Supporting information

Self-reduction gold@platinum bimetallic nanoparticles on $Ti_3C_2T_x$ MXene nanoribbons coupled with hydrogel and smartphone for colorimetric detection of silver ions

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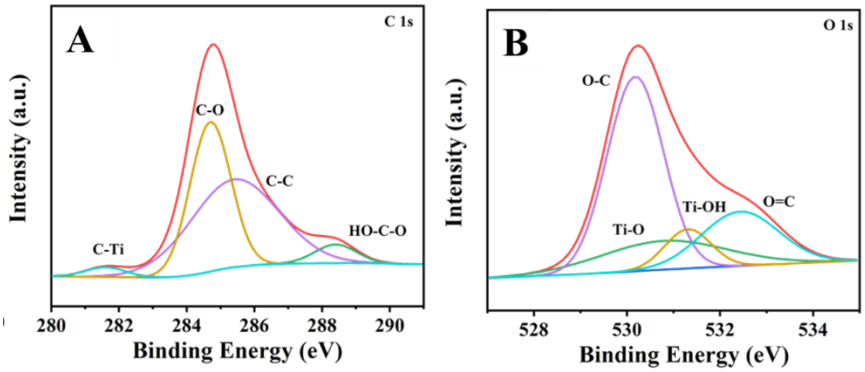

Figure S1. High-resolution spectra of C 1s (A) and O 1s (B).

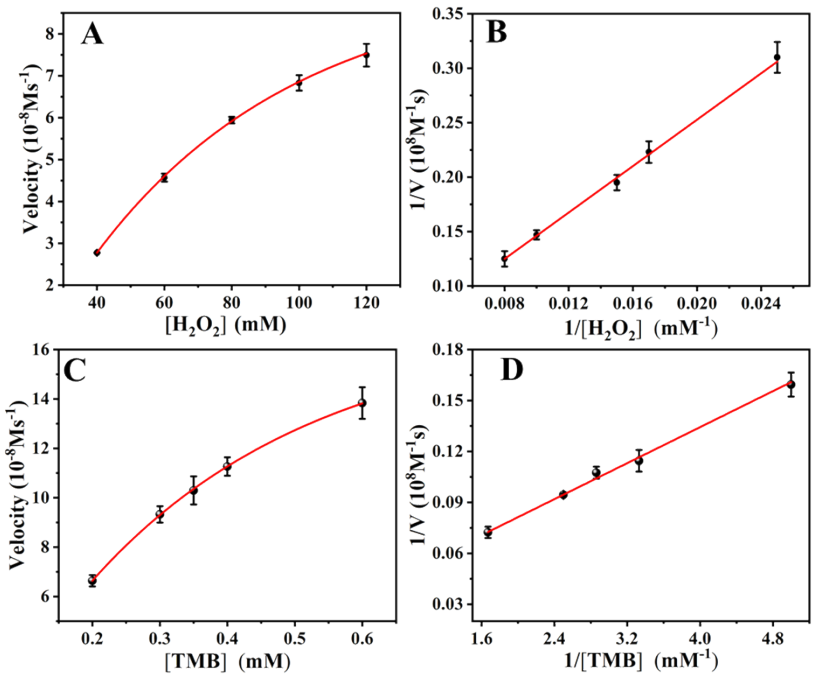

Figure S2. Steady-state kinetic analysis of Au@Pt-$Ti_3C_2T_x$NR with H_2O_2 (A) and TMB (C) as substrates, respectively. The corresponding Lineweaver-Burk plots of (B) and (D).

Table S1. Comparison of the kinetic parameters of HRP and other nanozymes.

