Integration of Garnet with Semiconductors for Nonreciprocal Devices

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Magneto-optical garnet has been successfully grown on semiconductors without optical defects by minimizing the thermal processing. The main hurtles for integration were 1) finding a semiconductor-appropriate high-energy process to form the complex garnet structure and 2) overcoming the difference in thermal expansion between YIG (10.4ppm/^{o}C) and semiconductors (Si:2.33,InP:4.75) or typical buffers (SiO_2:0.55, Si_3N_4: 2.1). To explore a semiconductor-friendly process and to overcome the initial problems of thermal expansion mismatch, rapid thermal annealing (RTA) was used. RTA proved very beneficial as lower temperatures (750^{o}C) compared to conventional annealing (1000^{o}C) and only 5 seconds were needed for complete crystallization. A reduction of interfacial area was accomplished simply by etching the waveguides into the amorphous films before annealing. The waveguides (0.7-2.0um wide) were not cracked at all. This yields several other advantages in addition to crack prevention: 1) the amorphous films had greatly increased etch rates compared to crystalline films and 2) the post thermal processing smoothed the waveguide edges. Once the YIG waveguides were fabricated, MgO buffer layers were deposited onto these waveguides and SmCo permanent magnets were added to bias the YIG layers for Faraday rotation. The aspect ratios of the YIG cores were maintained close to 1 to minimize the birefringence, which limits the ability of the YIG to rotate light. When the already crystallized YIG films were wet-etched, the sidewalls were very rough, and when RIE was used, the rates were prohibitively slow (~100nm/hour). Therefore, the high etch rates of the amorphous layers are very important for eventual device applications. Finally, a polarizer was integrated so that these isolators were truly "fully integrated." Photonic crystal polarizers were discovered that can be grown directly into the YIG films. These polarizers are highly significant as they reduce the number of reflecting interfaces along with completing the integration of isolators. PC polarizers were made using focused ion beam (FIB) lithography to define the pattern into the YIG film just before the waveguide rotator. These PC polarizers are also less susceptible to fabrication tolerances than interferometer designs. It is now our hope to integrate these isolators with light source.