Supporting Information

Matrix Colorimetry for High-resolution Visual Detection of Free Cyanide with Au@Au-Ag yolk-shell –Nanoparticles

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S.1 Preparation and characterization of different sizes of Au@ Au-Ag yolk-shell NPs

Three kinds of Au@ Au-Ag NPs, which are NP_1 (13-nm@3-nm@-3-nm), NP_2 (13-nm@6-nm@-2-nm), and NP_3 (13-nm@3-nm@-4-nm), were prepared.

For the synthesis of NP_1 with the size of 13-nm@3-nm@-3-nm, 13-nm Au cores were first prepared. Typically, 5 mL of $HAuCl_4$ (0.02428 M) were added into 100 mL of water, which were refluxed under vigorous stirring. Then, 10 mL of freshly prepared sodium citrate (0.0390 M) were quickly added into the above solution. The mixture was reacted for 15 min, and a color change from pale yellow to wine-red was observed during this process. 1.3 mL of the above Au colloid were added to 10.612 mL of deionized water containing 0.5 g PVP. Then, AA (0.25 M, 364 μL) and $AgNO_3$ (0.01 M, 364 μL) were separately dropped into the solution under stirring. The mixture was further stirred vigorously at room temperature for 10 min, and the color of the solution turned from red to orange, indicating the formation of Au@Ag NPs. Then, $NH_2OH{\cdot}HCl$ (0.3263 M, 180 μL) and $HAuCl_4$ (0.025 M, 180 μL) were dropped into the mixture. Stirring was continued for another 10 min until the color of solution became blue, demonstrating the formation of Au@-Au-Ag NPs.

Another two sizes of Au@-Au-Ag NPs with different shell-to-core ratios were synthesized by adjusting the amount of AA, $AgNO_3$, $NH_2OH{\cdot}HCl$ and $HAuCl_4$. The volume of reagents for different sizes of Au@Au-Ag NPs were listed in Table S1 below. The size characterization of NP_1, NP_2 and NP_3 was shown in Figure S1.

Table S1. The volume of AA, $AgNO_3$, $NH_2OH{\cdot}HCl$, and $HAuCl_4$ for three kinds of Au@Au-Ag NPs with different shell-to-core ratios.

Size	AA (μL)	$AgNO_3$ (μL)	$NH_2OH{\cdot}HCl$ (μL)	$HAuCl_4$ (μL)
13-nm@3-nm@-3-nm	364	364	180	180
13-nm@6-nm@-2-nm	468	468	180	180
13-nm@3-nm@-4-nm	364	364	300	300

