In order to investigate the effect of particle size and morphology on the optical properties of ZnO, a series of ZnO powders were synthesized by low-temperature hydrothermal processing using zinc acetate dihydrate and sodium hydroxide as the starting materials, and polyvinylpyrrolidone as the stabilizing agent. The particle size and morphology were tailored by adjusting the reactant molar ratios \( [\text{Zn}^{2+}] / [\text{OH}^-] \), while the reaction temperature and time remained unchanged. XRD, TEM, SAED and HRTEM analyses have shown that the powders have a high crystalline pure wurtzite structure with nanosized crystallites. The size and morphology of the ZnO powders were investigated by FE-SEM, which showed a modification from micro-rods via hexagonal-faceted prismatic morphology to nanospheres, by simply adjusting of the reactant molar ratios \( [\text{Zn}^{2+}] / [\text{OH}^-] \) from 1:1 to 1:5. The optical properties of the ZnO powders as well as their dependence on the particle size and morphology were investigated by Raman and UV-Vis diffuse reflectance spectroscopy (DRS).

Experimental

In the series of experiments, the reaction temperature and time were kept constant, while the \( [\text{Zn}^{2+}] / [\text{OH}^-] \) molar ratio in the starting solution was changed in order to tailor the particle size and shape. Namely, the \( [\text{Zn}^{2+}] / [\text{OH}^-] \) molar ratio was varied from 1:1, 1:2, 1:3,1:3.5, 1:4 to 1:5, resulting in the pH values of the reaction solution 8, 9, 10, 11, 12 and 13, respectively. The starting materials, zinc acetate dihydrate (\( \text{Zn(CH}_3\text{COO)}_2 \cdot 2\text{H}_2\text{O} \)), sodium hydroxide (\( \text{NaOH} \)) and polyvinylpyrrolidone (\( \text{PVP, } (\text{C}_6\text{H}_9\text{NO})_n \)) as a stabilizing agent, were used without any additional treatment. (0.01 mol) of zinc acetate dihydrate and \( 0.0574 \) (2.10-6 mol, i.e. 5 wt%) of PVP were dissolved in 750 ml of deionized water with a constant stirring at 1000 rpm and heating at 80 C. After the dissolution of zinc powders. Influence of the particle size and crystallite size (D) in crystallographic crystal phases. The unit cell parameters, hexagonal wurtzite ZnO without peaks diffraction peaks in the recorded XRD powders are presented in Fig. 1. All of the Raman spectra of ZnO powders. The modes that appear in the Raman spectra and can be assigned to the wurtzite crystal structure are the following: the most intensive band is \( \text{E}_2\text{L} \) near 100 cm\(^{-1}\), attributed to the vibrations of the zinc sublattice in ZnO the bands near 450, 580 and 680 cm\(^{-1}\), respectively. All of the spectra contain a strong, sharp and dominant peak located at about 440 cm\(^{-1}\), which is the characteristic scattering peak of the Raman-active dominant \( \text{E}_2\text{L} \) mode of wurtzite hexagonal ZnO and is assigned to oxygen vibration.

Table 1. Synthesis conditions and optical properties of prepared ZnO powders.

<table>
<thead>
<tr>
<th>Sample</th>
<th>( [\text{Zn}^{2+}] / [\text{OH}^-] )</th>
<th>( \text{pH} )</th>
<th>Crystallite size (D) nm</th>
<th>( \text{fwhm} ) cm(^{-1})</th>
<th>( \text{R} ) at 550 nm %</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZnO8</td>
<td>1:1</td>
<td>8</td>
<td>30</td>
<td>70</td>
<td>0.07</td>
</tr>
<tr>
<td>ZnO9</td>
<td>1:2</td>
<td>9</td>
<td>45</td>
<td>60</td>
<td>0.08</td>
</tr>
<tr>
<td>ZnO10</td>
<td>1:3</td>
<td>10</td>
<td>25</td>
<td>60</td>
<td>0.09</td>
</tr>
<tr>
<td>ZnO11</td>
<td>1:4</td>
<td>11</td>
<td>20</td>
<td>70</td>
<td>0.10</td>
</tr>
<tr>
<td>ZnO12</td>
<td>1:5</td>
<td>12</td>
<td>15</td>
<td>75</td>
<td>0.11</td>
</tr>
<tr>
<td>ZnO13</td>
<td>1:6</td>
<td>13</td>
<td>10</td>
<td>150</td>
<td>0.12</td>
</tr>
</tbody>
</table>

Table 2. Assignment of peak positions (in cm\(^{-1}\)) of Raman bands in the spectra of ZnO powders.

<table>
<thead>
<tr>
<th>Assignment</th>
<th>Peak position (in cm(^{-1}))</th>
<th>Raman bands</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{LO} )</td>
<td>180</td>
<td>( \text{LO} )</td>
</tr>
<tr>
<td>( \text{TO} )</td>
<td>200</td>
<td>( \text{TO} )</td>
</tr>
<tr>
<td>( \text{E}_1\text{G} )</td>
<td>270</td>
<td>( \text{E}_1\text{G} )</td>
</tr>
<tr>
<td>( \text{E}_2\text{L} )</td>
<td>100</td>
<td>( \text{E}_2\text{L} )</td>
</tr>
</tbody>
</table>

Fig. 8 shows the room temperature \( \mu \)-Raman spectra of the synthesized ZnO powders. The modes that appear in the Raman spectra and can be assigned to the wurtzite crystal structure are the following: the most intensive band is \( \text{E}_2\text{L} \) near 100 cm\(^{-1}\), attributed to the vibrations of the zinc sublattice in ZnO the bands near 200, 320 and 380 cm\(^{-1}\) are attributed to \( \text{E}_2\text{L} \) and \( \text{A}_1\text{G} \), respectively. All of the spectra contain a sharp, strong and dominant peak located at about 440 cm\(^{-1}\), which is the characteristic scattering peak of the Raman-active dominant \( \text{E}_2\text{L} \) mode of wurtzite hexagonal ZnO and is assigned to oxygen vibration.