Dielectric and magnetic birefringence in Zn$_{1-x}$Mn$_x$Se

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Dielectric and magnetic birefringence possess a temperature dependent magnetic moment as well as remarkable magnetooptic (MO) properties, which in conjunction with the electronic properties suggest future applications for MO and spintronic devices.

Results

The underlying mechanism of the giant Faraday effect is the interaction between the spin of the light and bound and unbound electrical charge. When $\mu_0H \neq 0$, the conduction and valence bands split, which is known as sp-d-exchange.

MO birefringence

- Change due to the sp-d interaction.
- The dielectric anisotropy is taken into account when modeling the MO effect.

The MO birefringence depends also on the orientation of the sample. Therefore it is necessary to have a model which takes this effect properly into account.

Dielectric tensor model

The formation of wurtzite planes parallel to the [111] direction causes dielectric birefringence in dependence of the Mn concentration $x$. At $x = 0.3$, a phase transformation from the sphalerite to the wurtzite structure occurs.

MO birefringence

The dielectric anisotropy can be obtained. The sample with highest magnetic birefringence is also the sample with highest Mn concentration.

The dielectric anisotropy can be measured in terms of the energy band gap shift.

$$E_{\text{gap}}(x) = E_0 - h (\omega_v + \omega_g) + \frac{h}{2} (\alpha_v^2 + \alpha_g^2)$$

**Landau**

$$E_{\text{gap}}(x) = E_0 - h (\omega_v + \omega_g) + \frac{h}{2} (\alpha_v^2 + \alpha_g^2)$$

**Zeeman**

$$E_{\text{gap}}(x) = E_0 - h (\omega_v + \omega_g) + \frac{h}{2} (\alpha_v^2 + \alpha_g^2)$$

The dipole anisotropy is proportional to the Mn concentration $x$. For $x$ closer to 0.13 the anisotropy reaches at least one maximum.

Experiment

Generalized Ellipsometry measures the general optical polarization response of samples in terms of Mueller matrix elements, and allows for reconstruction of the permittivity, permeability, and magnetoelectric response tensors.

We studied the dielectric and magnetic-field induced anisotropic optical properties of Zn$_{1-x}$Mn$_x$Se thin films with generalized spectroscopic ellipsometry in the VIS-UV spectral range for Mn concentrations of $x = 0.00, 0.02, 0.13$ and 0.28. The dielectric and magnetic field induced anisotropies in Zn$_{1-x}$Mn$_x$Se were treated separately into the diagonal and off-diagonal components of the Mueller tensor.

We are able to quantify the shift of the band gap energy between the DF parallel and perpendicular to the optical axis caused by the formation of wurtzite domains with increasing $x$.

The optical anisotropy occurs in the direction [111], which is in good concordance with previous TEM investigations. The dielectric anisotropy results in a red shift of the energy band gap parallel to the optical axis with a maximum for $x = 0.13$.

Measurements of the sp-d exchange energy at room temperature are presented and found a maximum value for the sample with maximum Mn concentration $x = 0.28$. 

**Our message**

We studied the dielectric and magnetic-field induced anisotropic optical properties of Zn$_{1-x}$Mn$_x$Se thin films with generalized spectroscopic ellipsometry in the VIS-UV spectral range for Mn concentrations of $x = 0.00, 0.02, 0.13$ and 0.28. The dielectric and magnetic field induced anisotropies in Zn$_{1-x}$Mn$_x$Se were treated separately into the diagonal and off-diagonal components of the Mueller tensor.

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