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Overview of the Second Order Optical Nonlinearity in GaN Waveguides for Use in Devices for Applications in Optical Communication

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Purpose: How second order nonlinearity of GaN is used in the realization of advanced optical devices in telecommunication.

Advantages of GaN:

- Supports all types of optical nonlinearity. Silicon does not have second order nonlinearity.
- GaN is CMOS compatible. Best option for both microelectronics and photonics.
- Shows ultrafast relaxation time in electro-absorption switching devices. ISB recovery time=150~400fs.
- GaN based lasers, switches, modulators, amplifiers, photodetectors are possible to materialize.
- Supports photonic integration with Silicon and Lithiun Niobate Micro-resonators.
- GaN does not suffer photorefractive effects. GaN bases optical frequency converters would not require heating during frequency conversion.

CMOS Compatibility: GaN needs to be CMOS compatible to function as both microelectronics and photonics in device development for ultrafa communication.

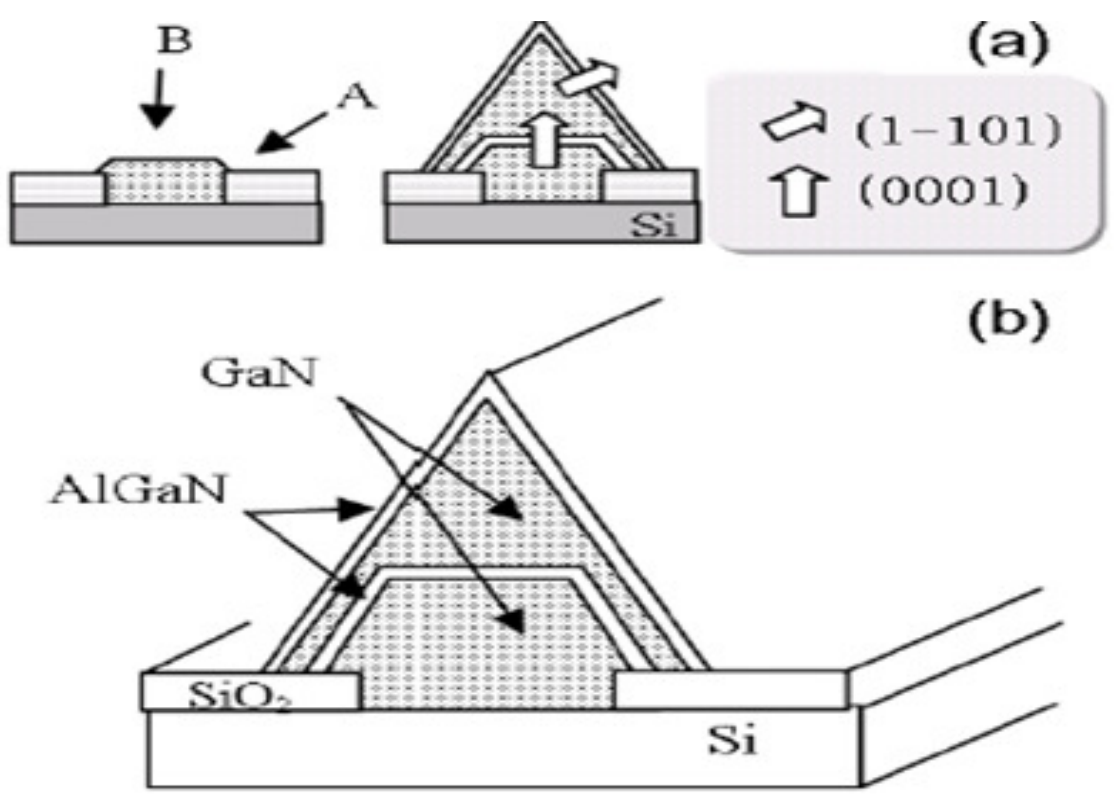

Fig 1. Diagram of AlGaN/GaN/AlGaN Waveguide [1]

