Supporting Information

Synthesis and characteristics of ZnGa$_2$O$_4$ hollow nanostructures via carbon@Ga(OH)CO$_3$@Zn(OH)$_2$ by hydrothermal method

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<table>
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<th>Sample</th>
<th>Carbon</th>
<th>Concentration of Ga(NO₃)₃•xH₂O</th>
<th>Urea</th>
<th>Concentration of (C₄H₆O₄)Zn*2H₂O</th>
<th>Solvent (water)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1</td>
<td>150 mg</td>
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<td>30 mmol</td>
<td>2 mmol</td>
<td>50 mL</td>
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<tr>
<td>Sample 2</td>
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<td>30 mmol</td>
<td>2.5 mmol</td>
<td>50 mL</td>
</tr>
<tr>
<td>Sample 3</td>
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<td>30 mmol</td>
<td>3 mmol</td>
<td>50 mL</td>
</tr>
<tr>
<td>Sample 4</td>
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<td>3 mmol</td>
<td>30 mmol</td>
<td>3.5 mmol</td>
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</tbody>
</table>

Table S1 Concentration of starting materials for carbon@Ga(OH)CO₃@Zn(OH)₂ core-shell-shell NSs.
Fig. S1 FESEM images of the carbon@Ga(OH)CO$_3$@Zn(OH)$_2$ core-shell-shell NSs before calcination: concentration of ZnAc: 2, 2.5, 3 and 3.5 mmol.
Fig. S2 shows the FTIR spectra in the 4000 ~ 400 cm\(^{-1}\) region of the carbon@Ga(OH)CO\(_3@\)Zn(OH)\(_2\) core-shell-shell NSs before calcination as a function of ZnAc. The vibration modes at 1600 and 1750 cm\(^{-1}\) are attributed to the C=O and C=C vibrations by the aromatization of glucose during hydrothermal treatment. The band absorption of carbon@Ga(OH)CO\(_3@\)Zn(OH)\(_2\) core-shell-shell NSs was observed at 1388 cm\(^{-1}\) due to the \(v_3\) mode of interlamellar [CO\(_3\)]\(^2-\) ions according to previous reports.\(^1\) Broad absorption peaks positioned at 486 ~ 648 cm\(^{-1}\) (Ga-OH and Zn-OH stretching vibration) are identified in the carbon@Ga(OH)CO\(_3@\)Zn(OH)\(_2\) core-shell-shell NSs before calcination.\(^{2-3}\)
The band absorption of ZnGa$_2$O$_4$ hollow NSs at 600 °C for 1 hour was observed at 1388 cm$^{-1}$. It indicated that the component of the shell are consist of residual interlamellar [CO$_3$]$^{2-}$ anions in Ga(OH)CO$_3$ shell. Strong absorption peaks positioned at 420 and 578 cm$^{-1}$ (Ga-O and Zn-O stretching vibration) in Fig. S3 are identified in the ZnGa$_2$O$_4$ hollow NSs.$^4$ Furthermore, the FTIR spectra show a broad absorption band of the -OH group (1631, 3436 cm$^{-1}$), which results from the H$_2$O absorbed by the ZnGa$_2$O$_4$ hollow NSs when the samples were analyzed at room temperature in the air.
Fig. S4 The STEM (a) image and the EDS (b) line scan of ZnGa$_2$O$_4$ (ZnAc : 2.5 mmol) hollow NSs. EDS line scan taken along the indicated lines shown in the STEM image.

The formation of ZnGa$_2$O$_4$ hollow NSs was verified again by scanning TEM (STEM) image and the elemental line scanning profile in Fig. S4 (a) and (b). The presence of Ga and Zn in the same edge region can be attributed to the formation of ZnGa$_2$O$_4$ shell.
Fig. S5 CL (a) spectra and representative band-structure scheme (b) for the UV and blue luminescence in ZnGa$_2$O$_4$ (ZnAc : 2.5 mmol) hollow nanostructures.

References