Materials	Substrate	Km (mM)	Ref
HRP	TMB	0.43	1
	H_2O_2	3.7	
g-C3N4/PdNPs/ Fe_3O_4NPs	TMB	1.05	2
	H_2O_2	7.71	
FeN4-SA	TMB	0.78	3
	H_2O_2	43.3	
Fe-MOF	TMB	2.60	4
	H_2O_2	1.30	
Au@Pt-$Ti_3C_2T_x$NR	TMB	0.41	This work
	H_2O_2	0.31	

In order to further study the peroxide-like activity of Au@Pt-$Ti_3C_2T_x$NR, TMB and H_2O_2 were used as substrates to study and analyze the steady-state kinetics, and the obtained results were compared with those by using horse radish peroxidase (HRP) (Figure S2 and Table S1). Under the optimal reaction conditions, Michaelis-Menten curve was drawn by changing the concentration of TMB and H_2O_2, and the corresponding Lineweaver-Burk double reciprocal curve was obtained. The Michaelis constant (K_m) and the maximum reaction rate (K_{max}) were obtained by fitting calculation. Among them, K_m is considered to be an indicator of the affinity between enzyme and substrate, and the smaller the value, the stronger the affinity between enzyme and substrate, and vice versa. Table S1 shows that Au@Pt-Ti3C2TxNR has superior catalytic activity since its Km value on substrate TMB or H2O2 is significantly lower than that of HRP and other nanozymes.

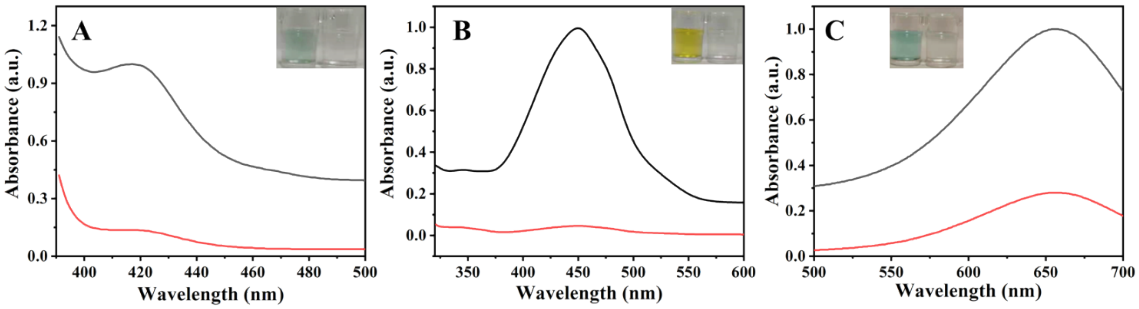

Figure S3. Peroxidase-like activity of Au@Pt-$Ti_3C_2T_x$NR nanozymes. Typical absorption spectra of ABTS (A); OPD (B); TMB (C) oxidation catalyzed by Au@Pt-$Ti_3C_2T_x$NR nanozymes and controls in the presence of H_2O_2 in the acetate buffer.

