Fundamental Principles of Optical Lithography

The Science of Microfabrication

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Bonus Homework Problems

Chapter 2

2.1. For a quasi-monochromatic, time harmonic wave traveling through a non-absorbing medium, show that

$$\vec{\nabla} \times \vec{H} = -i\omega\varepsilon\vec{E} \quad \text{and} \quad \vec{\nabla} \times \vec{E} = i\omega\mu\vec{H}$$

2.2 Consider a weakly absorbing, non-magnetic material as described in equations (2.22) – (2.23). Show that for this case

$$\frac{\sigma}{2\varepsilon\omega} \approx \frac{\kappa}{n}$$

So that the requirement that a material be 'weakly absorbing' can be stated as $\kappa << n$.

2.3 Show that for any non-magnetic substance

$$n^2 - \kappa^2 = \varepsilon_r \,, \quad \text{and} \quad n\kappa = \frac{\sigma}{2\varepsilon_0\omega}$$

Since many substances (such as metals) have $\kappa > n$, explain the significance of a negative dielectric coefficient.

2.3 Derive the continuity equation (conservation of electric charge) from Maxwell's equations:

$$\nabla \cdot \boldsymbol{J} = -\frac{\partial\rho}{\partial t}$$

2.4 Consider a plane wave incident on the plane boundary between two materials at an angle (with respect to the normal of the boundary) θ_1 in material 1. Derive Snell's Law:

$$\boldsymbol{n}_1 \sin\theta_1 = \boldsymbol{n}_2 \sin\theta_2$$

where $\boldsymbol{n}_1$ and $\boldsymbol{n}_2$ are the refractive indices of materials 1 and 2, respectively.

Chapter 3

3.1. Suppose that over the focus range of interest, the resulting aerial image follows equation (3.32). If the focus error experienced by the image follows a probability density function given by $P(\delta)$, show that

$$I_{defocus}(x) \approx I_{no-defocus}(x) - f(x)\left[\sigma_F{}^2 + \mu_F{}^2\right]$$

where μ_F and σ_F are the mean and standard deviation of the probability distribution $P(\delta)$, respectively.