PHOTOELECTRIC PROPERTIES OF PbS(I) THIN FILMS DOPED WITH NICKEL

E.S. Borisova[1], A.V. Pozdin[1], L.N. Maskaeva[1,2], V.F. Markov[1,2]

[1]Ural Federal University named after the First President of Russia B.N. Yeltsin, Yekaterinburg, 620002 Russia

[2]Ural Institute of State Fire Service, Emergency Ministry of Russia, Yekaterinburg, 620062 Russia

E-mail: boris12221@mail.ru

INTRODUCTION

One of the most effective methods to change the semiconductor properties of PbS layers is their doping by introducing metal salt additives into the reaction mixture during chemical deposition. This technique provides the possibility of obtaining highly functional films in one technological stage, excluding the additional process of sensitization. The known literature does not provide information on the photosensitivity of PbS(Ni) films; therefore, this work, which is a continuation of studies on the doping of chemically deposited PbS(I) layers, is devoted to studying the effect of nickel ions on their photoelectric properties.

SYNTHESIS

To obtain PbS(I, Ni) thin films was applied hydrochemical deposition method at a temperature of 353K for 120 min.

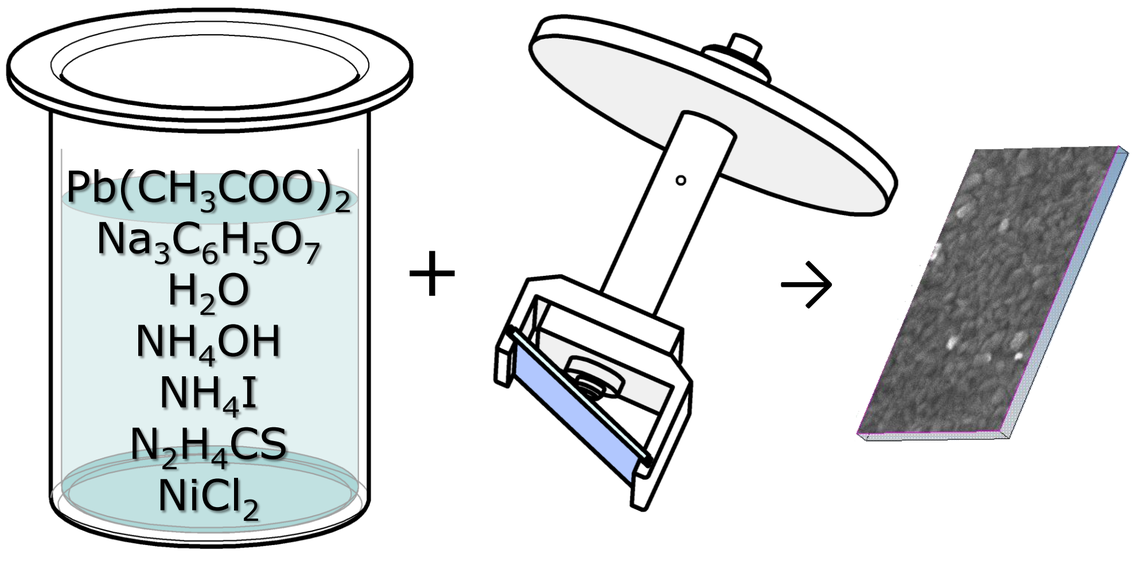

Fig.1. Synthesis procedure

PHOTOELECTRIC PROPERTIES OF PbS(I,Ni)

