Silicon Photonic Structures for Anti-reflection of Broadband Terahertz Waves

by

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ABSTRACT

Undesired reflection caused by impedance mismatch can lead to significant power loss and other unwanted effects. In electromagnetic, for example, RCL circuits, transformers and transmission lines are used to deal with impedance matching problem. In optics, a perfect anti-reflection design can be implemented by infinite layers of materials with refractive indices gradually changing between the two medium of interest. However, working with limited space and scarcely available materials, it becomes a difficult task to realize the goal. In the terahertz (THz) range, interest of antireflection implementation has been largely devoted to silicon. A material transparent in terahertz frequencies but opaque in the visible range, silicon also has a refractive index remains relatively unchanged throughout the terahertz range. The major disadvantage of silicon is its high relative refractive index (n=3.42) compared to air (n=1.00), resulting a Fresnel reflection loss of 30% at one interface. For an optical component using a silicon wafer, such as window, beam-splitter, or sample holder, the total power loss will be 50%. Significant research effort had been dedicated to implement antireflection coating for silicon in the THz range, but a true broadband solution has yet been brought into being.

In this research, we discuss theories and techniques of antireflection implementation for silicon in the THz range. Past research outcomes are listed and compared. Armed with gradient-index anti-reflection theory, we then propose a new implementation method called inverted photonic design. In this design, a 3-layer structure lies at the air and silicon interface. Each layer of this structure has a unique relative refractive index. Overall, they can reduce reflectance at the air-silicon interface significantly for a broad frequency range. Fabrication of this structure is carried out using standard CMOS processes. UV-lithography apparatus is used to pattern the design mask onto silicon and also utilized for alignment purpose. Deep reactive ion etching (DRIE) apparatus is employed to etch deep holes on silicon to form each layer. The fabricated structures, one with 20-μm period and one with 15-μm period, are examined under scanning electron microscope to insure uniformity across the wafer.

These two types of fabricated structures are evaluated using terahertz air-biased-coherence-detection (THz-ABCD) system for their anti-reflection performance. Both reflectance measurement and transmission measurement are taken. For reflectance

measurement of the 15-μm period structure, significant reduction is observed from 2.2 THz to 5.5 THz where reflectance is dropped from 30 % to 5%. For the same structure in transmission measurement, enhanced transmission is observed from 0.5 THz to 7.1 THz. Polarization and incident angle evaluation reveals that the fabricated structure is independent of polarization; it is also fit to be used up to a large incident angle (50º) with only slight performance reduction at high frequencies.