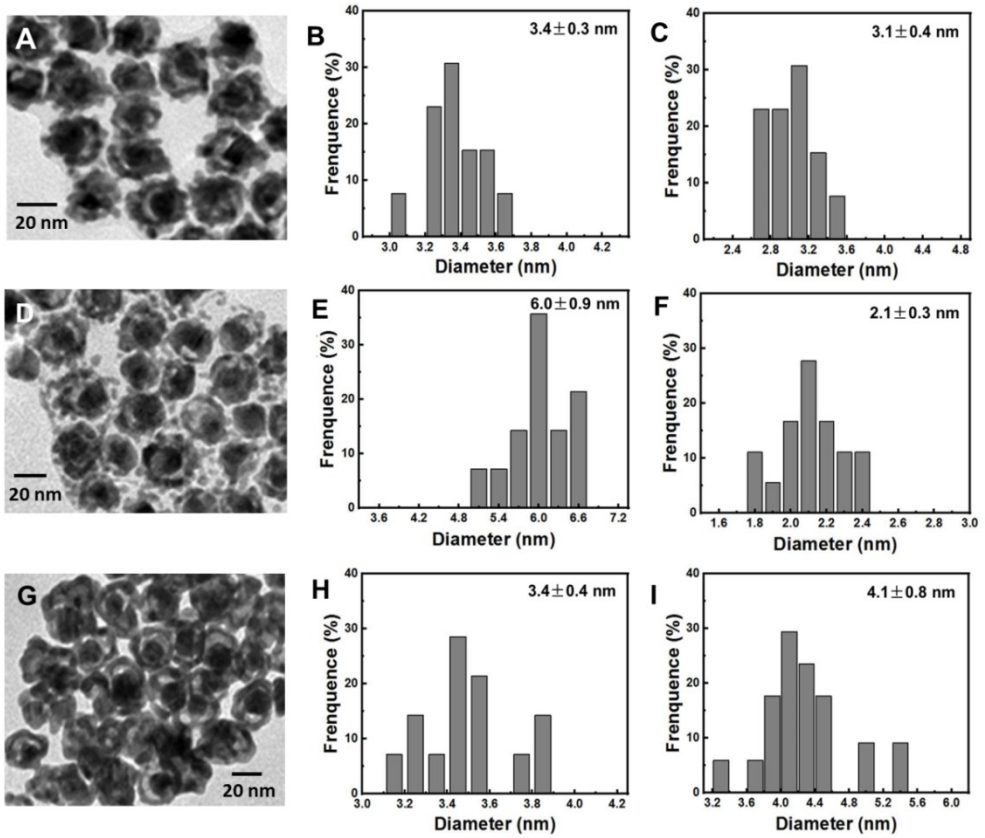

Figure S1. (A, D, G) TEM image of NP_1, NP_2, and NP_3. (B, E, H) Size distribution histograms of void for NP_1, NP_2, and NP_3. (C, F, I) Size distribution histograms of Au-Ag shells for NP_1, NP_2, and NP_3.

S.2 Characterization for the growth process of Au@ Au-Ag yolk-shell NPs

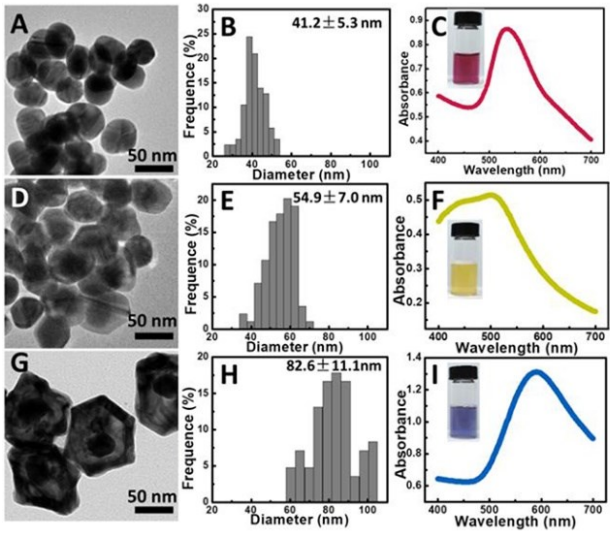

Figure S2. (A-C) TEM image, size distribution histogram, and UV-vis spectrum of Au NPs. (D-F) TEM image, size distribution histogram, and UV-vis spectrum of Au@Ag NPs. (G-I) TEM image,

size distribution histogram, and UV-vis spectrum of Au@Au-Ag yolk-shell NPs~~Au@Ag@Au NPs~~. The insets in the UV-vis spectra are corresponding photographs of the NP colloids.