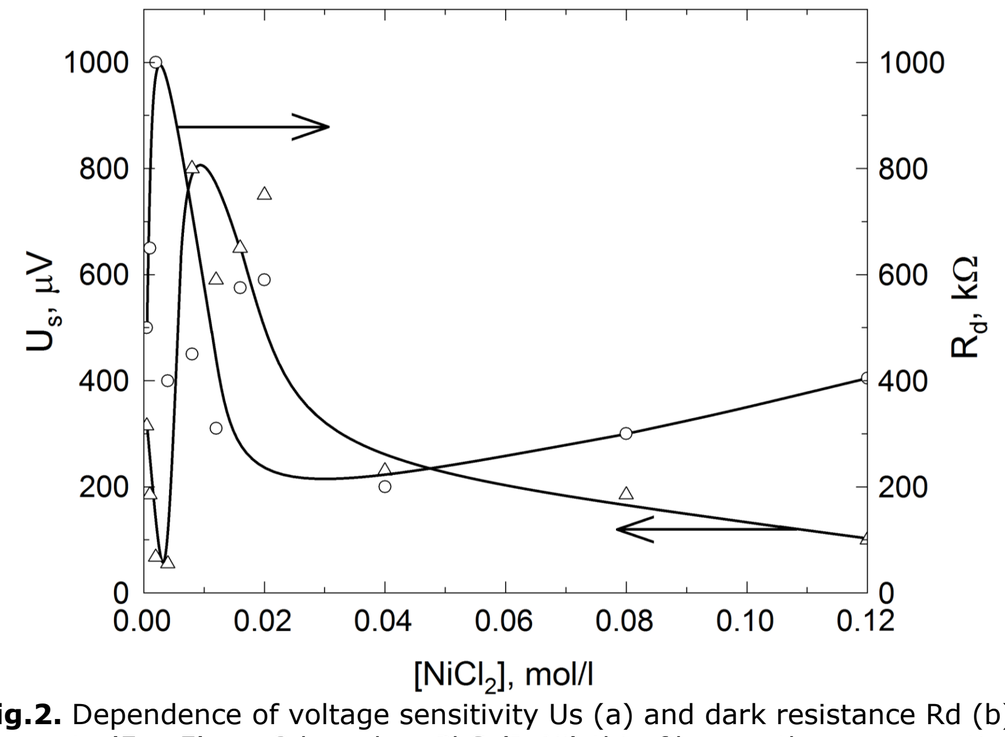

Fig.2. Dependence of voltage sensitivity Us (a) and dark resistance Rd (b) of elements (5 × 5) mm2 based on PbS (I, Ni) thin-films on the concentration of $NiCl_2$ in the reactor.

