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Chip-based waveguides for high-sensitivity biosensing and super-resolution imaging

Key words: Waveguide-based sensing; Waveguide-based imaging; Evanescent illumination; Frequency shifting and stitching

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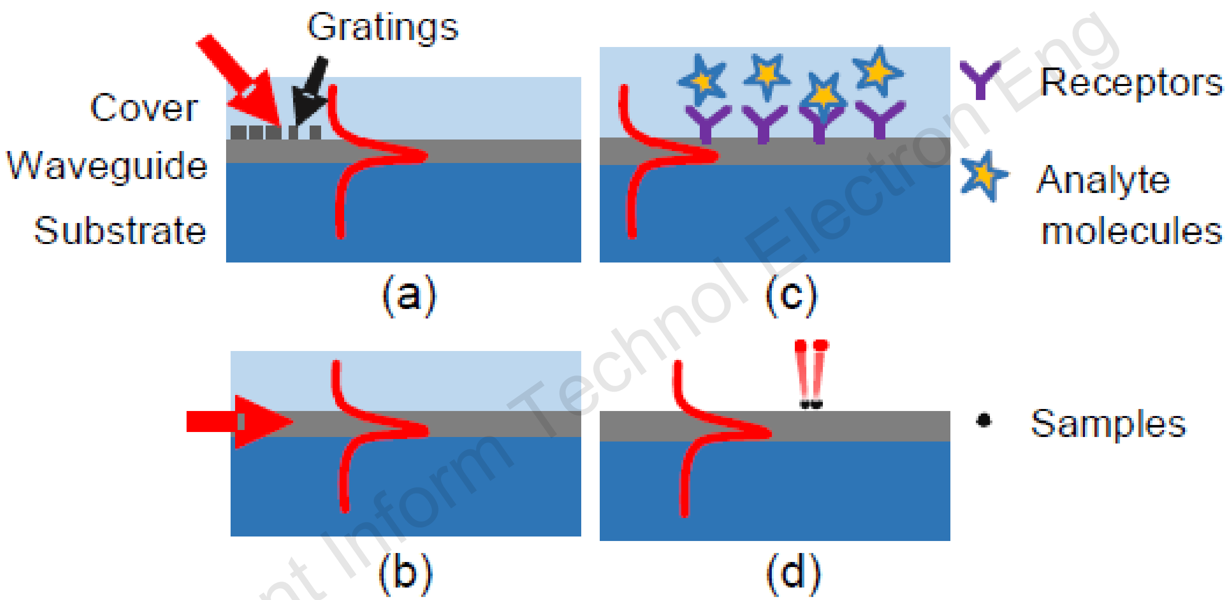
Motivation

1. In this review, we introduce some chip-based waveguide biosensing and imaging techniques. Optical sensors are immune to electro-magnetic interference and can provide multiplexed detection. In particular, waveguide-based biosensors have effectively reduced the complexity of the detection systems, and some of them have been commercialized.
2. The fabrication process for these waveguide chips is compatible with conventional semiconductor-fabrication methods, and thus the chips can be produced in high yields.
3. These chip-based waveguide biosensing and imaging techniques use a well-confined evanescent field to interact with the surrounding materials and achieve high sensitivity sensing and high signal-to-noise ratio (SNR) super-resolution imaging.