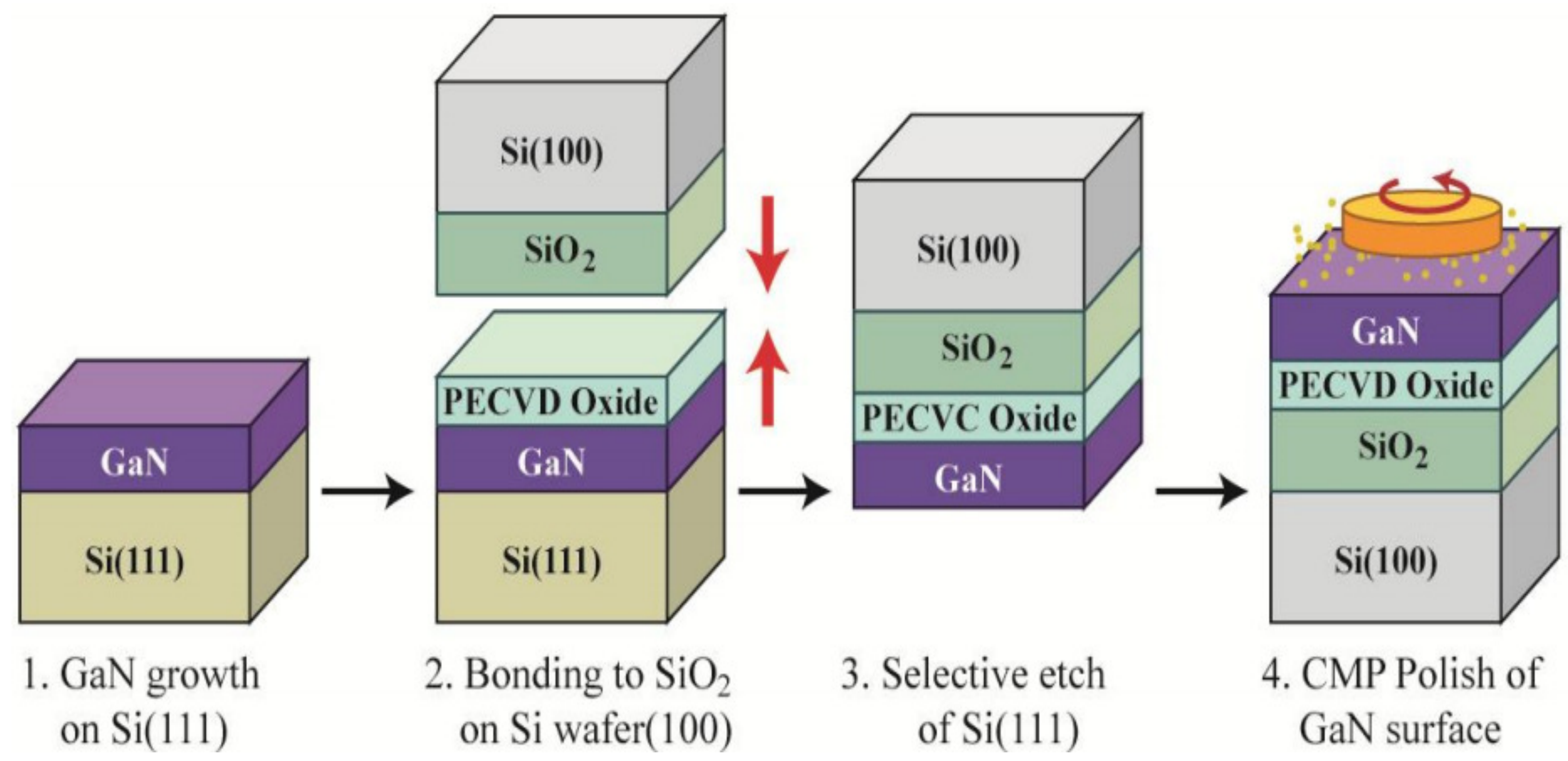

Fig 2. GaN on silicon dioxide on silicon substrate [2]

Exploitation of Second Order Nonlinearity:

- Second order susceptibility can be achieved by breaking the symmetry of the conduction band potential.
- Large conduction band offset close to 1.8 eV in the interface of GaN/ AlN in telecommunication band.
- Utilizing ISBT and high relaxation time in QW, terahertz level optical switching is possible.
- QW shows remarkable spontaneous strained-induced piezoelectric polarization and breaks the symmetry and shows very high value of second order nonlinearity.

