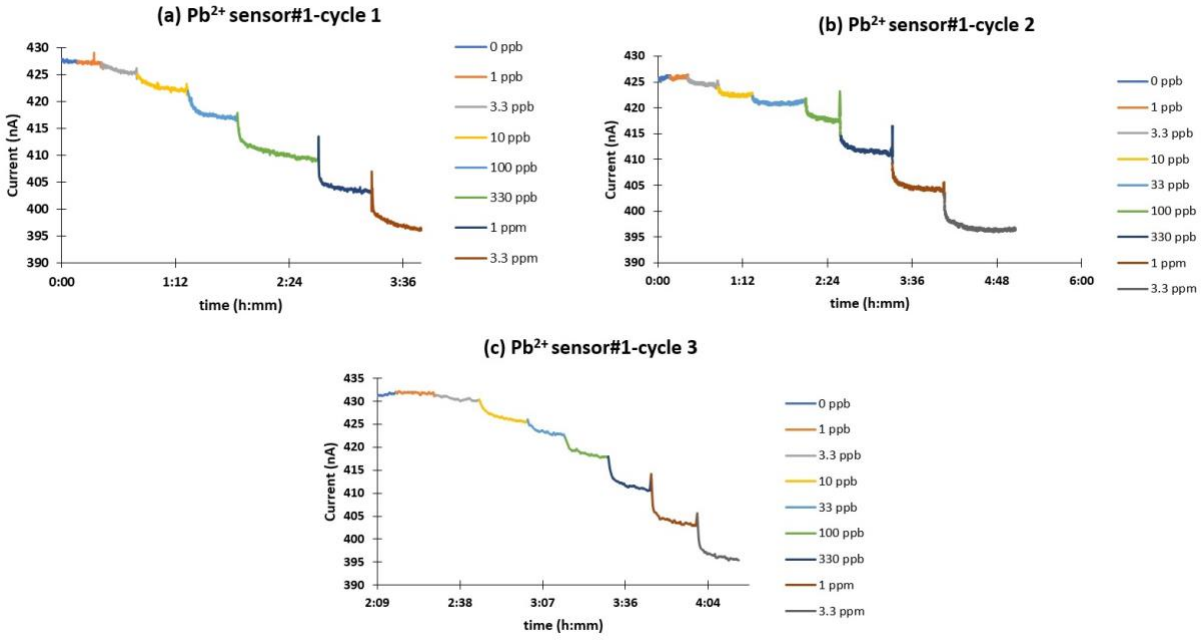

Fig. S4 Sensor response (current changes) of a fabricated Pb2+ sensor to various concentrations between 1 ppb to 3.3 ppm vs. time over three cycles. (a) sensor response in first cycle, (b) sensor response in second cycle, (c) sensor response in third cycle.

Table S1 Performance of tested Pb^{2+} sensors in three batches with different resistance ranges of CNT films

Sensor	***Resistance of CNT film (kΩ)***	***% Sensor response***	***Lowest detectable concentration (ppb)***	***Response time at first detectable concentration (s)***
Batch No. 1				
Sensor#1	9.2	7.6	3.3	8.6
Sensor#2	9.6	7.5	3.3	8.1
Sensor#3	8.9	7.8	3.3	7.9
Batch No. 2				
Sensor#9	5.5	6.8	10	10.2
Sensor#10	6.1	7.2	10	11.5
Sensor#11	7.8	7.7	3.3	10.9
Batch No. 3				
Sensor#13	12.3	4.3	10	7.5
Sensor#14	12.8	3.8	33	7.2
Sensor#15	13.2	2.9	33	7.8

