Multifunctional PEG encapsulated Fe$_3$O$_4$@silver hybrid nanoparticles: antibacterial activity, cell imaging and combined photothermo/chemo-therapy

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![Raman spectrum](image1.png)

Fig. S1. Raman spectrum of the as-obtained Fe$_3$O$_4$@PEG NPs.

![UV–visible absorption spectrum](image2.png)

Fig. S2. Typical UV–visible absorption spectrum of the as-obtained Fe$_3$O$_4$@PEG NPs.

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Fig. S3. Schematic illustration of the synthesis of Fe₃O₄@Ag-PEG hybrid NPs.

Fig. S4. Hydrodynamic diameter distribution of the Fe₃O₄@Ag-PEG hybrid NPs synthesized at 30 °C and [Ag⁺] = 0.19 mM for 1h.

Fig. S5. TEM images of the Fe₃O₄@Ag-PEG hybrid NPs synthesized at 30 °C and initial [Ag⁺] = 0.19 mM, but for different reaction time: (a) 1 h, (b) 3 h, (c) 6 h, and (d) 12 h.
Fig. S6 The bacterial inhibition efficiency of the dumbbell-like structured Fe₃O₄@Ag-PEG hybrid NPs (the average size of Ag NPs = 22 nm, concentration = 160 μg/mL) at different interaction time with bacteria.

Fig. S7. (a) The PL spectra of the Fe₃O₄@PEG template NPs and Fe₃O₄@Ag-PEG hybrid NPs synthesized at [Ag⁺] = 0.19 mM and 30°C for 1 h. (b) The fluorescence intensity of the Fe₃O₄@Ag-PEG hybrid NPs used in (a) under different excitation time. Excitation wavelength = 390 nm.
Fig. S8. Z-Scanning confocal fluorescence images of the B16F10 cells incubated with the Fe₃O₄@Ag-PEG hybrid NPs containing multiple Ag nanocrystals in the shell. Excitation wavelength = 405 nm.

Fig. S9. Typical UV–visible absorption spectra of the as-obtained Fe₃O₄@Ag-PEG hybrid NPs and DOX-loaded Fe₃O₄@Ag-PEG hybrid NPs.
Fig. S10 (a) Structure of DOX; (b) Schematic illustration of the NIR photo-controlled drug release from the DOX-loaded Fe$_3$O$_4$@Ag-PEG hybrid NPs.
Fig. S11. The heating curves of water and Fe₃O₄@Ag-PEG (0.2 mg/mL) hybrid NPs under NIR irradiation.

Fig. S12 In vitro cytotoxicity of B16F10 cells incubated with DOX-free Fe₃O₄@Ag-PEG NPs and DOX-loaded Fe₃O₄@Ag-PEG NPs under different incubation time.

Table S1. The loading content of Ag nanocrystals in and/or on the Fe₃O₄@Ag-PEG hybrid NPs

<table>
<thead>
<tr>
<th>Initial concentration [Ag⁺]/ mM</th>
<th>Remanent concentration [Ag⁺]/ mM</th>
<th>Loading content</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.19</td>
<td>0.0038</td>
<td>98%</td>
</tr>
<tr>
<td>0.38</td>
<td>0.0256</td>
<td>93%</td>
</tr>
<tr>
<td>0.58</td>
<td>0.1276</td>
<td>78%</td>
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