Principle and working mechanism

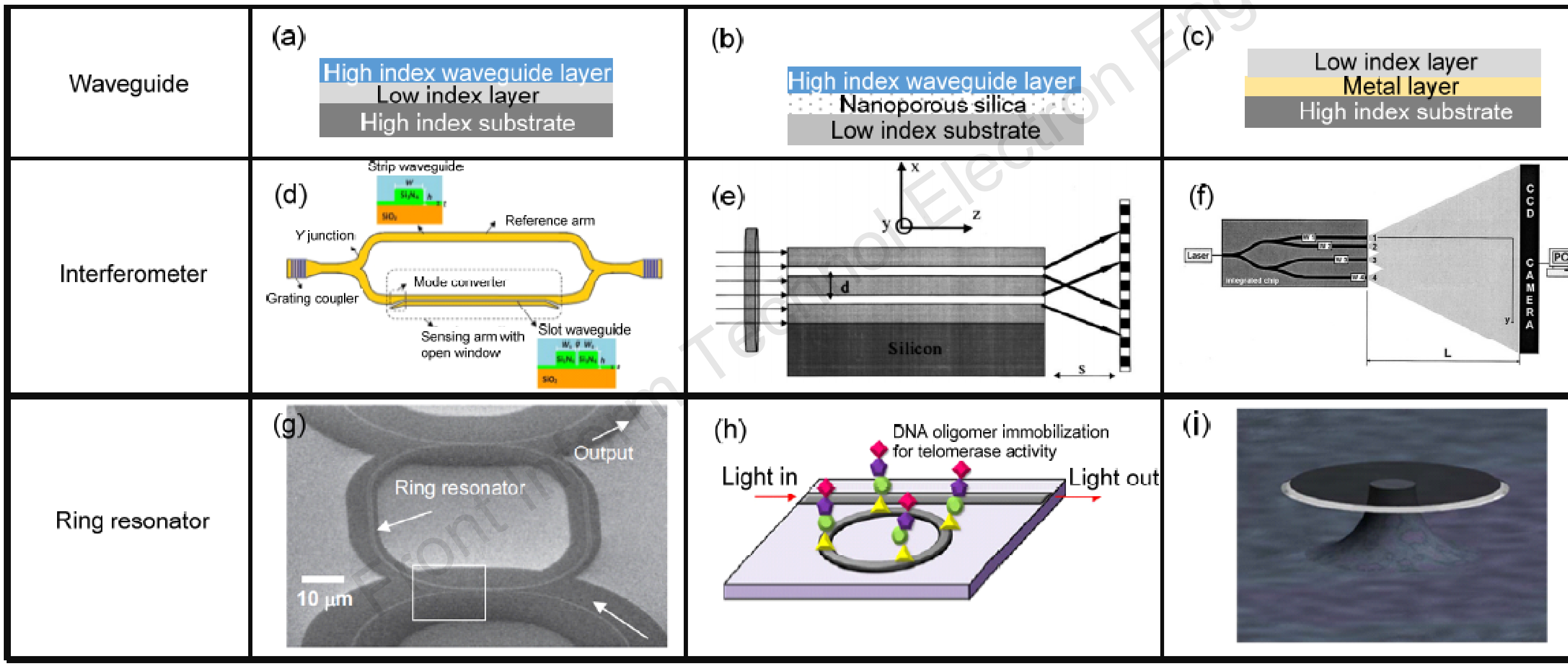
Light can be effectively coupled into the waveguide using methods like grating coupling, end-fire coupling, and prism coupling.



The evanescent field propagating in a planar waveguide can work as a light source with high wave vectors to tune the ON/OFF state of the labeled fluorescent molecules. The evanescent field around the interface of the waveguide can directly interact with the sample as well.

Chip-based optical waveguide biosensors

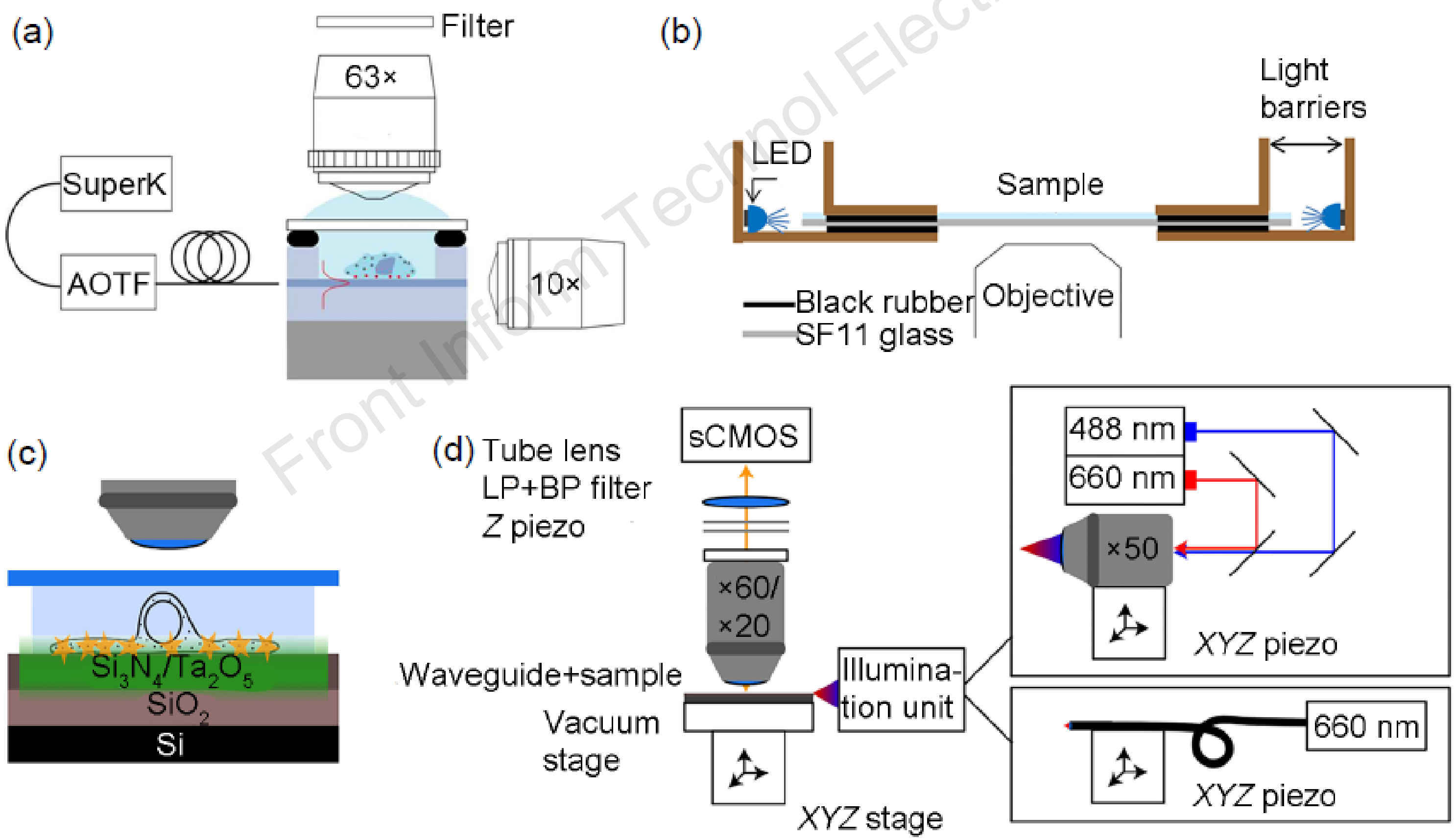
By coating a chemically selective layer on the surface, analyte molecules in the gaseous or liquid sample are absorbed. Hence, changes in the effective index of the TE and TM modes can be induced.



