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Determination of effective sp-d exchange integrals in wide-gap DMS[1]

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This work presents a magneto-optical study of diluted magnetic semiconductors (DMS) based on ZnO and GaN and doped with manganese, iron and cobalt. Both host materials, ZnO and GaN, are wide bandgap semiconductors with a wurtzite structure, a weak spin-orbit coupling and a strong electron-hole exchange interaction within the excitons. In the presence of magnetic field, the magnetic ions induce in such materials giant Zeeman effect with no straightforward interpretation, e.g.: excitons anti-cross, and not only the transition energies, but also the oscillator strengths are strongly affected by the giant Zeeman effect. On thin epitaxial layers grown on (0001) sapphire, we observed the giant Zeeman splitting of A and B excitons which are optically active in the Faraday configuration when the propagating light is parallel to the c–axis. The Zeeman splitting decreases with the temperature and increases non-linearly with the magnetic field, demonstrating a dependence on the magnetization of the localized spins. A quantitative analysis allows us to discuss the detailed behavior of the magnetization and to estimate the p-d exchange integral β for the studied wide bandgap DMS. For the d^5 electronic configuration ($Mn^{2+}$and Fe^{3+}) the magnetization follows a Brillouin function $B_{5/2}$, whereas, for d^7 or d^4 of Co^{2+} and Mn^{3+} respectively, the spin orbit coupling and the trigonal crystal field lead to an anisotropic magnetization, consistent with that deduced independently from the analysis of intra-ionic optical transitions. We find a positive sign of β for GaN:Mn^{3+} and GaN:Fe^{3+}. Assuming that the valence band ordering in ZnO is Γ_9, Γ_7, Γ_7 (this corresponds to usuall, positive sign of the spin-orbit coupling), we find β to be negative for ZnO:Co^{2+} and ZnO:Mn^{2+}.

[1]Work done in collaboration with D. Ferrand, P. Kossacki, J. Cibert, J. A. Gaj, A. Golnik, C. Deparis, C. Morhain, S. Marcet, E. Sarigiannidou, H. Mariette, E. Chikoidze, Y. Dumont, M. Wegscheider, A. Navarro-Quezada, and A. Bonanni.