FRACTIONAL CONCENTRATIONS OF COMPLEX FORMS OF Pb, Ni

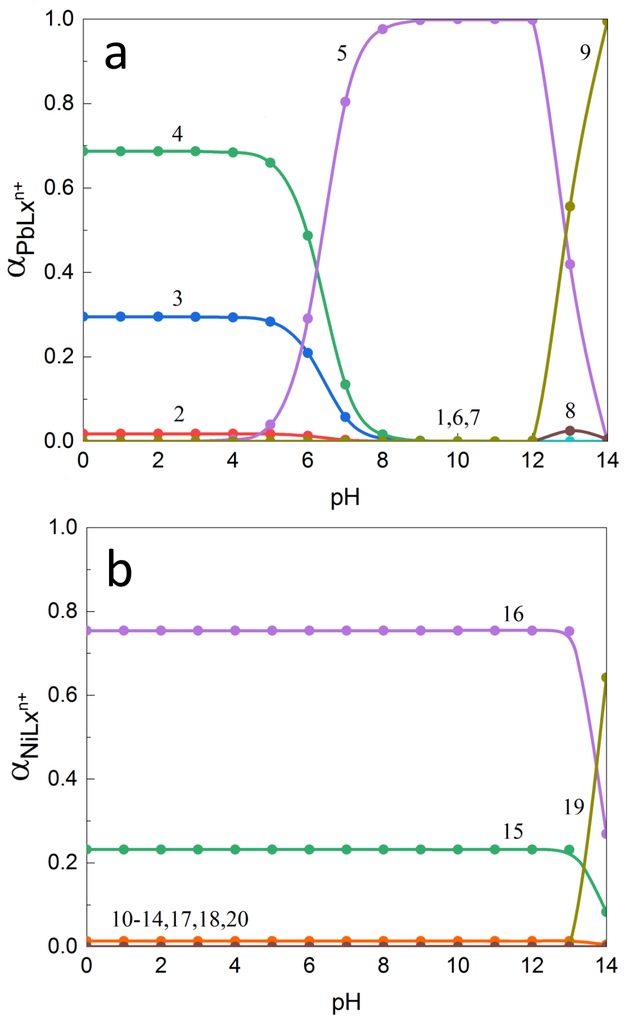

Fig.3. Diagrams of distribution of fractional concentrations of free forms of metal depending on pH in the system «$Pb(CH_3COO)_2$ – Na_3Cit – NH_4OH – NH_4I – H_2O» (a): Pb^{2+} (1), $PbCit^-$ (2), $Pb(Cit)_2^{4-}$ (3), $Pb(Cit)_3^{7-}$ (4), $PbOHCit^{2-}$ (5), $PbOH^+$ (6), $Pb(OH)_2$ (7), $Pb(OH)_3^-$ (8), $Pb(OH)_4^{2-}$ (9) and «$NiCl_2$ – Na_3Cit – NH_4OH – NH_4I – H_2O» (b): Ni^{2+} (10), $NiNH_3^{2+}$ (11), $Ni(NH_3)_2^{2+}$ (12), $Ni(NH_3)_3^{2+}$ (13), $Ni(NH_3)_4^{2+}$ (14), $Ni(NH_3)_5^{2+}$ (15), $Ni(NH_3)_6^{2+}$ (16), $NiOH^+$ (17), $Ni(OH)_2$ (18), $Ni(OH)_3^-$ (19), $NiCit^-$ (20). The calculation was performed at the total analytical concentration of lead salt in the solution [Pb(CH3COO)$_2$]=0.04 mol/l, [Na_3Cit]=0.3 mol/l and [NH_4OH]=4 mol/l and T=298 K.

