Digest of Tech. Papers *The 11th Conf. (1979 International) on Solid State Devices, Tokyo*

B—4—1 (Invited) Materials and Devices for Long Wavelength Optical Communication

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Since the advent of injection lasers and optical fibers, the trend has been continueing to extend to longer wavelength communication.

The recent important impetus has been the improvement of the fiber loss. As shown in Fig. 1, the loss characteristics reached the theoretically predicted ultimate point, 0.2 dB/km , which offers new various feasibilities in the communication.

As no other possibility exists in the choice of practical fiber materials, the wavelength is restricted in the near IR range of 0.8 ~ 1.6 μm.

Aiming at long-wavelength devices, study of multicomponent compound such as ternary GaInAs was conducted since 10 years. Various technologies for lattice matching of ternary epitaxial structure by inserting a grading layer were tried, and the crystalline property of the grown ternary epitaxial layer was investigated. As the required two degrees of freedom need quarternary compound, the conclusion is that GaInAsP on InP is best suited both to the lattice matching and the wavelength adjustment.

As the quarternary alloy has an excess freedom in atomic bond pairing configurations, the epitaxial lattice matching is accomplished relatively easy. Also the flexibility in bond angle deformation, associated with incorporated In, results in the self-adjustment of lattice-matching in the epitaxial growth.

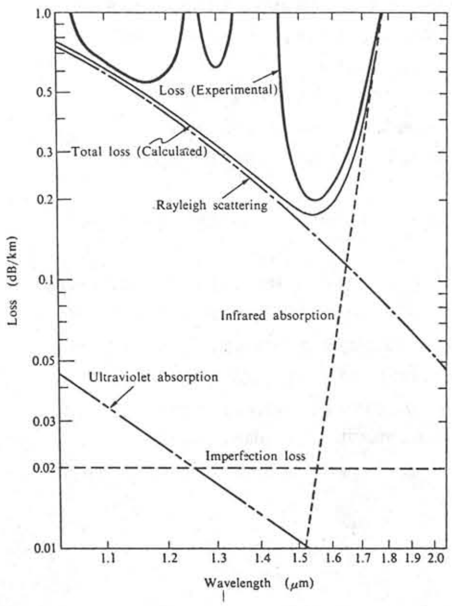

Fig. 1
Single mode fiber loss spectrum with individual loss contribution

Small surface recombination velocity and the corresponding intense photoluminescence are also benefited by the incorporated In, which decreases the number of interband states.

Other quarternaries are more or less inferior to GaInAsP, with respect to crystalline quality and miscibility gap, at least with LPE method.

Several technical problems for fabricating lasers are being almost solved. Various DH structures, such as were proposed for GaAlAs lasers, have been successfully applied. Self-aligned, proton-implanted and buried-mesa structures are fabricated and exhibit good performances. Single-mode is easier to be realized. Axial as well as transverse mode control is attained and compared with theoretical estimation.

At 1.3 µm, 40 mW per facet is obtained and operates until at 100°C. The threshold current density reaches as low as 1.0 kA/cm^2.

In 1.5 µm range, fabrication is relatively difficult due to the meltback phenomenon, which is avoided by the quarternary cap-contact layer. CW LD of 1.5 µm operates at 0°C, and 1.67 µm LD pulsed operation at RT. LED external efficiency reaches 3 %.

The lifetest reveals that the estimated degradation speed is at least by an order of magnitude less than with GaAlAs, although the activation energy is similar. Also the optical damage is by an order of magnitude smaller.

As for optical detectors, the most practically useful material is germanium. The wavelength extends to 1.6 µm, which is coincident with that of the silica fiber. Germanium APD has been developed since 11 years, and APD with 2 GHz bandwidth is commercialized.

In the long wavelength region, the dark current problem becomes less important for PIN. For lower speed application, Ge PIN with incorporated amplifier exhibits various merits and high gain.

Ternary and quarternary materials are being investigated for a sharp breakdown property. High amplification factor, in excess of 3000, has been observed with GaInAsP DH structure.

According to the decrease of the fiber loss, isolation function is increasingly attracting attention. A good isolator is realized with YIG, with which the insertion loss is 0.9 dB and the backward loss is 30 dB at 1.3 µm.

Among wave-multiplexing devices, brazed silicon grating seems most promising with small insertion loss.

Some transmission experiments are in progress. Some of the successful results are as follows. At 1.3 µm, 1.2 Gb/s x 23 km and 1.6 Gb/s x 13 km. At 1.5 µm, 100 Mb/s x 29 km and 400 Mb/s x 18 km. These are single-modes. Long-distance multimode experiments are 32 Mb/s x 62 km and 100 Mb/s x 52 km at 1.3 µm. All of them are without repeaters.

Utilizing the above results, long-wavelength systems, including submarine transmission, are in planning. Wavelength multiplexing is also under developement as for interactive TV.