Hybrid Integrated Photonics with 2D Materials

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Starting with the isolation of graphene in 2004, the family of 2D materials has extensively expanded and has attracted tremendous interest for both fundamental research as well as for applications in photonics and optoelectronics. Moreover, despite the high application potential of nonlinear optics for all-optical information processing, no nonlinear material candidate has emerged as a clear choice to complement silicon photonics so far and create effective hybrid optical circuits. Suitable materials are sought to scale down devices while providing a strong optical nonlinearity. In this context, the nonlinear optical properties of various 2D materials have been experimentally investigated. Integrating these materials into a scalable and silicon-compatible platform could provide a pathway towards realizing low-power nonlinear optical devices [1]. Indeed, 2D materials in general have the potential to offer attractive properties that complement silicon photonics. Most importantly, these 2D materials can easily be integrated onto nanophotonic devices for the next-generation of chip-scale high-speed optical communications, radiofrequency optoelectronics, and all-optical signal processing. We aim to study and identify 2D materials with suitable nonlinear properties that could be integrated onto chip-based devices. In particular, 2D materials that can be generated by using the so-called liquid metal chemistry method that has been recently developed at RMIT [2]. The 2D material generation principle is as follows, a "Skin" can form on the surface of many liquid metals, which is a self-limiting native oxide. This skin is often crystalline with minimal grain boundaries, promising an outlook to the field of atomically thin materials. For this method, post-transition elements, together with zinc-group metals and their alloys belong to an emerging new group of materials that possesses simultaneous metallic and liquid nature that award them interesting properties. Their low melting point (i.e. between room temperature and 300 °C) makes their liquid state accessible for the synthesis of novel materials and physical chemistry [3]. Hence, we consider the technique as a relevant method for the integration of 2D materials which cannot be easily generated via other traditional methods. Gallium Nitride (GaN) and Indium Nitride (InN) appear to be suitable 2D materials that can be synthesized by the liquid metal chemistry, while they are expected to exhibit interesting nonlinear optical properties [4, 5].Our progress so far has been that we first synthesized GaN and InN on glass and silicon substrates and measured their structural and optical properties and next we will integrate them onto photonic devices. As a first chip-based platform, we chose Si_3N_4 waveguides as the underlying photonic circuit to test the 2D materials deposited on top of them. Si_3N_4 waveguides display relatively low propagation loss, to promote light-matter interaction between the 2D material and the waveguide mode. We investigate adequate transfer methods for integrating these 2D materials onto photonic devices, to realize optimized nonlinear devices.

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