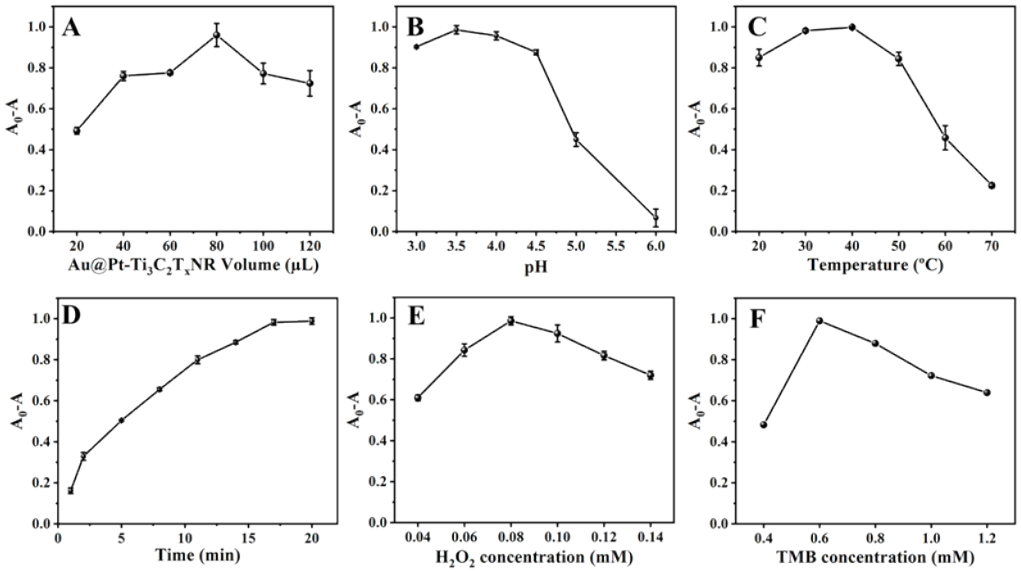

Figure S4. Optimization of the Au@Pt-$Ti_3C_2T_x$NR catalytic activity relative to Au@Pt-$Ti_3C_2T_x$NR volume (A); pH value (B); temperature (C); time (D); H_2O_2 concentration (E) and TMB concentration (F).

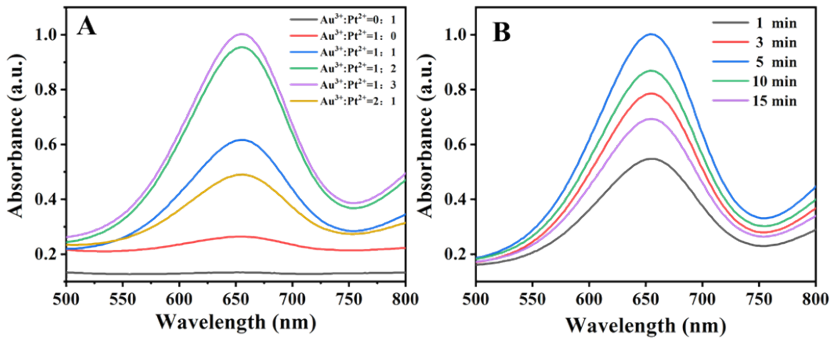

Figure S5. (A) The optimization of Au and Pt concentration ratios; (B) The optimization of the reduction reaction time for the preparation of Au@Pt-$Ti_3C_2T_x$NR.

As for preparing the Au@Pt-$Ti_3C_2T_x$NR nanozyme, Au@Pt NPs were introduced on the surface of $Ti_3C_2T_x$NR via a self-reduction approach without the use of any extra reducing agents based on the superior reductibility of $Ti_3C_2T_x$NR. In order to obtain a better catalytic activity, the ratio of Au^{3+}-Pt^{2+} and self-reduction time were optimized. As demonstrated in Figure S5A, when Au: Pt = 1:2, the Au@Pt-$Ti_3C_2T_x$NR exhibits exceptionals catalytic activity. Compared with the pure Pt^{2+}solution, the introduction of Au^{3+} in the precursor mixture can efficiently promote the growth of Pt NPs on $Ti_3C_2T_x$NR, probably due to the lower reduction potential of Au^{3+} than that of Pt^{2+}.[5] In light of the catalytic activity of Au@Pt-$Ti_3C_2T_x$NR toward H_2O_2/TMB system, we chose Au@Pt-$Ti_3C_2T_x$NR (Au: Pt = 1:2) to continue the following experiments. Figure S5B that the Au@Pt-$Ti_3C_2T_x$NR nanozyme showed the best catalytic activity when the reducing time was 5 min. The catalytic activity displayed a downward trend rather than steady increase as the reducing time was extended during the reducing reaction. In light of this trend, we speculate that it is caused by the formation of larger nanoparticles in conjunction with increasing reducing time,[6] which may have a major effect on the catalytic activity of Au@Pt-$Ti_3C_2T_x$NR. Based on the above experimental results, we chose concentration ratio of 1:2 for Au^{3+}-Pt^{2+} and the reduction time of 5 minutes.

References

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