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***Abstract*—We propose a novel whispering gallery mode (WGM) microsphere resonator integrated with a tapered optical fiber. In the proposed structure, the surface of the silica microsphere is coated with a thin layer of Hafnia (HfO_2 (Hafnium dioxide)). The ~~R~~results from analytical and numerical simulations ~~show~~ indicated that the WGMs can be efficiently excited with quality factors, Q, up to 1.9×10^5 in a silica coated ~~silica~~ microsphere with a diameter of 24.08 µm, coupled to a tapered silica fiber with 1µm core radius. The sensitivity, S, and figure of merit, FOM, of the proposed structure ~~are,~~were 69nm/R.I.U (nanometers per refractive index unit) and 1.3×10^7, respectively. Integration of microspheres and coupling system with High-Q and Ultra-High-S can be used for various applications such as detection and biosensing.**

***Index Terms*— Microresonator, Integrated optic devices, Tapered fiber, Quality factor, Sensitivity**

I. INTRODUCTION

In recent years, researchers ~~attention~~ have been paying increasing attention to optical whispering gallery mode microsphere resonators ~~has increasingly grown~~, ~~due~~ thanks to their high-quality factor and the small mode volume [1]. Whispering gallery mode (WGM) optical microresonators are used as biosensors ~~in~~ across various microcavity geometries such as ~~Disks~~disks [2], ~~Rings~~rings [3], ~~Toroids~~toroids [4], and ~~Microspheres~~microspheres [5]. WGM resonances occur close to the surface of the cavity and have a high sensitivity to perturbations in the surrounding medium via its evanescent tail. Therefore, the WGM resonances are widely used in applications such as miniature biosensors for ~~the~~ monitoring ~~of~~ viruses, peptides, proteins, and etc. [6]. The quality factor and the sensitivity are two key parameters that determine the sensing performance of ~~the~~ microresonators by using ~~a~~ figure of merit (FOM) defined as ~~the~~ a product of Q and S [7].

Among the various types of microresonators, the microsphere resonators can support a very high-quality factor, ~~because~~ as low transmission loss and high coupling efficiency will be achieved ~~by~~ through the optimum gap between the microsphere and the tapered optical fiber [1,2]. High-quality factor and small modal volume have been reported for strong light confinement in the microsphere resonators ~~have been reported~~. However, there are practical limitations on the use of ~~the~~ microsphere resonators due to the alignment requirements [7]. In such systems, the maximum optical coupling efficiency is achieved by adjusting the distance between the microsphere and the tapered optical fiber with a nano-positioning system. ~~However~~On the other hand, the control of the distance between the microsphere and the tapered optical fiber is very difficult. The optimum distance between the microsphere and the tapered optical fiber can be affected by the air flow and mechanical vibrations~~, . as well as~~as Also, the tapered optical fiber may be contaminated during the sensing experiment, thus resulting in low coupling efficiency [8]. In order to obtain ~~the higher~~greater mechanical stability of the microsphere resonator coupling system, ~~it is an important requirement to integrate~~ the microsphere resonator should be integrated with the tapered optical fiber [9].

In recent years, different types of research have been done on this subject. ~~In fact~~Indeed, various methods have been reported for light WGMs excitation in the microsphere ~~have been reported~~. The excitation of the WGMs resonances into the microsphere cavity, ~~which is~~ encapsulated inside the optical fiber, was first reported by Kosma et al. In the proposed structure, ~~the~~ a quality factor of about 10^3 was achieved [10]. Another method for coupling light into the microsphere cavity, was ~~adhesive~~ attaching the microsphere and the optical fiber taper to each other with a UV curable polymer [9, 11-13]. ~~The stability~~ Stability in such systems can be ~~obtained~~fulfilled, but the sensing capability will be limited ~~because~~ since the adhesive layer isolates the microsphere resonator from the external environment. The WGM resonances inside the microsphere cavity ~~are~~ could be excited ~~by the~~via an integrated in-fiber coupler. In the proposed structure, the resonant wavelength, the full width at half maximum (FWHM), and the quality factor ~~are~~ have been measured, 1561.42 nm, 0.0988 nm, and 1.58×10^4, respectively .[14]. An integrated system based on a silver iodide phosphate glass microsphere fused on a tapered optical fiber was fabricated by Milenko et al.; ~~At~~ at the resonant wavelength of 1532 nm, the quality factor of 1.6×10^4 was obtained [15].

In recent years, thin coating layers on the surface of the microsphere resonators have gained ~~a great interest~~popularity among ~~the~~ researchers. The main advantages of these microsphere resonators are simple fabrication, low cost, flexible mechanical characteristics, high surface functionalities, and diversity [16-20].

II. THEORETICAL MODEL

In this paper, we use the finite element method (FEM) to solve the time-domain Maxwell's equations ~~because~~ as the electromagnetic field as well as the radiation energy distribution can be easily obtained by the finite element analysis. In the present study, we have introduced a model to integrate the microsphere resonator and the tapered optical fiber. In the proposed structure, the silica microsphere is coated with a 250nm thin ~~Hafnium~~ hafnium dioxide (HfO_2) layer. The diameter of the microsphere resonator with the coating layer is 24.08 µm. The refractive index of the sphere and the coating layer at the wavelength of 1550 nm are 1.444 and 2.0709, respectively. Fig. 1 illustrates a simple schema~~tic~~ of the proposed structure.

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