

Supplementary Information

# Machine Learning-Based Multi-Level Fusion Framework for a Hybrid Voltammetric and Impedimetric Metal Ions Electronic Tongue

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**Citation:** Lu, T.; Al-Hamry, A.; Hao, J.; Liu, Y.; Qu, Y.; Kanoun, O. Machine Learning-Based Multi-Level Fusion Framework for a Hybrid Voltammetric and Impedimetric Metal Ions Electronic Tongue. *Chemosensors* **2022**, *10*, 474. <https://doi.org/10.3390/chemosensors10110474>

Academic Editors: Hailong Wu and Tong Wang

Received: 13 October 2022

Accepted: 10 November 2022

Published: 12 November 2022

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**Table S1.** The preparation details of the sensors in voltammetric sensor array (VSA).

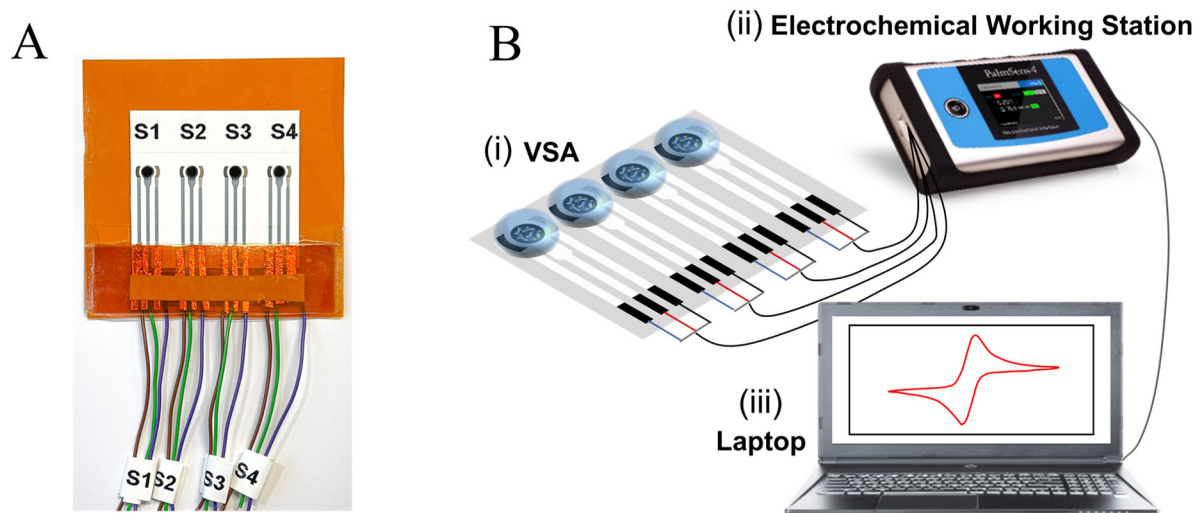
|                   | Sensor 1      | Sensor 2      | Sensor 3      | Sensor 4      |
|-------------------|---------------|---------------|---------------|---------------|
| <b>FePc</b>       | 1.0 wt%       | 1.0 wt%       | N/A           | N/A           |
| <b>CuPc</b>       | N/A           | N/A           | 1.0 wt%       | 1.0 wt%       |
| <b>MWCNT-COOH</b> | 0.1 wt%       | 0.1 wt%       | 0.1 wt%       | 0.1 wt%       |
| <b>AgNPs</b>      | EC-deposition | N/A           | EC-deposition | N/A           |
| <b>AuNPs</b>      | N/A           | EC-deposition | N/A           | EC-deposition |

