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## Synthetic phase and morphology control over colloidal nickel sulfide nanocrystals

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Binary nickel sulfides exist in a variety of phases and stoichiometries, including  $\text{NiS}_2$ ,  $\text{Ni}_3\text{S}_4$ ,  $\alpha\text{-NiS}$ ,  $\beta\text{-NiS}$ ,  $\text{Ni}_9\text{S}_8$ ,  $\text{Ni}_7\text{S}_6$  and  $\text{Ni}_3\text{S}_2$ . Distinct phases of the binary nickel sulfide system have potential to be used as bifunctional catalysts for water splitting, cathode materials for lithium-ion batteries, absorber layers for solar cells, hydrodesulfurization catalysts, or supercapacitors. However, the complicated nature of the Ni-S phase diagram makes the solution synthesis of phase-pure colloidal nanocrystals challenging. In this presentation, the phase- and morphology-controlled solution synthesis of colloidal nickel sulfide nanocrystals is demonstrated. Nanocrystals of  $\text{Ni}_3\text{S}_4$ ,  $\alpha\text{-NiS}$ ,  $\beta\text{-NiS}$ ,  $\text{Ni}_9\text{S}_8$  and  $\text{Ni}_3\text{S}_2$  can be independently prepared by tuning key synthetic parameters of S:Ni precursor ratio, capping ligand, reaction time and temperature. S:Ni ratio and temperature influences the phase of nanocrystals, a phase transformation from cubic  $\text{Ni}_3\text{S}_4$  to hexagonal  $\alpha\text{-NiS}$  and then rhombohedral  $\beta\text{-NiS}$  with increasing S:Ni ratios and temperature is observed. 1-dodecanethiol is shown as an important phase and shape-directing agent. In the presence of 1-dodecanethiol,  $\text{Ni}_9\text{S}_8$  nanocrystals with quasi-spherical morphology or  $\text{Ni}_3\text{S}_2$  nanoparticles with a multi-pod like morphology can be obtained by using various disubstituted thioureas as sulfur precursors.

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