S.3 ESI-TOF-MS analysis of the products of Au@Au-Ag NPs reacted with CN^-

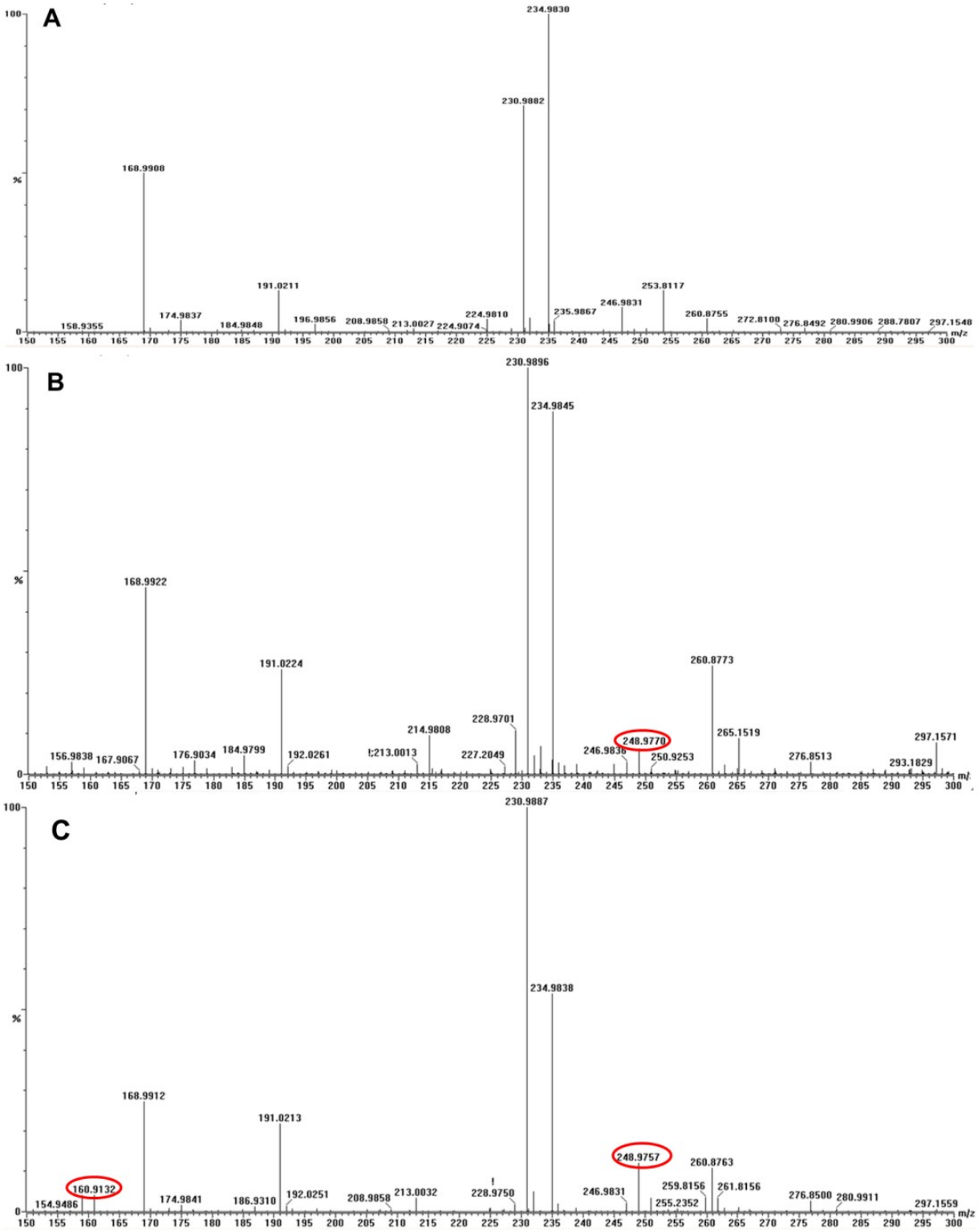

Figure S3. ESI-TOF-MS spectrum of the products of Au@Au-Ag NPs reacted with

CN^- (A) 0 μM, (B) 16 μM, (C) 48 μM.