BOUNDARY CONDITIONS OF FORMATION OF PbS, NiS, $Pb(OH)_2$, $Ni(OH)_2$

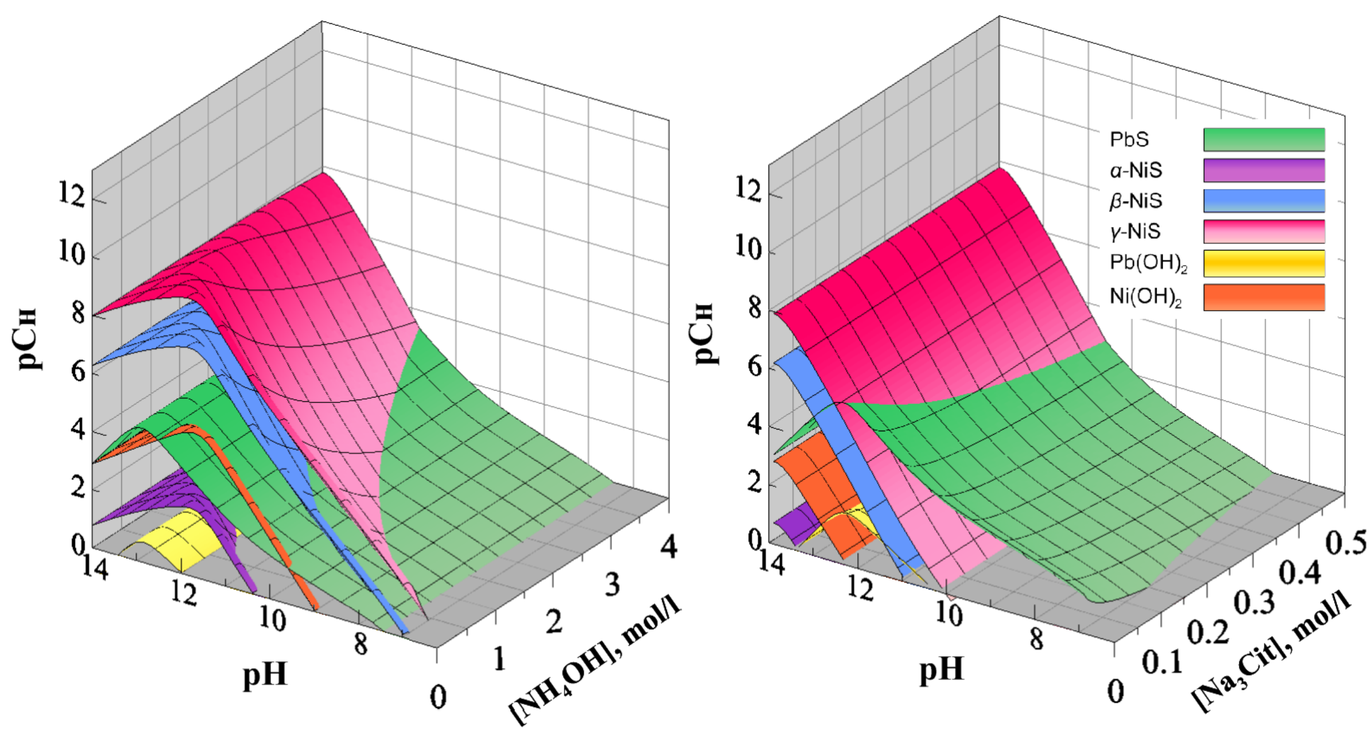

Fig. 4. Boundary conditions for the formation of low solubility phases PbS, NiS-α(-β,γ), $Pb(OH)_2$, $NI(OH)_2$ in the system«$Pb(CH_3COO)_2$ – $NiCl_2$ – Na_3Cit – NH_4OH– N_2H_4CS» with a change concentration of ammonia solution (a) and sodium citrate (b). The calculation was performed at [Na_3Cit] = 0.3 mol/l (a), [NH_4OH] = 4 mol/l (b), [N_2H_4CS] = 0.58 mol/l and T=298 K.

SCANNING ELECTRON MICROSCOPY

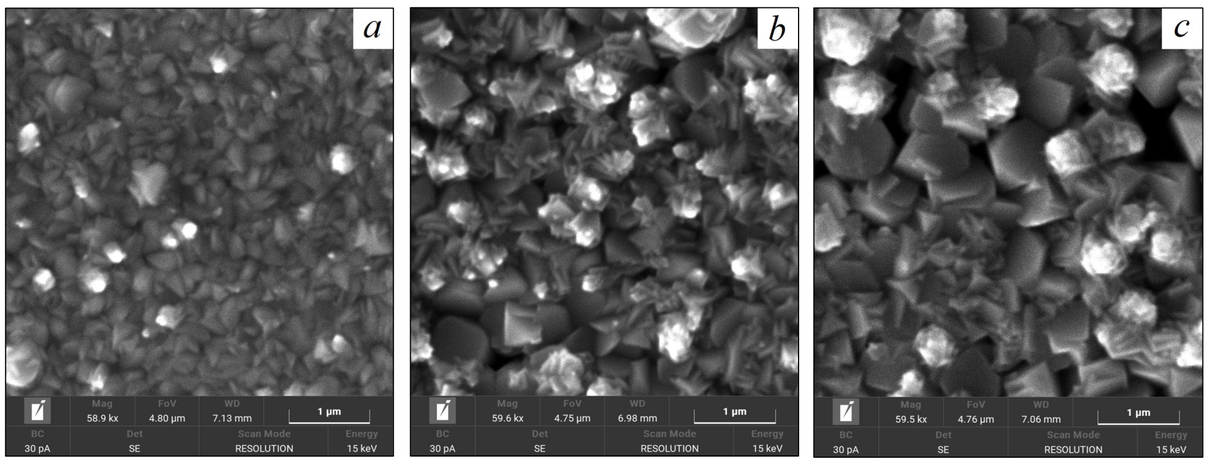

Fig. 5. Micrographs of the PbS(I,Ni) thin-films scale 1.0 μm doped with $NiCl_2$ mol/l: 0.012 (*a*), 0.04 (*b*), 0.12 (*c*).

CONCLUSIONS

1. By chemical deposition from a reaction mixture containing Na_3Cit as a ligand for Pb^{2+} and NH_4OH for Ni^{2+} were obtained mirror thin films NiPbS with good adhesion to a glass substrate with a thickness of 320-420 nm.
2. Based on the results of scanning electron microscopy was found that with an increase in the concentration of $NiCl_2$ from 0.012 to 0.12 leads to an increase in the grain size by 3-4 times with the formation of secondary nucleation from the surface.
3. The calculation of the boundary conditions for the formation of solid phases PbS and γ-NiS (β-NiS) allows to make an assumption about the probability of the formation on their basis of solid solutions $Ni_xPb_{1-x}S$
4. The extreme nature of the dependence of the voltage sensitivity on the concentration of $NiCl_2$ in the reactor is associated with the nonmonotonic incorporation of nickel into the PbS crystal lattice.