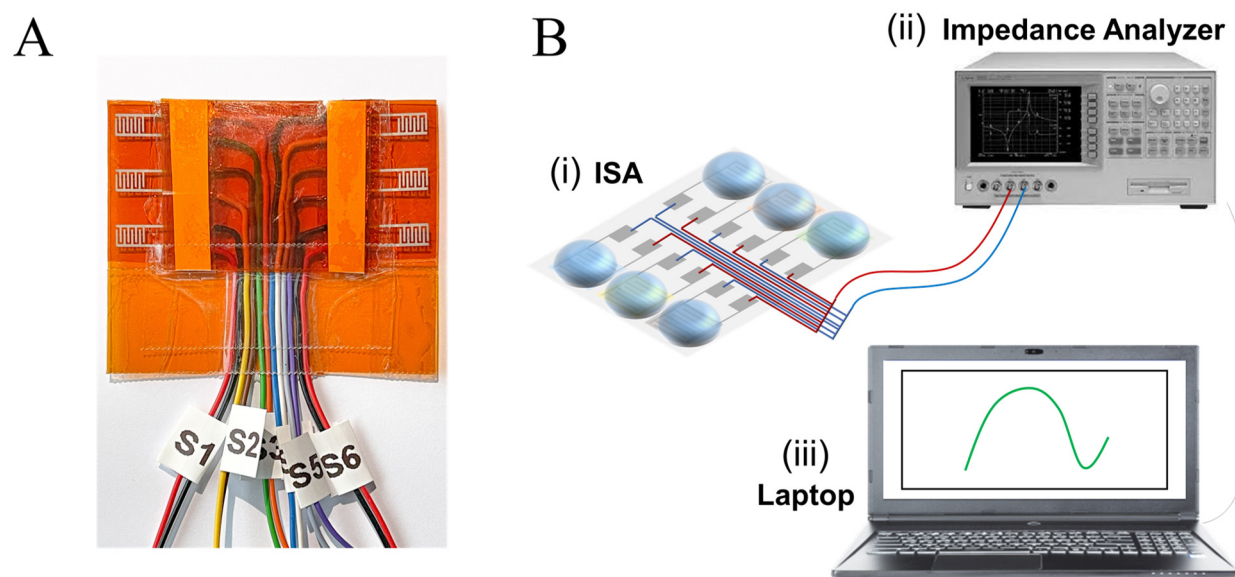
FePc: Iron phthalocyanine; CuPc: Copper phthalocyanine; MWCNT-COOH: COOH-functionalized multi-walled carbon nanotubes; AgNPs: Silver nanoparticles; AuNPs: Gold nanoparticles.