S.4 UV-vis spectrum analysis of the Au@Au-Ag NPs with addition of various amounts of CN^-

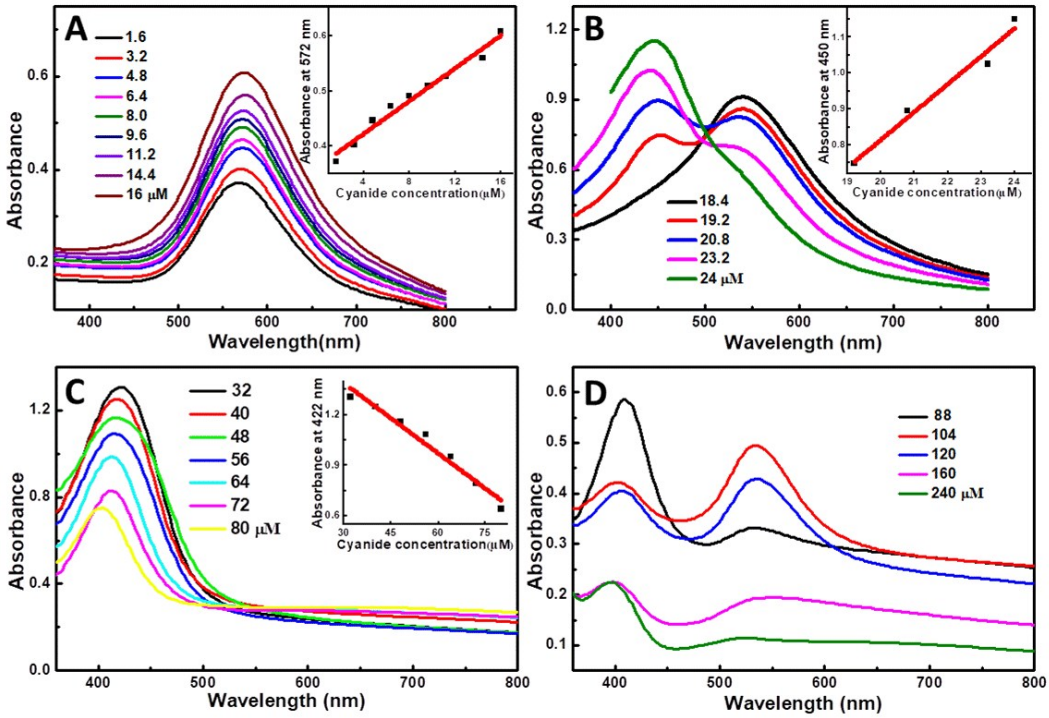

Figure S4. UV-vis spectra of the Au@Au-Ag –NP solutions with addition of various amounts of CN^-. (A)1.6-16 μM CN^-. (B) 18.4-24 μM CN^-. (C) 32-80 μM CN^-. (D) 88-240 μM CN^-. The insets in the UV-vis spectra are corresponding linear plots.

S.5 Pictures of three kinds of Au@Au-Ag –NP solutions after treated with different concentrations of CN^-

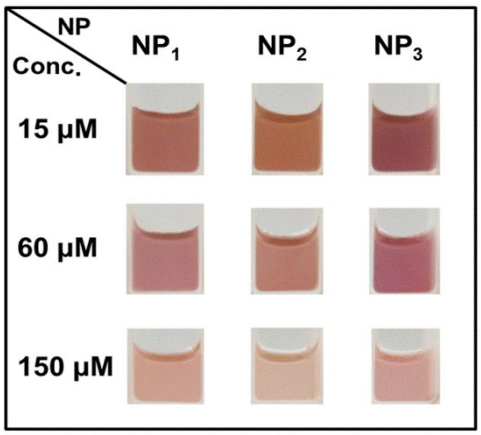

Figure S5. Pictures of three kinds of Au@Au-Ag –NP solutions after treated with CN^- of 15 μM， 60 μM and 150 μM.

S.6 Analytical results for the detection of CN^- in pond water samples

Table S2. Analytical results for the detection of CN^- in pond water samples

No.of the samples	Detected (μM)	Added (μM)	Found (μM)
1		4	4
2	Not detected	60	60
3		150	150