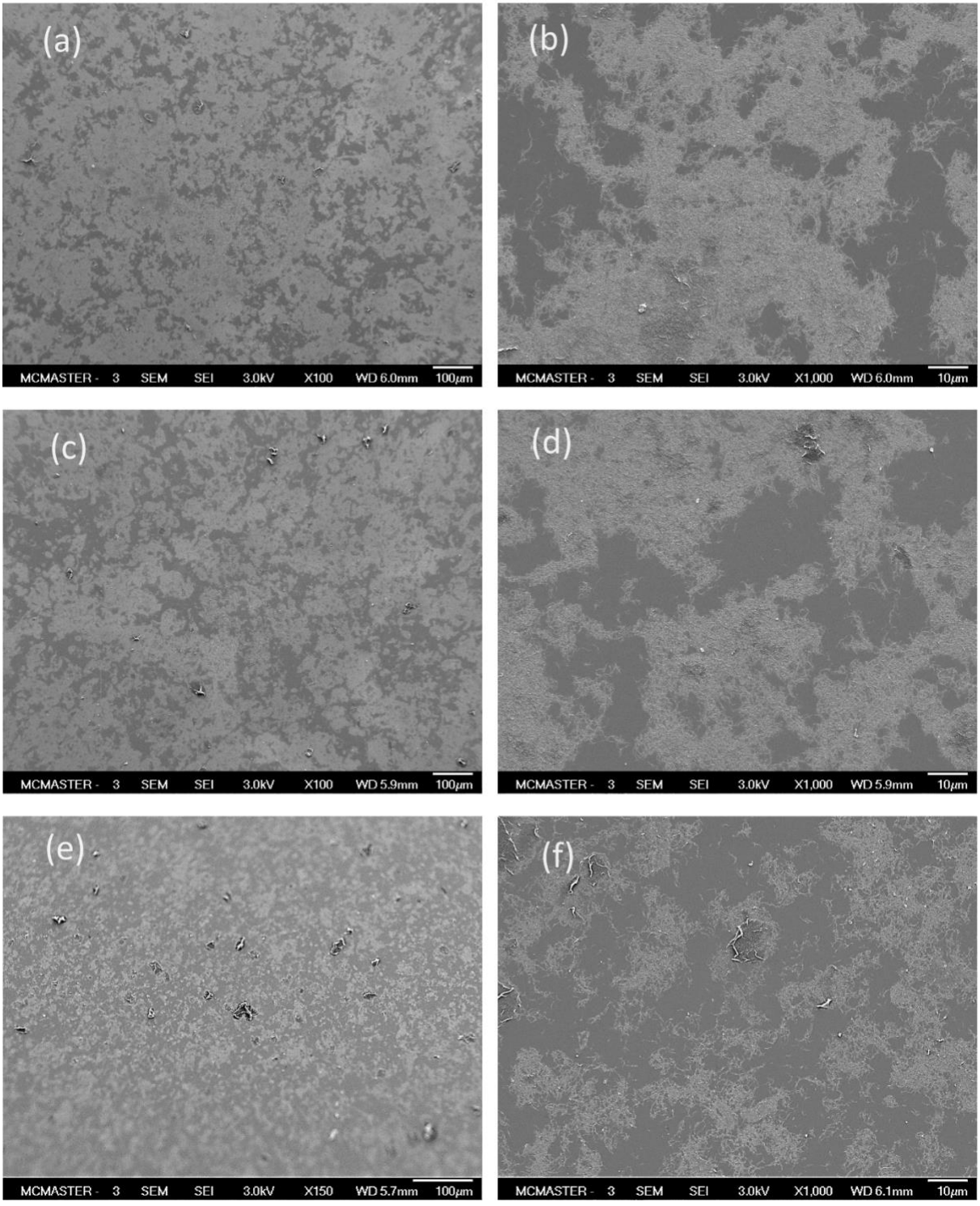

Fig. S5 SEM images of air-brushed CNT films of three different batches in two bar scales of 100 µm and 10 µm. (a & b) SEM images of a representative CNT film of batch No. 1 (resistance 9.2 kΩ), (c & d) batch No. 2 (resistance 5.5 kΩ), (e & f) batch No. 3 (resistance 12.3 kΩ).