**Table S2.** The preparation details of the sensors in impedimetric sensor array (ISA).

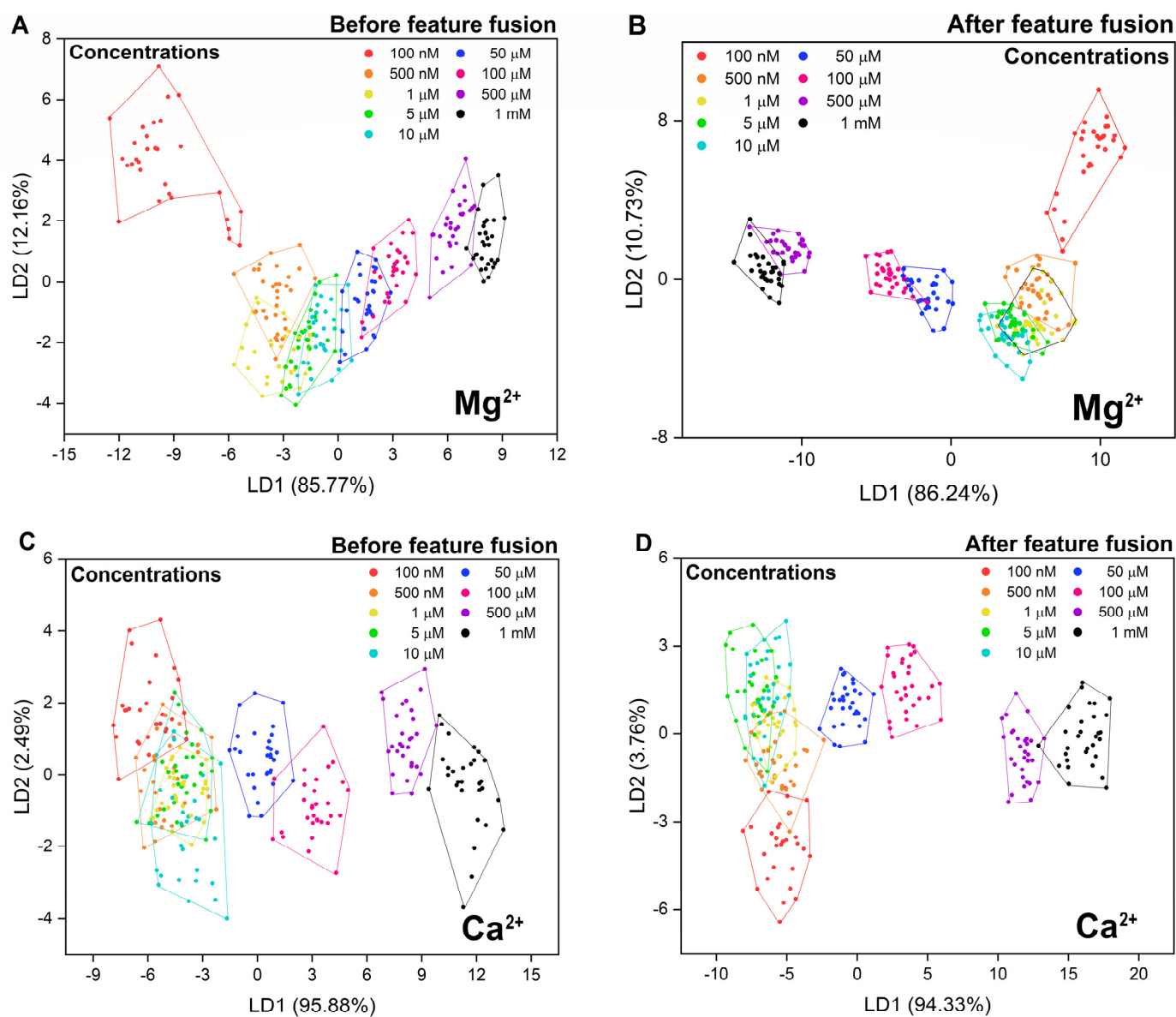
|                   | Sensor 1 | Sensor 2 | Sensor 3 | Sensor 4 | Sensor 5 | Sensor 6 |
|-------------------|----------|----------|----------|----------|----------|----------|
| <b>PEDOT:PSS</b>  | 1.6 wt%  | 1.6 wt%  | 1.6 wt%  | 1.6 wt%  | 1.6 wt%  | 1.6 wt%  |
| <b>MWCNT-COOH</b> | N/A      | 0.05 wt% | N/A      | N/A      | 0.05 wt% | 0.05 wt% |
| <b>FePc</b>       | N/A      | N/A      | 0.2 wt%  | N/A      | 0.2 wt%  | N/A      |
| <b>CuPc</b>       | N/A      | N/A      | N/A      | 0.4 wt%  | N/A      | 0.4 wt%  |

PEDOT:PSS: Poly(3,4-ethylenedioxythiophene) - poly(styrene sulfonic acid).

