Announcing the Final Examination of Geunsik Lim for the degree of Doctor of Philosophy

Time & Location: September 22, 2014 at 1:00 PM in CREOL 103
Title: An Uncooled Mid-Wave Infrared Detector Based on Optical Response of Laser-Doped Silicon Carbide

An uncooled Mid-Wave Infra-Red (MWIR) detector is developed by doping an n-type 4H-SiC with Ga using a laser doping technique. 4H-SiC is one of the polytypes of crystalline silicon carbide and a wide bandgap semiconductor. The dopant creates an energy level of 0.30 eV, which was confirmed by optical spectroscopy of the doped sample. This energy level corresponds to the MWIR wavelength of 4.21 μm. The detection mechanism is based on the photoexcitation of electrons by the photons of this wavelength absorbed in the semiconductor. This process modifies the electron density, which changes the refraction index and, therefore, the reflectance of the semiconductor is also changed. The change in the reflectance, which is the optical response of the detector, can be measured remotely with a laser beam such as a He-Ne laser. This capability of measuring the detector response remotely makes it a wireless detector. The variation of refraction index was calculated as a function of absorbed irradiance based on the reflectance data for the as-received and doped samples. A distinct change was observed for the refraction index of the doped sample, indicating that the detector is suitable for applications at 4.21 μm wavelength. The Ga dopant energy level in the substrate was confirmed by optical absorption spectroscopy. Secondary ion mass spectroscopy (SIMS) of the doped samples revealed an enhancement in the solid solubility of Ga in the substrate when doping is carried out by increasing the number of laser scans. Higher dopant concentration increases the number of holes in the dopant energy level, enabling photoexcitation of more electrons from the valence band by the incident MWIR photons.

The detector performance improves as the dopant concentration increases from 1.15×1019 to 6.25×1020 cm-3. The detectivity of the optical photodetector is found to be 1.07×1010 cm•Hz1/2/W for the case of doping with 4 laser passes. The noise mechanisms in the probe laser, silicon carbide MWIR detector and laser power meter affect the performance of the detector such as the responsivity, noise equivalent temperature difference (NETD) and detectivity. For the MWIR wavelength 4.21 and 4.63 μm, the experimental detectivity of the optical photodetector of this study is found to be 1.07×1010 cm•Hz1/2/W, while the theoretical value is 2.39×1010 cm•Hz1/2/W. The values of NETD are found to be 404.03 and 15.48 mK based on experimental data for an MWIR radiation source of temperature 25°C and theoretical calculation respectively.

The doped SiC also has a capability of gas detection since gas emission spectra are in infrared range. Similarly, the sensor is based on the semiconductor optics principle, i.e., an energy gap is created in a semiconductor by doping it with an appropriate dopant to ensure that the energy gap matches with an emission spectral line of the gas of interest. Specifically four sensors have been fabricated by laser doping four quadrants of a 6H-SiC substrate with Ga, Al, Sc and P atoms to detect CO2, NO, CO and NO2 gases respectively. The photons, which are emitted by the gas, excite the electrons in the doped sample and consequently change the electron density in various energy states. This phenomenon affects the refraction index of the semiconductor and, therefore, the reflectivity of the semiconductor is altered by the gas. The optical response of this semiconductor sensor is the reflected power of a probe beam, which is a He-Ne laser beam in this study. The CO2, NO, CO and NO2 gases change the refraction indices of Ga-, Al-, Sc- and Al-doped 6H-SiC, respectively, more prominently than the other gases tested in this study. So these doped 6H-SiC samples can be used as CO2, NO, CO and NO2 gas sensors respectively.

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