Sensitivity analysis of grating couplers in gigascale integration (GSI)

Y-M. Wu, T. K. Gaylord, E. N. Glytsis, and J. D. Meindl
School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332-0250
tgaylord@ece.gatech.edu

Abstract: Rigorous Coupled-Wave Analysis (RCWA) is applied to calculate the effect of general angular misalignments of volume grating couplers used in gigascale integration (GSI) chips. The misalignment angles for realistic chip tolerances are presented.

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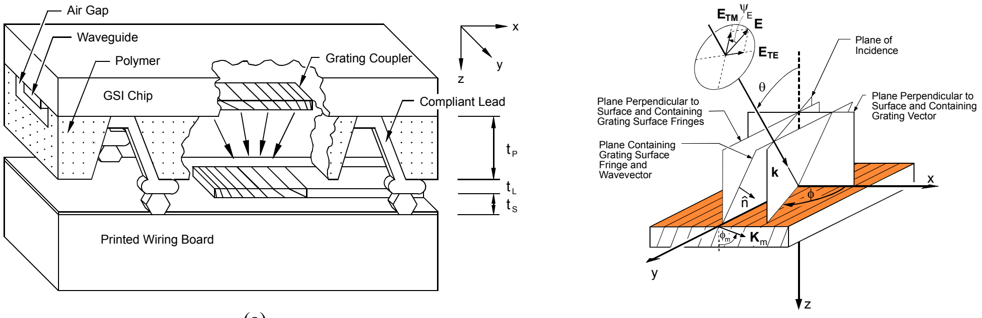
Optical interconnects are a promising approach to overcome the performance limitations of electrical interconnects in gigascale integration (GSI) chips. The diffraction efficiency of grating couplers, an essential component of optical interconnects, is highly sensitive to angular misalignments. Because of manufacturing tolerances of chips and printed wiring boards (PWB), the couplers can experience yaw, pitch, and roll misalignments. Therefore, a thorough analysis of the sensitivity of the couplers is needed to understand the effects of the misalignment. Rigorous Coupled-Wave Analysis (RCWA) is applied to analyze the effects of the misalignments on the grating. A grating coordinate system is defined, and the ranges of misalignment angles are obtained from chip tolerances.

As shown in Fig. 1 (a), the separation between the GSI chip and the PWB in the z direction is determined by the sum of the polymer thickness (t_P), electro-plated lead thickness (t_L), and solder bump height (t_S). Consequently, the manufacturing tolerances of the components can lead to different separations of the chip at two adjacent solder bump locations and result in angular misalignments of the bottom grating coupler. The misalignment angles of the grating in the x and y directions are calculated by assuming worst-case tolerances at two adjacent solder bump locations, with the smallest separation at one location and the largest at the other. The misalignment angles in the z direction caused by lateral shifts of the solder bump position are calculated by assuming lateral shifts at two adjacent solder bump locations that move in the opposite directions. As a result, the range of misalignment angles is found to be (-12.6^{o}, 12.6^{o}) in the x and y directions and (-2.3^{o}, 2.3^{o}) in the z direction of the chip.

Several conventions for the grating diffraction calculation coordinate system exist; the coordinate system used in the analysis is shown in Fig. 1 (b) [2]. After angular misalignments, the incident wavevector will most likely not satisfy the Bragg condition giving rise to conical diffraction. For an incident plane wave, the new incident (θ) and azimuthal (φ) angles after angular misalignments are given by $(\theta,\varphi) = \left(\cos^{-1}(\mathbf{z}\cdot\mathbf{k}), \tan^{-1}(k_y/k_x)\right)$, where **z** is the unit z vector, **k** is the incident wavevector after misalignment, and k_y and k_x are the y and x components of **k**. The angles (θ, φ) are functions of the misalignment angles and are obtained given these angles. The corresponding diffraction efficiencies are presented.



(a) (b)

Fig. 1. (a) GSI chip showing polymer, lead, and solder bump thickness for calculation of angular misalignment. (b) Grating diffraction calculation coordinate system. Incident and azimuthal angles are denoted by (θ, φ).

References:

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