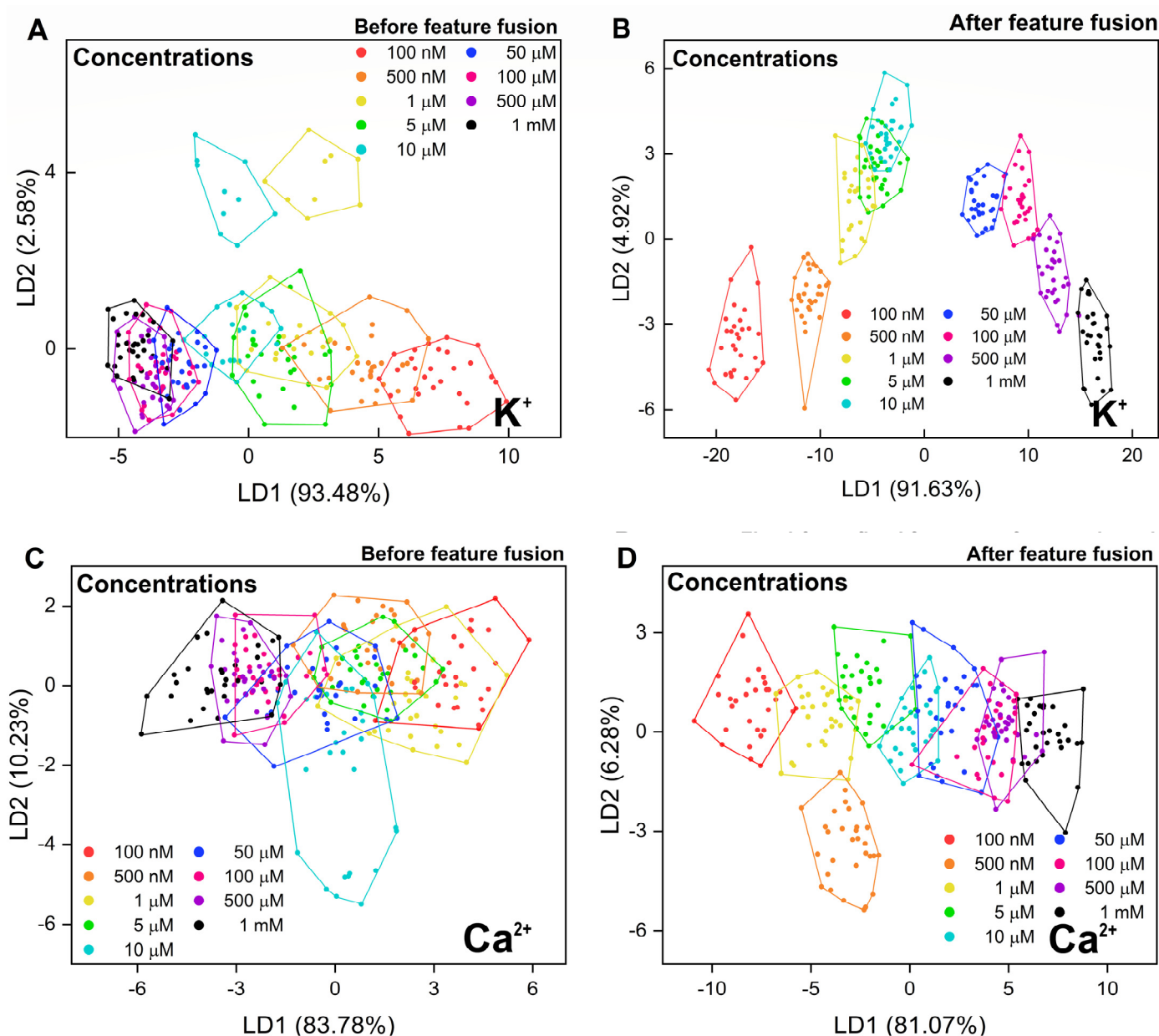
**Figure S1.** Setup of the voltammetric measurement: (A) the prepared VSA consists of 4 sensors and (B) schematic diagram of voltammetric measurement.