Implementation of Second Order Nonlinearity:

- Modulators
- Resonators
- Bragg reflection Waveguide
- Optical Polarization based Logic Functions
- Parametric Optical Amplification
- Array Waveguide grating
- Quantum Optical Applications
- Quasi-phase matching

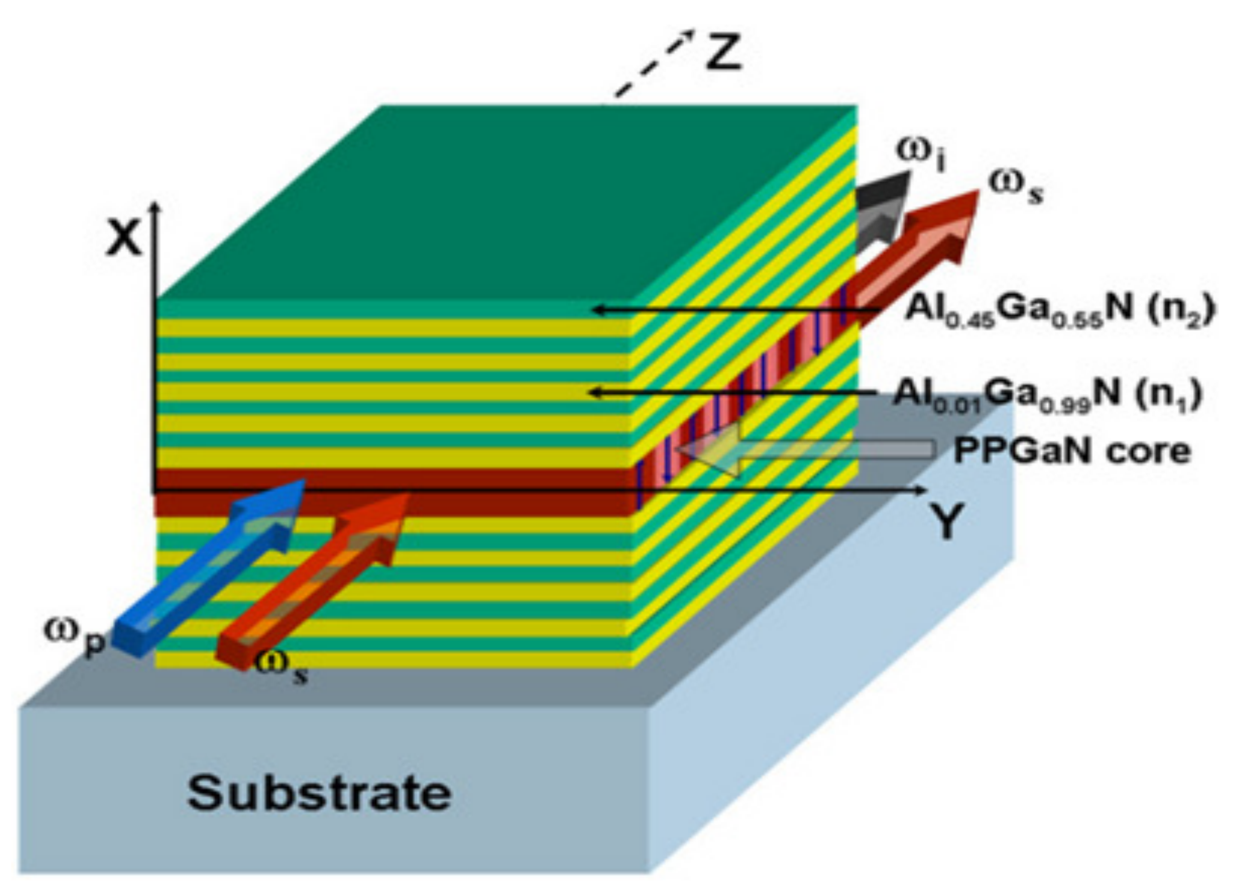

Fig 3. Diagram of Bragg Reflection Waveguide [3]