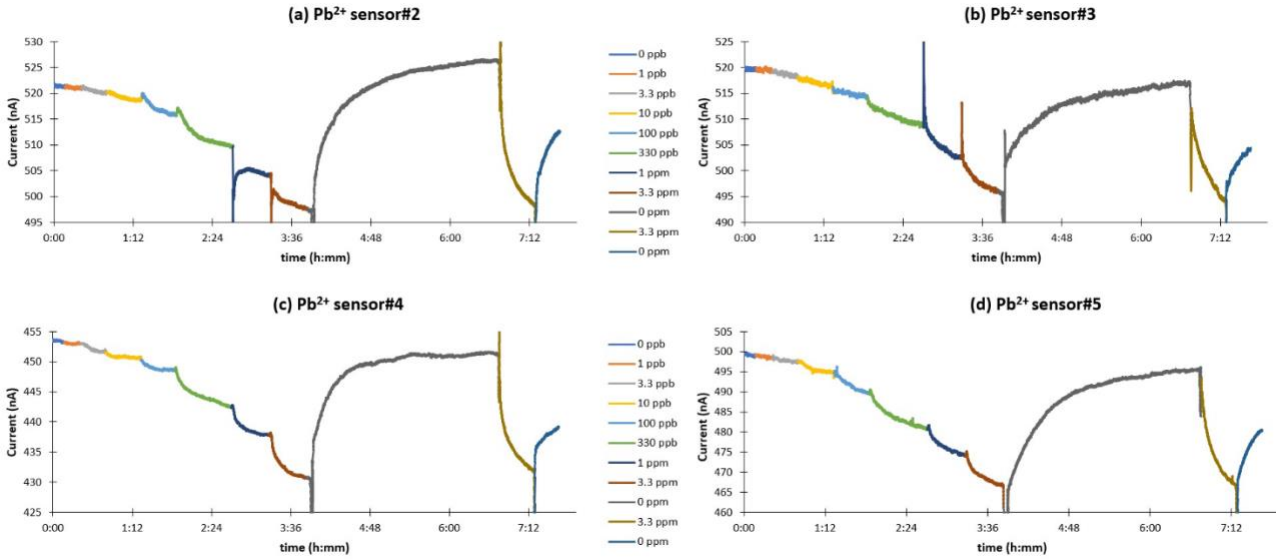

Fig. S6 Responses of several fabricated Pb^{2+} sensors and their recovery over time in a Pb^{2+} concentration range of 1 ppb to 3.3 ppm. (a) performance of Pb^{2+} sensor#2, (b) Pb^{2+} sensor#3, (c) Pb^{2+} sensor#4, and (d) Pb^{2+} sensor#5.

