복소 복굴절함수 행렬에 기초한 흐레넬-존스 반사계수의 도입

Concrete introduction of Fresnel-Jones reflection coefficient based on complex refractive index function matrix

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In optical disk substrate injection molding, poly-carbonate which is lowly tilted and of good molding characteristics with high transfer rate is available. Fig.1 shows exaggerated double refraction that is disk substrate anisotropy. The origin of birefringence is known as polymer orientation due to manufacturing process and time varying residual stress.[0] Jones matrix of disk is described as,

[Disk]=[Substrate][RML][Substrate]....................(1)

[Substrate]=R(-θ) t^2 [exp(j k_0 · d[n])] R(θ)...(2)

Where [n] is 2by2 CRIFM(Complex Refractive Index Function Matrix). Substrate birefringence is described by anisotropy angle θ_a and complex angle birefringence $\boldsymbol{\theta}_B = \theta_B - j\eta_B = 2\pi(n_f - n_s)t/\lambda$,

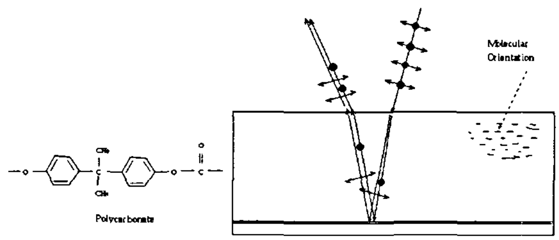
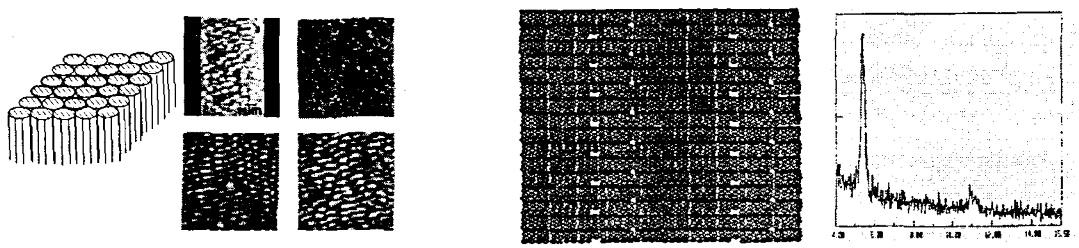


Fig.1 Disk substrate anisotropy

Where t is the thickness of substrate and $n_{f(s)}$ is refractive index of fast(slow) axis. Birefringence is proportional to refractive index difference of fast and slow axis. PMMA is known as lowly birefringent enough to be molded to LD size optical disk. Annealing treatment of the substrate is known as good for reducing the birefringence.



A) Columnar structure B) Super lattice & low angle XRD

Fig.2 Anisotropy of MO materials

There are a lot of examples of anisotropy in optical disk. Fig.1 shows disk substrate anisotropy formed in the injection molding process. Fig.2 A) shows columnar structure of sputtered thin film grain of magneto-optic recording multi-layer(RML). Fig.2 B)shows conceptual figure of super lattice thin film Co2Å /Pd9Å and its x-ray diffraction graph with low angle peak. In the case of oblique incidence, it is necessary to extend the CRIFM to 3×3 matrix. Jones matrix can also be extended to 3×3 matrix. We'd like to call it Maxwell-Jones (MJ) matrix. CRIFM is square root of dielectric tensor. Maxwell-Jones matrix that is an exponential power of scalar multiple of CRIFM is solution of Maxwell equation in the an-isotropic medium. Jones matrix of magneto-optical recording medium is derived as [MO]= rR($\boldsymbol{\theta}_k$) where complex circular birefringence $\boldsymbol{\theta}_k = \theta_k - j\eta_k$.[1] Fresnel-Jones refraction coefficient (FJRC) derived from CRIFM for normal incidence is useful for the calculation of magneto-optic Kerr rotation.

[r] = ([n]-1)/([n]+1)..3)

Reflection coefficients are probably easy to be to be extended to oblique incident case. However, the following consideration should be taken. With CRIFM, we should modify the Snell's law for double refraction. 2 by 2 matrix CRIFM is appropriate to describe polarization dependent refraction phenomena. Fig.3 shows matrix index Snell's law. Modified Snell's law may be written as follows.

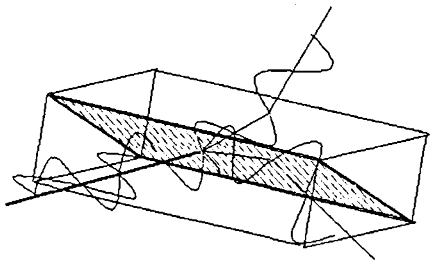


Fig3. Matrix index Snell's law

$\sin\theta_i$ (1, 1)n_i = ($\sin\theta_{rp}$, $\sin\theta_{rs}$) [n $_r$].......4)

Where (A,B)= Ap_p+Bp_s or Ap $_p$+Bp $_s$, where p_i and p'_i are eigen-states of polarization vectors of incident light and refractive light respectively. And, [n] is diagonal matrix consisted of n_p and n_s for birefringent material. Angular dependence of refractive index is considered with Maxwell equations. Maxwell wave equation is given by[2].

$k(k(^{-1}D)) + \omega^2 D = 0$ ....5)

Im-permeability is the inverse of dielectric tensor that is square of CRIFM. Conventionally, im-permeability was used to calculate angular dependence of refractive index. At this work, angular dependence of CRIFM was calculated like Jones matrix. To verify angular dependence of CRIFM, we apply it to POPO (Pulsed Optical Parametric Oscillation). Pump wave is partially split to signal wave and idler wave. The efficiency increases when the phase is matched. Phase matching consists of energy and momentum conservation and require double refractive index spectrum. It is exact to use impermeability matrix instead of dielectric matrix for obliquely incident with crystal axis. Conventional angular dependence of refractive index is given as follows

$n^{-2}(\theta) = \sin^2\theta n_e^{-2} + \cos^2\theta n_e^{-2}$ ....6)

A CRIFM n(θ) of a medium should be calculated as follows.

$n(\theta) = (R(\theta)\eta R(-\theta))^{-1/2} = R(\theta)[CRIFM]\ R(-\theta)$.....7)

Fig.4 shows POPO (Pulsed Optical Parametric Oscillation) using nonlinear optical crystal. Double refractive index of BBO(beta barium borate) crystal were used for phase matching. Te results of conventional and matrix phase matching are nearly the same.

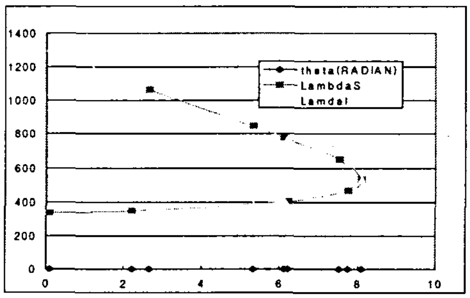


Fig.4 POPO matrix phase matching.

In conclusion, thin substrate or lowly birefringent material were adopted for optical disk and pulse reproducing method was also promising against nonlinear degradation of reproduced signal.[3] Complex refractive index is nonlinear functional & an-isotropic matrix. Maxwell-Jones matrix, exponential of CRIFM is solution of Maxwell equation in an-isotropic medium. Fresnel reflection & transmission coefficient is matrix in birefringent medium. (Fresnel Jones Matrix) Snell's law can be modified with CRIFM to describe double refraction. Triple refractions are expected to be observed. (tri-refringence) Angular dependence of refractive index was modified for CRIFM.

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