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1	Supporting Information
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4	Fabrication of Ag-Cu ₂ O/PANI nanocomposites for visible-light
5	photocatalysis triggering super antibacterial activity
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21 Fig. S1. The elemental distribution scan image and EDS spectrum of the Ag-Cu₂O/PANI (a). Line

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22 scan image of the Ag-Cu₂O/PANI (b).

As shown in Fig. S1, the synthesized materials were subjected to surface scanning and line scanning by X-ray scattering spectroscopy to characterize the composition, content and distribution of the elements. According to the EDS test results in Fig. S1a, it was clear that the Ag-Cu₂O/PANI composite contained only C, N, O, Cu, and Ag elements, indicating that the composites were of higher purity. Because PANI acted as a carrier, the carbon content was the highest about 75%. The content of Cu in the composite material was relatively low, and its atomic content was about 8.77%, which was in line with the environmental requirements of low copper. The content of silver was at least about 0.86%. From the first elemental distribution map, the distribution of Cu_2O and Ag nanoparticles on the surface of PANI can be seen very intuitively.

Line scanning image of Ag-Cu₂O/PANI (Fig. S1b) can be used to visually and clearly 33 characterize the chemical composition of samples with different elements at different locations. 34 Draw a line from where the white spheres gather to a position where there is no white sphere, 35 and perform component analysis along the line drawn. The changes in the contents of C, N, O, 36 Cu, and Ag were shown in Fig. S1b. The increase in C and N content indicated that PANI was 37 gradually increasing. The contents of O, Cu, and Ag were sharply reduced at a certain position, 38 39 indicating that the white sphere was Ag-Cu₂O, which indicated that Ag-Cu₂O was supported on the surface of PANI. 40

41 Table S1. Different valence copper content in Cu₂O/PANI and Ag-Cu₂O/PANI after
42 immersing 0 day and 30 days.

Valence	D0 Cu ₂ O/PANI	D30 Cu ₂ O/PANI	$\Delta Cu_2O/PANI$	D0 Ag-Cu ₂ O/PANI	D30 Ag-Cu ₂ O/PANI	Δ Ag-Cu ₂ O/PANI
Cu^+	100%	4.7%	-95.3%	100%	84.2%	-15.8%
Cu^{2+}	0%	95.3%	+95.3%	0%	15.8%	+15.8%

Table S1 showed the changes in the content of cuprous copper in different valence states of Cu₂O/PANI and Ag-Cu₂O/PANI after immersion for 0 days and 30 days. It can be seen from Table 1 that most of Cu₂O was oxidized to CuO after immersion for 30 days, the percentage of divalent copper was increased by 86.5%, and the content of Ag-Cu₂O/PANI was only increased by 10.4%. Therefore, Ag-Cu₂O/PANI can maintain its original chemical properties very well.



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49 Fig. S2. Digital pictures of dispersion of Cu₂O, PANI, Cu₂O/PANI and Ag-Cu₂O/PANI after
50 storage for 0, 1, 3, 7, 14, 30 days.

⁵¹ Cu₂O, PANI, Cu₂O/PANI, and Ag-Cu₂O/PANI were separately added to ultrapure water for ⁵² ultrasonic dispersion, and allowed to stand at 0, 1, 3, 7, 14, and 30 days at room temperature, ⁵³ as shown in Fig. S2. On the 7th day, Cu₂O samples had undergone very serious agglomeration, ⁵⁴ mainly because the specific surface energy of inorganic materials was relatively high, resulting ⁵⁵ in agglomeration easily. The occurrence of agglomeration would reduce the chance of contact ⁵⁶ with bacteria, so it is necessary to improve the dispersibility to improve the sterilization performance. However, the dispersion of Cu₂O/PANI and Ag-Cu₂O/PANI combined with PANI was greatly improved, and there was still no agglomeration on the 14th day until the material began to aggregate on the 30th day. Therefore, PANI can make up for the defects of easy agglomeration of inorganic materials, and it is a good carrier for preparing composite materials.



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63 Fig. S3. Digital photographs of *S. aureus* (the bacteriostatic concentration is 75 μg/mL)
64 bacterial CFU counting treated with blank sample (a₁), PANI (a₂), Cu₂O (a₃), Ag (a₄),

65 Cu₂O/PANI (a₅), and Ag-Cu₂O/PANI (a₆). Digital photographs of *P. aeruginosa* (the
66 bacteriostatic concentration is 50 μg/mL) bacterial CFU counting treated with blank sample
67 (b₁), PANI (b₂), Cu₂O (b₃), Ag (b₄), Cu₂O/PANI (b₅), and Ag-Cu₂O/PANI (b₆).