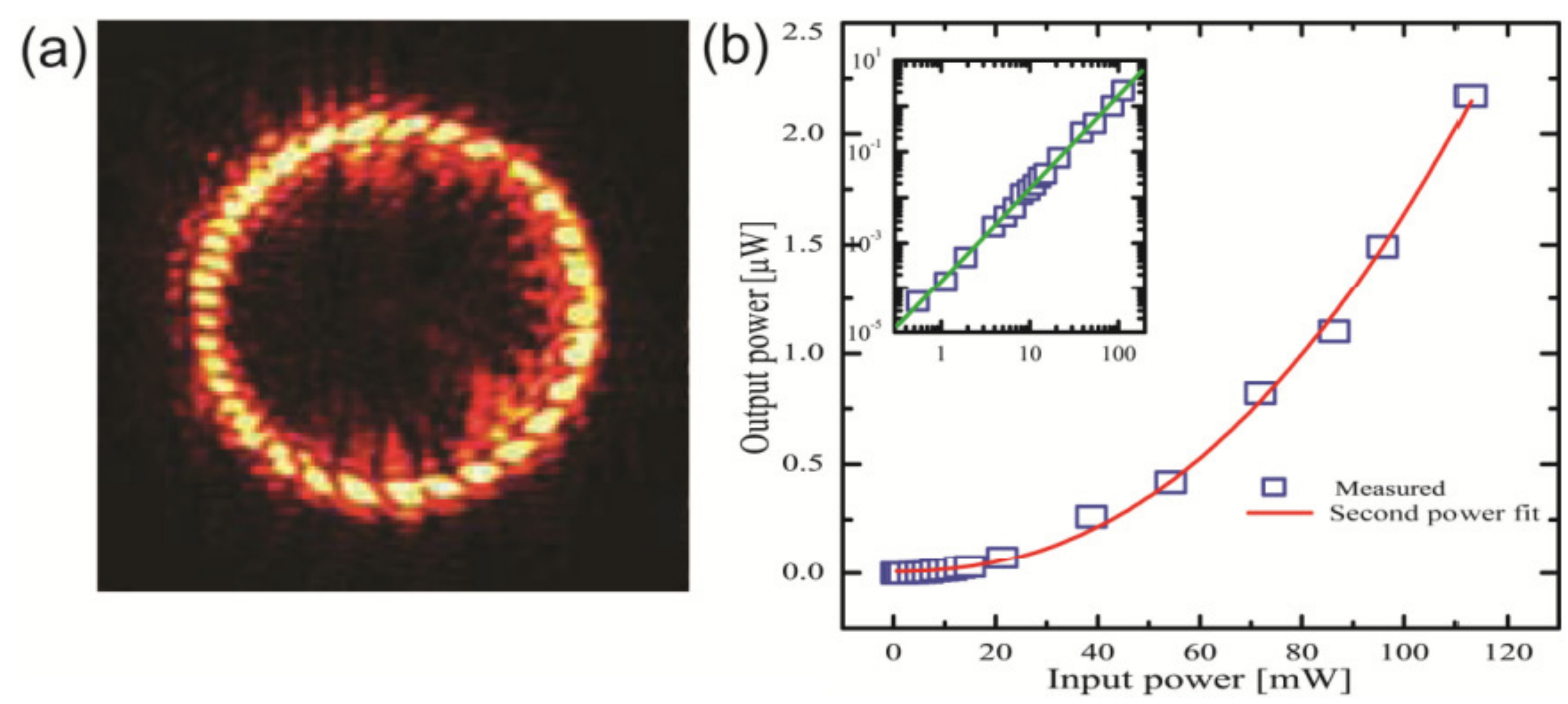

Fig 4. (a) Capture Image of GaN microring during second harmonic generation
(b) Power of the second harmonic power as a function of the pump power [4]

Constraints:

- GaN is expensive compared to Silicon
- Lack of stable lattice-matched substrate
- Processing technology is not matured enough

References:

[1] Kim, H., et al. "Optical characteristics of the AlGaN/GaN/AlGaN waveguide grown on (111) Si substrate." Journal of the Korean Physical Society 42 (2003): S622-S624.GaN is expensive compared to Silicon

[2] Xiong, Chi, et al. "Integrated GaN photonic circuits on silicon (100) for second harmonic generation." Optics express 19.11 (2011): 10462-10470.

[3] Das, Ritwick. "Ultra-broadband optical parametric amplification by tailoring the group-velocity dispersion of Bragg reflection waveguides." Journal of Physics D: Applied Physics 42.23 (2009): 235106.

[4] Xiong, Chi, et al. "Integrated Photonic Circuits in Gallium Nitride and Aluminum Nitride." International Journal of High Speed Electronics and Systems 23.01n02 (2014).