ELEC2228 Jitt1 Compare Waveguide Loss 2023/24

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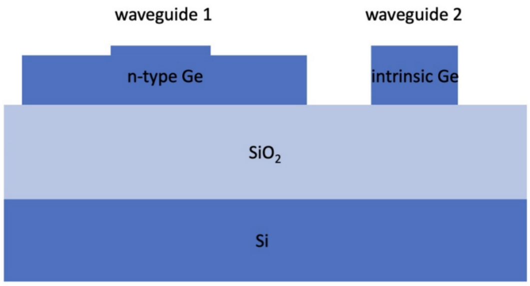

$$\alpha = \frac{4\sigma^2 h^2}{\beta(r+2/p)} = \frac{\sigma^2 k_0^2 h^2}{\beta} \cdot \frac{E_s^2}{\int E^2\, dx} \cdot \Delta n^2 \tag{1}$$

The figure compares two germanium-on-insulator (GOI) waveguides. Waveguide 1 uses n-type germanium, while waveguide 2 uses intrinsic germanium. Intrinsic germanium is a pure form of germanium without any significant amount of impurities or dopants. N-type germanium, on the other hand, is doped with impurities that provide extra electrons (negative charge carriers) to the material.

Intrinsic germanium waveguide (waveguide 2) has fewer free carriers than n-type germanium, which means it will generally have lower free-carrier absorption and, therefore, potentially lower propagation loss.

But due to the equation of surface scattering (1), the loss of a waveguide (α) is depends on the surface roughness(σ), modal propagation constant(β), free space wavenumber(k_0), waveguide thickness(h), and the refractive index(Δn). β, k_0, h are same for these two waveguides, so we only consider σ and Δn.

The n-type germanium waveguide (waveguide 1) is a rib waveguide, where a portion of the waveguide core material extends into the upper cladding layer, forming a rib-like protrusion. The protrusions of the rib waveguide is much smaller than that of the strip waveguide at the same hight. The mode of the rib waveguide is confined at the central region, therefore there is less contact with the peripheral region, so the surface roughness of the slab part of rib waveguide can be ignored. Thus the surface roughness will impact smaller region on rib waveguide compared to strip wave guide, leading to relatively lower propagation loss.

The refractive index of a material usually represented by Cauchy's equation:

$$n(\lambda) = A + \frac{B}{\lambda^2} \tag{2}$$

Which means it is depends on the wave length of the material. At the same wavelength, n-type Ge always have a smaller wave length than intrinsic Ge. Therefore the propagation loss of n-type Ge is smaller.

Assuming that the surface scattering has more significant impact on the loss of the waveguide, due to its structure and material, waveguide 2 will have a greater propagation loss.