Polymer/compound semiconductor hybrid micro resonators with very wide free spectral range

Cem Ozturk, Yi-Jen Chiu and Nadir Dagli
Electrical and Computer Engineering Department
University of California
Santa Barbara, CA 93106

Micro resonators shaped as rings or disks coupled to optical waveguides offer the possibility of highly integrated, compact photonic integrated circuits. Building blocks of such circuits, such as ring resonator band stop filters have been realized in several different technologies [1], [2], [3]. But all these approaches have a common drawback. In order to keep the Q factor of the micro resonator high, the radius should be many times the operating wavelength. This makes the resonator multi moded and many closely spaced resonances are supported. As a result the free spectral range of the filter is narrow. Although this could be desirable for some specific applications, in general it is undesirable since it is not possible to filter a specific wavelength over a band of wavelengths. We resolve this difficulty using a hybrid integration technology. For this purpose we use the coupling between a GaAs epilayer removed from its substrate and a polymer channel waveguide as shown in Figure 1. In our previous work we demonstrated the coupling between a GaAs epilayer and a polymer channel waveguide [4]. The structure formed this way is an asymmetric directional coupler, and works as a narrow band filter. In other words coupling in this structure is very wavelength selective. But to see this coupling epilayer does not have to be long and straight. It can be shaped as either a ring or a disk. Shaping the epilayer as a ring or a disk introduces another condition to see the coupling. This is the resonance condition of the mode excited in the ring. This condition can be written to a very good approximation as $\left(\frac{2\pi}{\lambda}n_{eff}\right)(2\pi R)\cong 2m\pi$, where R is the radius of the disk and n_{eff}^{Poly} is the effective index of the polymer mode.

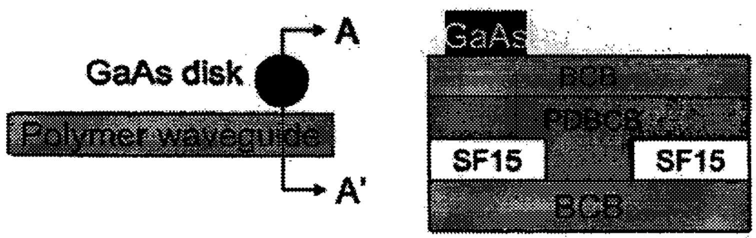

Figure 1. Top schematic and cross sectional profile along AA' of a GaAs disk resonators integrated with a polymer waveguide.

This condition physically states that the electrical length of the disk circumference should be a multiple of 2π. In a conventional resonator this equation has many solutions and the wavelength range between the adjacent solutions is known as the free spectral range. However, in our case the coupling between the GaAs epilayer and the polymer waveguide is also very wavelength sensitive since modes supported by both materials have very different effective index dispersion. This situation is illustrated in Figure 2. In this case the GaAs epilayer that acts as a slab waveguide and is multi moded. The highest order mode can have an effective index matching to that of the polymer waveguide as shown in Figure 2. Coupling between the GaAs and the polymer is possible only at this wavelength or when $n_{eff}^{Poly}=n_{eff}^{GaAs}$. If this wavelength coincides with one of the disk resonances than coupling between the resonator and the waveguide becomes possible and a transmission dip is observed. This condition forces the resonance

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equation to have only one solution; hence multiple resonances due to large disk radius are suppressed as illustrated in Figure 2.

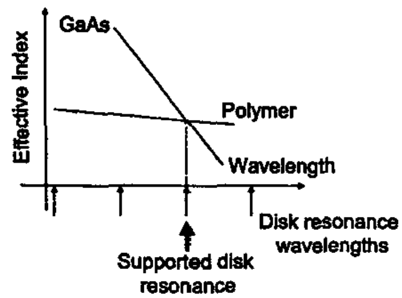

Figure 2. Dispersion of the polymer and GaAs showing how a particular disk resonance is supported when others are suppressed.

We fabricated such a structure and measured its transmission though the polymer waveguide. As expected we only observe a single transmission dip. Figure 3 shows the photograph and the transmission through a polymer waveguide coupled to a GaAs disk resonator. In this case the free spectral range due to ring radius is only about 7 nm. However, we only observe one dip over 60 nm, which is the one coincides with the coupling wavelength. Hence filtering out the other undesired wavelengths is achieved. In this case the transmission goes down to 75% of its maximum value, since the round trip loss and coupling per pass are not matched. But achieving this matching critical coupling condition can be obtained and transmission can be totally suppressed.

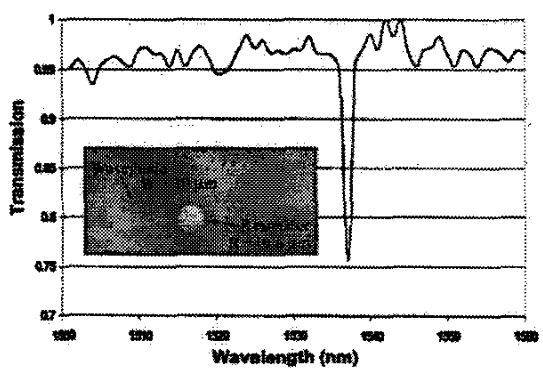

Figure 3. Photograph of the fabricated disk resonator and the measured transmission through the polymer waveguide.

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