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Photonic Power Converters for Telecom Optical Wavelength Bands

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Abstract*: This talk will give an introduction into the requirements and boundary conditions for photonic power converters (PPCs) for telecom optical wavelength bands. The existing literature will be reviewed. Examples of different technological realizations for telecom wavelengths PPCs will be discussed. Moreover, recent approaches and results of telecom wavelength PPCs under development at Fraunhofer ISE will be presented.*

1. Introduction

Photonic power converters (PPCs) are photovoltaic cells optimized for the conversion of monochromatic or narrow band light in optical wireless and fiber power transmission (OWPT) systems. In the field of OWPT, systems based on telecom wavelengths receive an increasing interest and, thus, the same holds for PPCs for telecom optical wavelength bands.

These bands, also known as O-, E-, S-, C-, L-, and U-band, refer to the so-called second (around 1310 nm) and third (around 1550 nm) transmission window in optical fibers, see table 1. Note that the names have rather historical reason. The first window refers typically to around 850 nm wavelengths.

Today, for OWPT systems telecom wavelength bands are of interest for different reasons: For fiber coupled systems, here the attenuation coefficient in optical fibers is low. It reaches a minimum typically around 1550 nm. Thus, light can be transmitted over hundreds of meters or even kilometers of optical fiber [1,2]. For wireless systems, these bands are (a) advantageous in terms of laser safety [3,4], and (b) atmospheric transmission windows exist around 1200-1300 nm and 1510-1750 nm which is especially relevant for long-range free space optical links [5].

Table 1. Optical fiber transmission windows and wavelength bands

Win-dow	Band	Description	Wavelength Range
1st		first window	800-900 nm (650-950 nm)
2nd	O	original	1260-1360 nm
	E	extended	1360-1460 nm
	S	short wavelengths	1460-1530 nm
3rd	C	conventional	1530-1565 nm
	L	long wavelengths	1565-1625 nm
	U	ultralong wavelengths	1625-1675 nm

2. Absorber Materials

III-V compound semiconductors constitute well suited absorber materials for wavelengths in the telecom bands. Fig. 1 plots bandgap versus lattice constant for various III-V materials. For the fabrication of photovoltaic cells, different material class approaches can be considered to realize appropriate absorber material bandgaps:

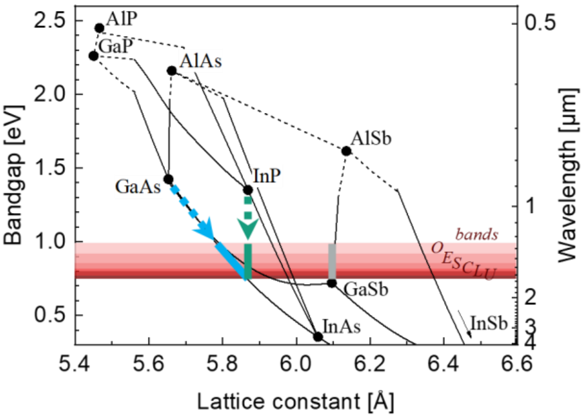

Fig. 1. Bandgap energy and associated wavelength plotted versus lattice constant for various III-V compound semiconductors (circles: binary, lines: ternary, encircled areas: quaternary). The telecom optical wavelength bands are highlighted in red.

1. (green bar) Quaternary InGaAsP or InAlGaAs grown lattice matched on InP substrate.
2. (blue bar) Ternary GaInAs grown lattice mismatched on GaAs substrate.
3. (gray bar) AlGaAsSb (or more generally AlGaInAsSbP compounds) grown lattice matched on GaSb substrate (not further considered here).
4. (not shown) Dilute nitride materials GaInNAs (or more generally other AlGaInBiNAsSb compounds) grown lattice matched on GaAs substrate (not further considered here).

Lattice matched growth on InP substrate facilitates high material quality with low defect density, as required for high efficiency PV cells. However, downsides of InP bulk substrates are their brittleness and high cost. In addition, they are commercially hardly available larger than 4” (10 cm) diameter. For that reason, the ternary compound GaInAs grown lattice mismatched on a GaAs substrate poses an interesting alternative. GaAs in comparison with InP is mechanically more stable and less expensive; in addition, scaling of industrial manufacturing can build on commercially available substrates up to diameters of 8” (20 cm). On the other hand, to realize decent material qualities the lattice mismatch requires to incorporate a metamorphic buffer structure to compensate for the lattice mismatch [6]. For buffers graded from GaAs to InP, we have demonstrated threading dislocations densities below

2×10^6 cm² [7]. Another way of looking at it can be to grow a metamorphic buffer grading to the target GaInAs material with the appropriate Indium composition and then stop the growth with a defined target layer. Thus, "engineered substrates" with flexibly tunable lattice constant can be fabricated.

3. Telecom Wavelength PPCs at Fraunhofer ISE

At Fraunhofer ISE PPC devices for O-band (around 130 nm) and C-band (around 1550 nm) optical wavelengths are under development. For O-band wavelength PPCs were realized following both above mentioned approaches: 1) Single-junction InGaAsP based devices grown lattice-matched on InP substrates, and 2) single-junction GaInAs based devices grown lattice-mismatched on GaAs following a step-graded metamorphic buffer approach. For C-band wavelength PPCs, single- and multi-junctions based on $In_{0.53}Ga_{0.47}As$ subcells are currently under development. Single-, dual-, and 10-junction $In_{0.53}Ga_{0.47}As$ PPCs have been grown lattice-matched on InP substrates and at the time of writing this short paper are being processed to functional devices.

4. Content of the Conference Presentation

This talk will give an introduction into the requirements and boundary conditions for photonic power converters (PPCs) for telecom optical wavelength bands. Relevant literature will be reviewed. Examples of different technological realizations for telecom wavelengths PPCs will be discussed. Moreover, recent approaches and results of telecom wavelength PPCs under development at Fraunhofer ISE will be presented.

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