Depression of positive magneto-conductance due to anti-weak localization effect in annealed In_2O_3-ZnO thick films

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For thick $(In_2O_3)_{0.965}$-$(ZnO)_{0.035}$ films with different resistivity ρ by post annealing in air, we have investigated $\rho(T)$ characteristics and magneto-conductance $\Delta\sigma$. The weak localization theory for the 3D system has been fitted to data of $\Delta\sigma(T)$ at temperatures below 50 K by the use of suitable inelastic scattering time $\tau_{in}(T)$ and T-independent spin-orbit(S-O) scattering time τ_{so}. We have found the ρ dependences of both times τ_{in} and τ_{so} for films with 4×10^{-6} Ωm $< \rho(300\ \mathrm{K}) < 1.5\times10^{-3}$ Ωm. As increasing of ρ, the ratio of τ_{so} and τ_{in}, τ_{so}/τ_{in} decreases from $\approx4\times10^3$ to ≈10 and then, the sign of $\Delta\sigma$ at low temperatures changes from positive to negative. This means localization changes to anti-localization due to the heat treatment. However, strong ρ dependence of the ratio τ_{so}/τ_{in} cannot be explained by the simple free electron model under the assumption that the S-O scattering originates from the same atom in the whole region of ρ. We suggest a picture that the annealing in air brings the change of the S-O scattering atom from light to heavy atoms, namely, oxygen to indium and/or zinc atoms.