MEMS Modulated Photonic Integrated Circuits (PICs)

Motivation & current state-of-the-art at ISIT:

MEMS and PICs

Integrated photonics has developed from a table-top optical systems in the research laboratories to the chip scale with compact sizes, portable weight, and low power consumption. Thanks to the advancement in nanofabrication technologies from MEMS sectors, large scale foundries made valuable contributions to the commercialization of integrated semiconductor lasers, waveguides, modulators, photodetectors, as well as low-loss PICs.

Waveguides

Since delivering the light to the chips via fiber coupling has always been a big challenge to reduce the optical loss, the alternative was to implement waveguide arrays in PIC chips. According to the research in the past decades various material platforms have been developed, and our technological advances at the Fraunhofer Institute for Silicon Technology (ISIT) enables us to fabricate waveguides from Si, AlN, and Si_3N_4, including Silicon Oxide cladding under both PECVD and LPCVD process.

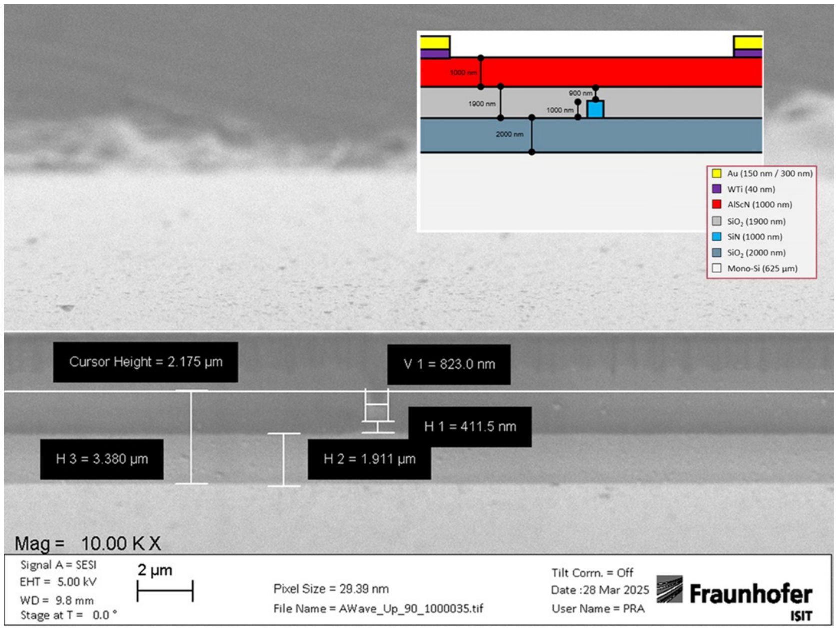

Fig. 1. A Si_3N_4 waveguide with SiO_2 cladding and AlScN layer for investigating the Surface Acoustic Wave (SAW). SEM image and the inserted designed cross-section shows a good agreement of our fabrication. This is one of the chips (5mmx6mm) from 200mm wafer shown in the header.

As the final goal is to bring these chips in a CMOS compatible packaging, Si has been the leading material for commercialized optical modulators in data center and optical telecommunication systems. In the last decade, various materials have been investigated to increase the efficiency and multifunctional capabilities. As a result, Silicon Nitride has attracted much attention due to its wide transparency window, ultra-low linear losses, large Kerr nonlinearity, and flexibility in dispersion engineering and large-scale foundries are implementing this platform in their fabrication procedures.

Actuation with AlN and Al(Sc)N Piezo-electric modulators

To add multi-functionalities or narrow the precision in optical domain, efficient and high-speed tuning of integrated photonic circuits is of high demand for various state-of-the-art applications. As an example, resonance tuning can be used for tunable filters and overcome fabrication errors. In addition, the programmability of PICs enables more complex photonic circuits to be built, such as photonic neural network and photonic quantum computing.

The optical waveguides (such as: AlN, AlScN), can be modulated in combination of strain/electro-optical effects (Fig. 1) and thanks to the change of the refractive index in these materials, by external electric field, the fine tuning of such devices can support broader application areas. The thermo optical tuning is one of the first and still widely used platform, which is limited by slow tuning speed (~1 ms), high power consumption (~1 mW), and large thermal cross-talk. These properties of thermal actuators brings a lot more challenges in large scale production.

AlScN which is one of the main innovation and fabrication concentration at ISIT in the past decade, has shown unique physical properties, such as:

- Bidirectional linearity, bias free operation
- Simple stacks: No buffer, no demanding passivation
- Good endurance
- Greatly reduced reactive power and lower losses (ϵ_r ~ 20, tan δ ~ 0.3%)
- Lead-free
- Low deposition temperature (< 350°C) and diffusivity for post-CMOS integration
- Extreme maximum use temperatures (> 1000°C)

Technological achievements and capabilities at ISIT:

- ISIT isspecialized in the development and manufacturing of a wide variety of (acoustic and optical) microelectromechanical systems.
- With ISIT´s expertise in the deposition and processing of Silicon Oxide, Silicon, Silicon Nitride, and Aluminum Nitride broad-wavelength-ranges can be covered.
- Piezo-electric materials are one of our core technological advances. We are capable to produce single and multilayer stacks of AlScN and AlN with good morphological properties across 200mm wafers for MEMS actuators and PICs.
- The state-of-the-art at ISIT is the capability of combining various waveguide mediums with the novel piezoelectric materials, implementing various optical and electronic characterizations to optimize the necessities fabricating multifunctional devices (Fig. 2). This makes us a powerful partner in the field of photonic integrated circuits.

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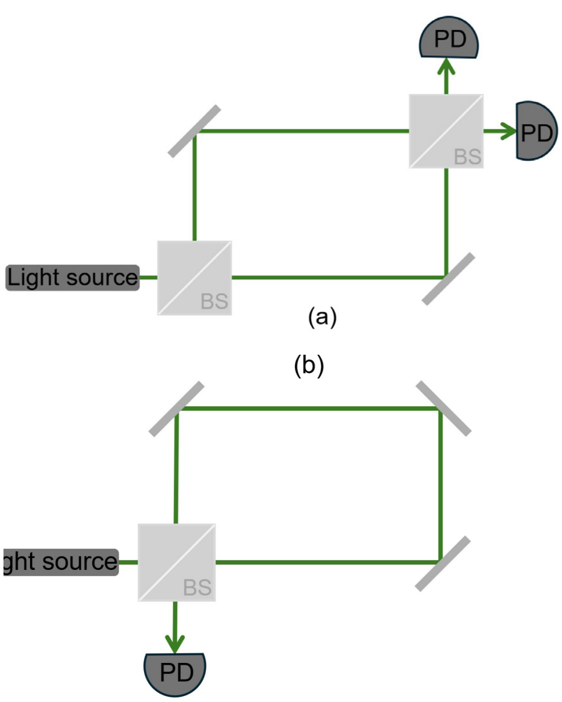

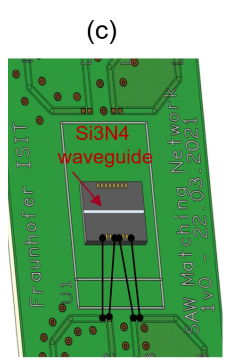

Fig. 2. Two Optical interferometric setups,
a. Mach-Zehnder,
b. Sagnac, that we use to characterize our chips.
c. shows the section of our designed PCB for SAW investigations where the light couples to the waveguide.