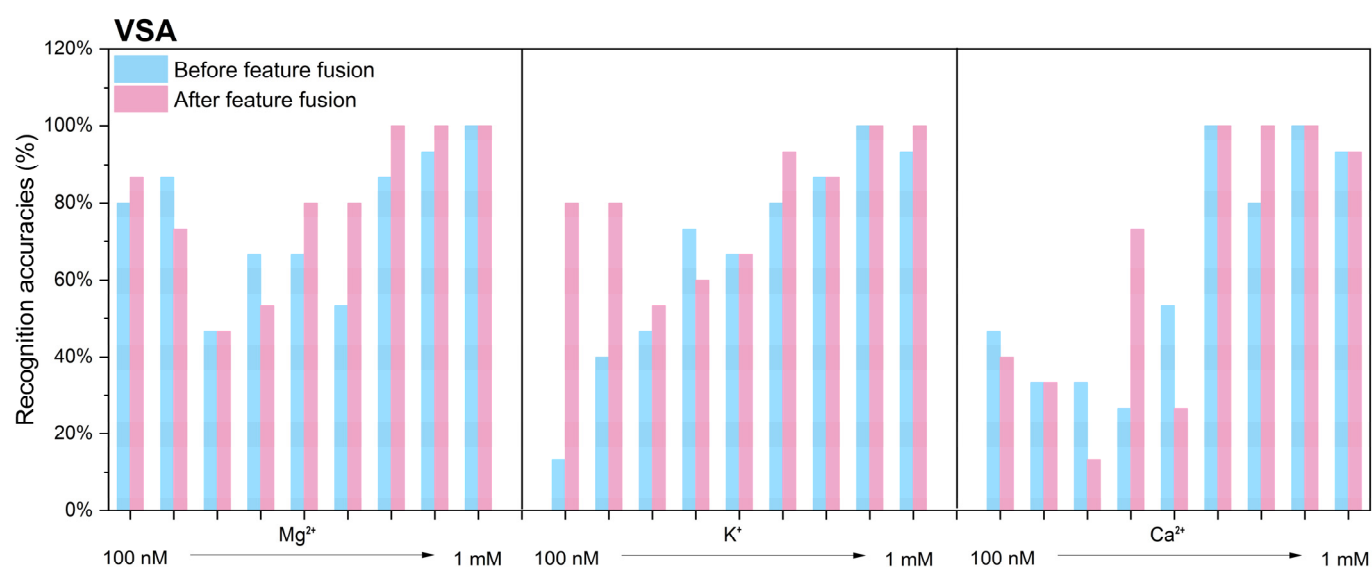
**Figure S2.** Setup of the impedimetric measurement: (A) the prepared ISA consists of 6 sensors and (B) schematic diagram of impedimetric measurement.