By measuring the refractive index (RI) change induced by ambient conditions, many waveguide chip-based optical methods, such as optical waveguide based biosensors, waveguide based interferometer biosensors, and waveguide based ring resonator biosensors, are designed for detection and testing.

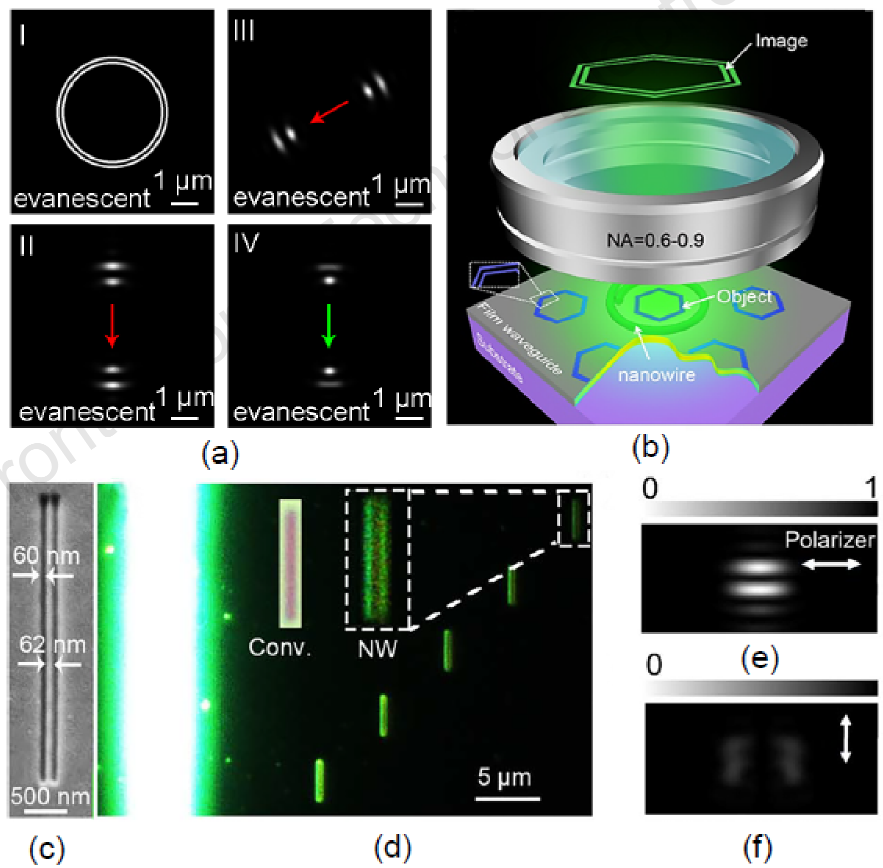
Fluorescence labeling chip based micro/nanoscopy

Fluorescence labeled chip based waveguide microscopy combines the advantages of conventional fluorescent microscopy and dark field imaging, achieving a high SNR image in a wide field of view (FOV) with tens of nanometers resolution.