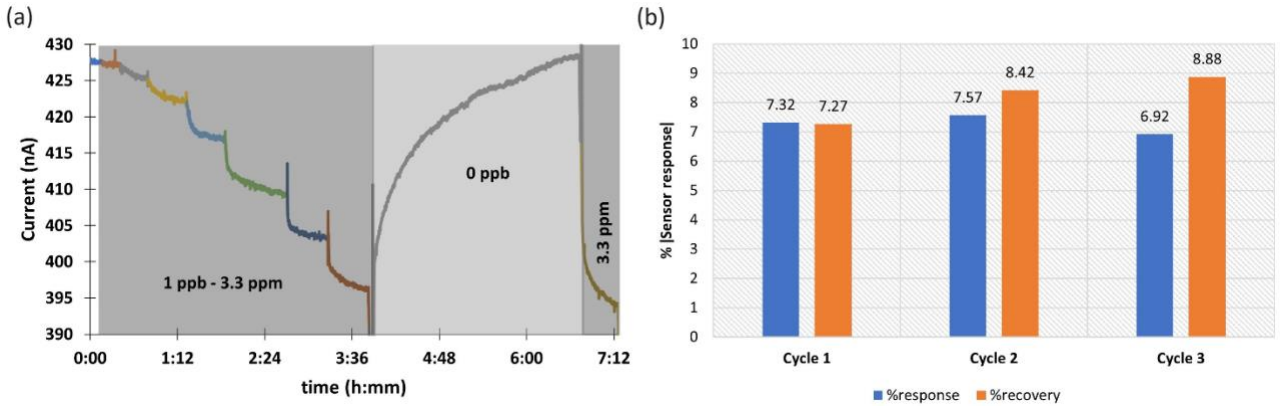

Fig. S7 (a) Lead sensor's response and recovery between 0 ppb and 3300 ppb of Pb^{2+} ions, (b) absolute values of response and recovery percentages of a fabricated lead sensor between 0 ppb and 3300 ppb of Pb^{2+} ions over three cycles

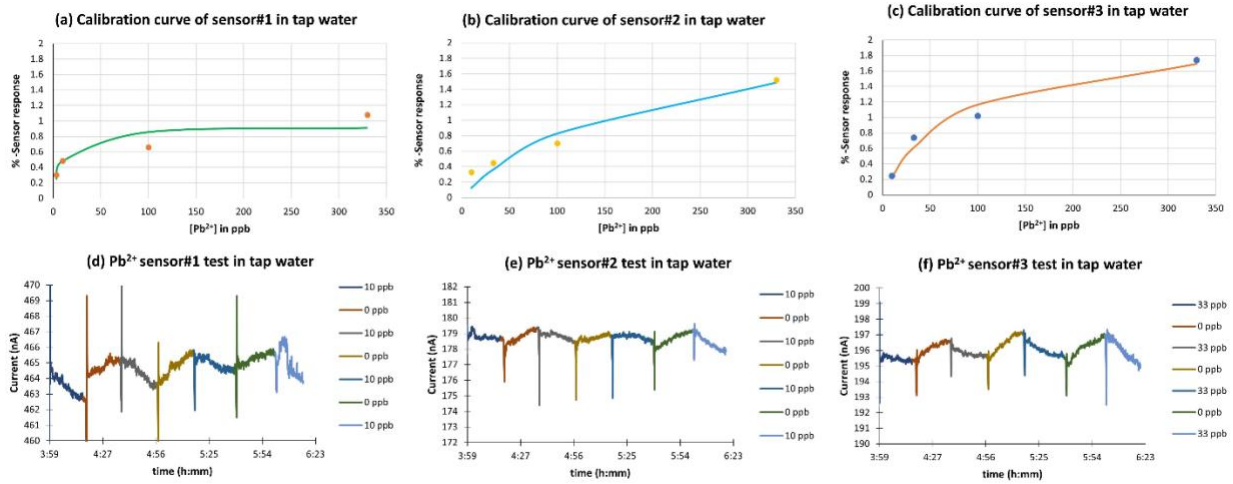

Fig. S8 Calibration curves of Pb^{2+} sensors prepared for real sample test and the response of the sensor to 10 ppb and 30 ppb of Pb^{2+} ion. (a) Calibration curve of sensor#1, (b) sensor#2 and (c) sensor#3 in tap water in a range of 10 ppb to 330 ppb of Pb^{2+} ions, (d) response of the sensor#1 to 10 ppb of Pb^{2+}, (e) response of the sensor#2 to 10 ppb of Pb^{2+}, and (f) response of the sensor#3 to 33 ppb of Pb^{2+} over three cycles (n=3) in tap water.

Table S2 Hall measurement data of the four-probe device on Si/SiO_2 substrate with sputter coated Au contacts after different fabrication steps, exposure to and removal of Pb^{2+} ions.