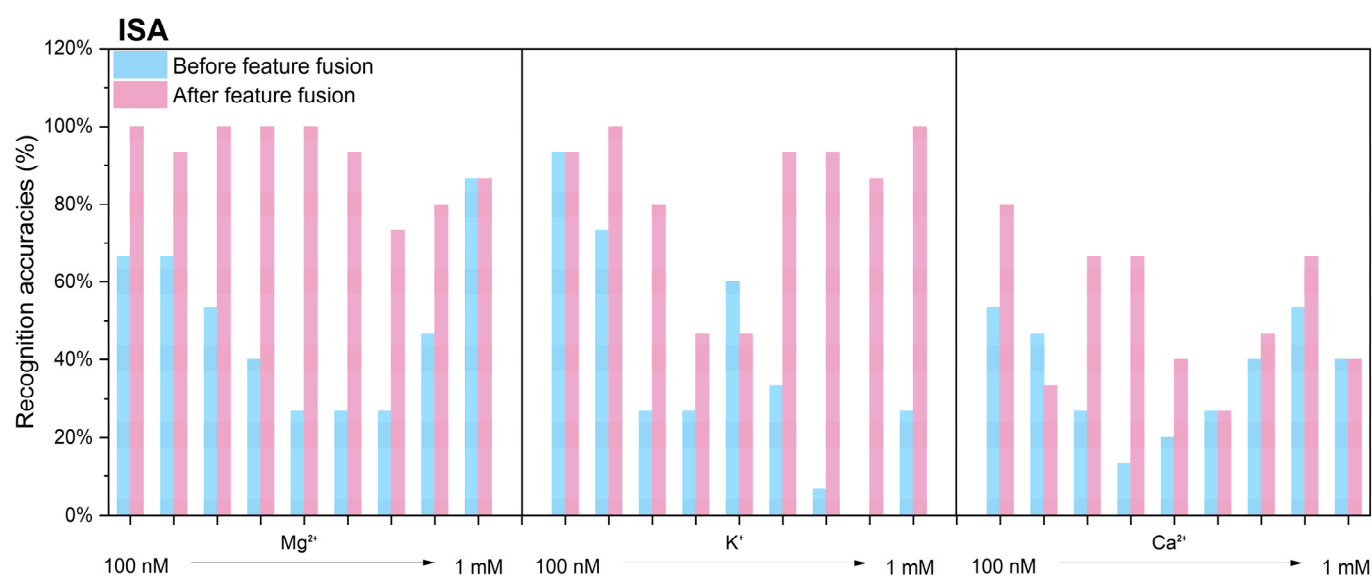
**Figure S3.** LDA score plots (2D) of the VSA for the concentrations discrimination of (A,B)  $Mg^{2+}$  and (C,D)  $Ca^{2+}$ , respectively, based on (A,C) current features and (B,D) both current and potential features (after feature fusion).



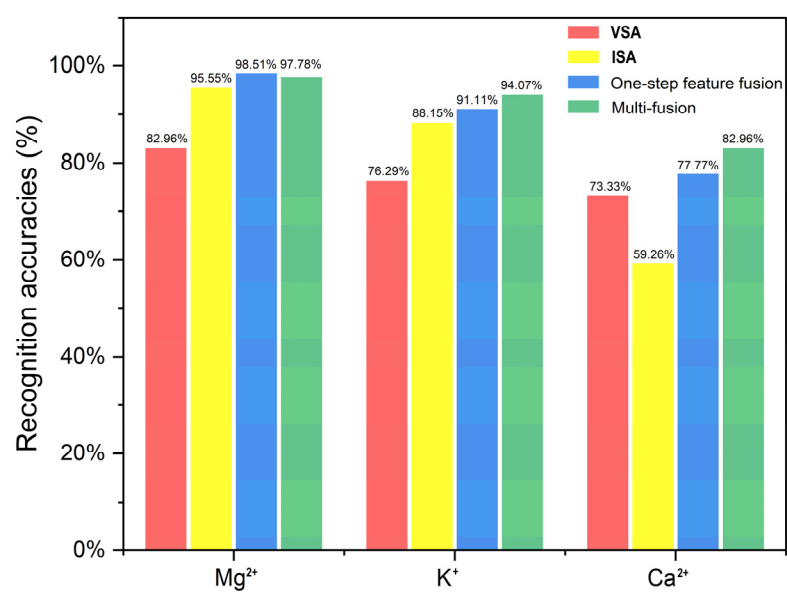
**Figure S4.** LDA score plots (2D) of the ISA for the concentrations discrimination of (A,B)  $K^+$  and (C,D)  $Ca^{2+}$ , respectively, based on (A,C) characteristic point features and (B,D) both characteristic point and fixed frequency features (after feature fusion).



**Figure S5.** Quantitative recognition accuracies (LDA, 3D) of VSA based on current features (before feature fusion) and both current and potential feature (after feature fusion).



**Figure S6.** Quantitative recognition accuracies (LDA, 3D) of ISA based on characteristic point features (before feature fusion) and both characteristic point and fixed frequency point features (after feature fusion).



**Figure S7.** Average recognition accuracies of VSA, ISA, one-step feature fusion, and multi-fusion toward  $Mg^{2+}$ ,  $K^{+}$ , and  $Ca^{2+}$ .