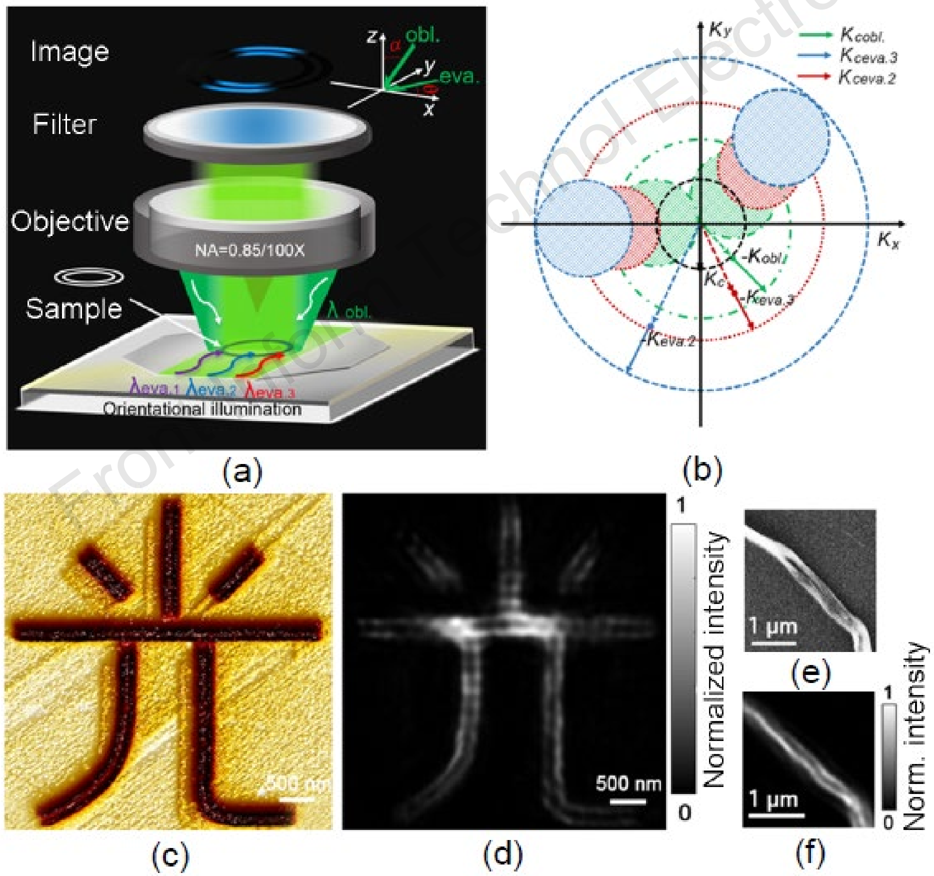
Label-free chip based waveguide micro/nanoscopy

By shifting the high spatial frequency information of subwavelength samples to the passband of a microscope system, techniques based on frequency-shift effect have demonstrated optical super-resolution capability. The reported FOV reached 6000 μm^2, while the system resolution reached 122 nm.



Label-free chip based waveguide micro/nanoscopy

A polymer fluorescent film based super-resolution chip (SRC) with a polygon working region has been designed and fabricated. Using this SRC, a wide spatial frequency spectrum of the 2D sample was achieved, and the real size of the sample was reconstructed successfully.



Conclusions and perspective

1. The eventual goal of both waveguide-based biosensors and super-resolution imaging chips is to develop portable devices.
2. With the development of smartphones, the concept of mobile health has been proposed and related smartphone-based biosensors have been reported. In the future, a portable multifunctional biosensor, similar to the Apple Watch, will achieve many applications in healthcare.
3. With the developments in photonic integrated circuits (PIC), future on-chip laser sources will make the system more compact and easier to use, providing the possibility to realize self-powered label-free waveguide based super-resolution imaging.

Chen-lei PANG, first author of this invited paper, received his PhD degree in Optical Engineering in 2019 from Zhejiang University. He was awarded a scholarship under the State Scholarship Fund to study at California Institute of Technology as a joint PhD student from March 2018 to March 2019. He currently works at Zhejiang Lab, and his research interests focus on chip-based super-resolution imaging and defect inspection.

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