Sample	*Sheet resistivity (kΩ/sq)*	*Sheet Hall resistance coef. (m^2/C)*	*Hall mobility ($cm^2/V.s$)*	*Sheet concentration (Carrier density) (cm^{-2})*
Pristine SWCNT	8.304	2.46	70.7	2.5×10^{14}
f-SWCNT	21.5	-43.2	20.1	-1.4×10^{13}
f-SWCNT coated with ISM	24.04	579	241	1.078×10^{12}
Exposed to 3 ppm of Pb^{2+} for 24 hours	13.76	-14	10.2	-4.461×10^{13}
Washing off Pb^{2+} ions in DI water for 5 hours	9.806	16.9	211	3.69×10^{13}

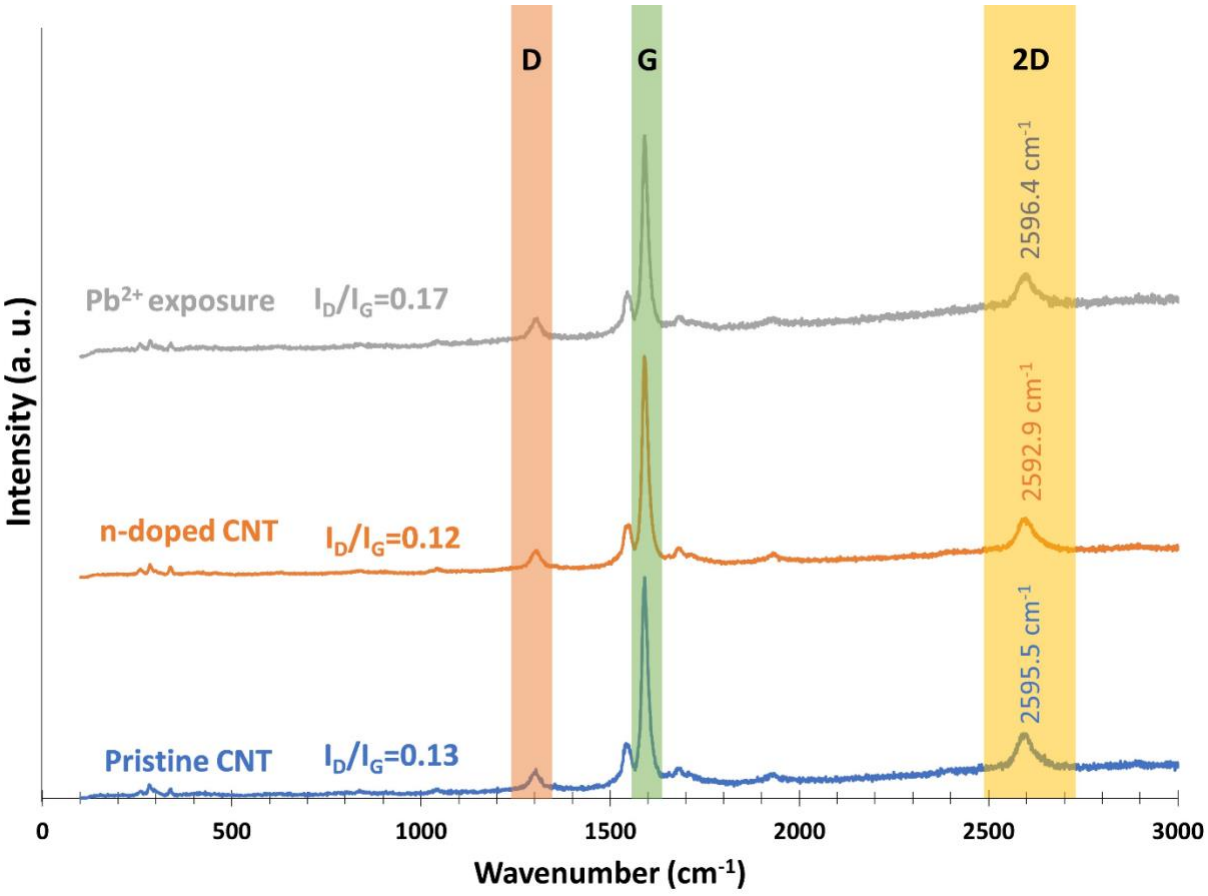

Fig. S9 Raman spectra of pristine CNT, n-doped CNT and n-doped CNT exposed to 3 ppm of Pb^{2+} ions for 5 hours.