The inhibitory effect of PANI, Cu₂O, Ag, Cu₂O/PANI, and Ag-Cu₂O/PANI on the Gram-68 positive (S. aureus) was detected by colony counting method. The concentration of fungicide 69 was 75 µg/mL, which was the MIC of Ag-Cu₂O/PANI. As shown in Fig. S3a₁-a₆, the number 70 of colonies of Ag-Cu₂O/PANI was the lowest, followed by Cu₂O/PANI, and the colonies 71 treated by PANI were the most. Similarly, the inhibitory effect of PANI, Cu₂O, Ag, 72 Cu₂O/PANI, and Ag-Cu₂O/PANI on the Gram-negative (P. aeruginosa) was detected by 73 colony counting method. The concentration of fungicide was 50 µg/mL, which was the MIC 74 75 of Ag-Cu₂O/PANI. As shown in Fig. S3b₁-b₆, the test results were similar to those of S. aureus, thereby Ag-Cu₂O/PANI has the best bactericidal effect. Although the PANI alone has no 76 germicidal properties, it can be synergistically sterilized after being compounded with Cu₂O 77 and Ag. The inhibition rates of the five samples against S. aureus and P. aeruginosa are shown 78 in Fig. S3. Finally, we ranked the antibacterial effects of the samples as: Ag-79 Cu₂O/PANI>Cu₂O/PANI>Cu₂O>Ag>PANI. 80

To efficiently find the best experimental conditions, we performed the optical spectra calculations. As for the optical spectra calculations, we adopt DFT calculations, which were conducted by the CASTEP simulation module on the basis of Material Studio software. Here, we only examined the optical-absorption ability of the Ag-Cu₂O heterostructures. We choose the direction of the interface in the heterostructures, which is the Z direction occupied the vacuum layer of the model, as the main research direction of the dielectric constant calculation.

The main optical spectra, such as adsorption coefficient $I(\omega)$, can be obtained from the dynamical 87 dielectric response functions $\varepsilon(\omega)$. 88

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$$\varepsilon(\omega) = \varepsilon_1(\omega) + i\varepsilon_2(\omega)$$

The explicit expressions are given by 90





Fig. S4. Optical absorption spectrum of the interface of Ag-Cu₂O heterostructures 93

As is shown in Fig. S4, heterostructures display its absorptive capacity over a wide range in the 94 visible regions, the highest absorption peak appears near the visible region at approximately 380 nm. 95 A high absorption peak also appears in the visible region at approximately 485 nm. The heterostructure 96 exhibits light absorption over a wide range in the visible region. It should also be noted that the 97 absorptive capacity may increase even further by considering the excitonic effects. So, we chose a T5 98 energy saving lamp purchased by Zhejiang Yankon Group Co., Ltd as our experimental light source to 99 produce visible light. The wavelength of light ranges from 400 to 700 nm. The reaction was controlled 100 for 12 hours under the direct light every day. 101

102 In order to explain the specific charge transfer and propensity of enhanced oxidation of silver, we used the CASTEP software package to calculate the differential charge of the system, and used the 103

Dmol3 software package based on density functional theory (DFT) to carry out the Mülliken charge density population analysis. When calculated using the CASTEP software package, the calculation parameters were the same as the previous settings. When using the Dmol3 software package, we used the LDA-PWC type exchange correlation functional, set the B point of the Brillouin zone to $5\times5\times1$. The OBD algorithm was used for Van der Waals correction. The single atomic energy convergence standard is 1.0×10^{-6} eV, and the crystal model was calculated.



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111 Figure S5. The charge difference diagram of the heterostructure of Ag-Cu₂O.

At the same time, the Mülliken charge density population of the structure was calculated. Since the system was a two-dimensional layered structure, we simply divided the atom into atoms close to the interface of the heterojunction and atoms away from the interface of the heterojunction. It should be noted that in the computational simulation, the Mülliken charge density population does not have a unit in the strict sense, so there is no need to add units, only for comparative analysis.

117 Table S2. Mülliken charge density population.

Ag Cu O		Ag	Cu	0
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Near the interface	0.009	0.426	-0.627
Away from the interface	0.102	0.212	-0.773

The following conclusions can be drawn: 1) Combined with the charge difference diagram of the 118 119 heterojunction system and the Mülliken charge density population calculation results, it can be seen that the Cu atoms and O atoms near the heterojunction interface exhibited stronger positive charge, 120 while the positive charge density of Ag atoms was lower, which indicated that electrons transferred 121 122 from Cu₂O to Ag in the heterojunction system. 2) Ag is prone to oxidation because it is a good electron acceptor. In the heterostructure, Ag obtained electrons transported from Cu₂O, its electron density was 123 increased, and the ability to attract electrons was lowered, so that the propensity of oxidation of Ag in 124 125 presence of Cu₂O core.



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127 Fig. S6. CV curves of the Ag-Cu₂O/PANI after 500 cycles.

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129 Table S3. Exponential decay-fitted parameters of fluorescence lifetime for Cu₂O, Cu₂O/PANI, Ag-

130 $Cu_2O/PANI$ samples.

Samples	A ₁ (%)	τ_1 (ns)	$A_{2}(\%)$	τ_2 (ns)	$\tau_{n}\left(ns\right)$
Cu ₂ O	23.98%	4.40679	76.02%	0.161174	0.209598

Cu ₂ O/PANI	26.71%	2.87808	73.29%	0.342334	0.447704
Ag-Cu ₂ O/PANI	34.61%	2.70609	65.39%	0.381535	0.542948

131 A biexponential function fitting was employed to analyze the PL decay curves, and the average PL

132 lifetime (τ_n) was deduced by the following equation:

$$\tau_{i} = \frac{A_{1}\tau_{1}^{2} + A_{2}\tau_{2}^{2}}{A_{1}\tau_{1} + A_{2}\tau_{2}}$$

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134 where τ_i is the estimated lifetime value and A_i is the corresponding amplitude.