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Thermodynamic probability of formation solid solutions $Fe_xPb_{1-x}S$ by hydrochemical precipitation

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Abstract

Analysis of the literature showed that narrow-gap lead sulfide PbS (0.4 eV at 300 K), due to its unique properties, has found wide application in such devices as photodetectors with a wide (from infrared to ultraviolet) radiation range, solar energy converters, chemical sensors, temperature sensors, flame detectors, etc. Doping of lead sulfide with various metal ions can affect the bandgap, and hence expand the scope of its application. Of particular interest is the preparation of thin film solid solutions in the PbS – FeS system, which can lead to the appearance of ferromagnetism in lead sulfide. To obtain doped films of lead sulfide and solid solutions based on it, the method of chemical deposition from aqueous media is considered promising, which, in addition to its cost-effectiveness and simplicity of the process, allows one to determine in advance the areas of formation of the semiconducting metal chalcogenides of interest. The analysis of ionic equilibria in the systems "$PbAc_2$ – $FeCl_2$ – Na_3Cit – NH_4OH – N_2H_4CS", "$PbAc_2$ – $FeCl_2$ – NaAc – NH_4OH – N_2H_4CS "and " $PbAc_2$ – $FeCl_2$ – Na_2C2O_4 – NH_4OH – N_2H_4CS "made it possible to reveal predominantly forms of metals in a given pH range. To assess the conditions for the deposition of the main and impurity phases by thermodynamic calculations taking into account the sizes of critical nuclei, the boundary conditions and regions of the formation of FeS, PbS, $Fe(OH)_2$, $Pb(OH)_2$ in the reaction systems under study were found. It is shown that the most promising for the preparation of the three-component PbFeS compound, which does not contain impurity phases of lead and iron hydroxides, is the reaction system "$PbAc_2$ – $FeCl_2$ – Na_3Cit – NH_4OH – N_2H_4CS". The possibility of obtaining PbS: Fe films with a uniform iron distribution of ~ 0.5 at.% and deviation from stoichiometry towards Pb deficiency (47.7 at.%) and S excess (50.7 at.%) was experimentally demonstrated.

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