Abs. 958, 204th Meeting, © 2003 The Electrochemical Society, Inc.

Laser-Metallized Silicon Carbide Schottky Diodes for Millimeter Wave Detection and Frequecny Mixing

I.A. Salama[1], C. Middleton[1], N.R.Quick[2], G.D. Boreman[1] and A. Kar[1]

[1]University of Central Florida, School of Optics
Center for Research and Education in Optics and Lasers
(CREOL), Orlando, Florida, 32816, USA.
[2]Applicote Associates LLC
3259 Progress Drive, Room 2-158
Orlando, Florida 32826, USA.

The primary objective of this work is to demonstrate that the electrical properties of silicon carbide substrates can be altered by using a laser direct write technique. This technique has been used to accomplish metallization within SiC substrates in situ. The importance of this process is that it does not require any external addition of metals to the substrate – it is an intrinsic metallization process. The laser direct write technique can also be used to carry out both n-type and p-type doping in wide bandgap materials such as SiC and GaN. This technique will be discussed, and results pertaining to laser metallization and doping will be presented. Schottky diodes have been fabricated using the laser-metallized structure as an Ohmic contact and are comparable to nickel metal layer, which was deposited by magnetron sputtering, electrical contact diodes. Schottky diodes comprised of a laser-metallized Ohmic contact and titanium Schottky junction, which was formed by magnetron sputtering of titanium on silicon carbide, are found to respond as an antenna to mm waves and also behave as a frequency mixer.

The laser direct write is a technique in which the substrate is placed in a controlled environment and then it is irradiated with a scanning laser beam. The controlled environment could be a vacuum chamber or a chamber filled with inert or active gases depending on the type of changes (e.g., metallization, doping or insulative tracks) that we want to induce in the substrate. Nanosecond-pulsed Nd:YAG (λ= 1064 and 532 nm) and excimer (λ= 193, 248 and 351 nm) lasers have been used for this work to accomplish metallization and doping in SiC substrates. Mg (p-type) doping has also been carried out in GaN substrates.

Metal-like conductive tracks are produced in both n-type and p-type SiC substrates by the laser direct write technique in inert ambients (Ar and He). The electrical resistivity of such tracks is found to be four orders of magnitude lower than that of the as-received SiC samples. The Schottky barrier height (SBH) between the laser-metallized track and the original n-type SiC ($N_D= 10^{18}cm^{-3}$) is 0.8 eV and 1.0 eV as calculated from the current-voltage and capacitance-voltage characteristics of the junction at room temperature, respectively. A linear transmission line method pattern is directly fabricated in n-type ($N_D= 10^{18}cm^{-3}$) SiC substrate by the laser direct write method and the specific contact resistance of the laser-metallized tracks is calculated to be in the range of 0.04-0.12 Ωcm^2. The stability of the interface between the laser-treated layer and original SiC structure is studied through annealing experiments under different conditions, e.g., ambient, temperature, time and time-temperature product. The electron diffraction pattern of the laser-synthesized conductive phase is investigated to examine the crystalline nature of the tracks and TEM studies are carried out to obtain the crystallographic orientation with respect to (0001)-Si face of SiC epilayer.

The n-type or p-type semiconductor component of devices can also be created by laser doping. Laser doping is accomplished by irradiating SiC wafers in dopant-containing ambients such as nitrogen and a mixture of trimethylaluminum and argon for n-type and p-type doping, respectively. SIMS depth profiling data indicates a typical dopant layer of thickness 500 nm with dopant concentrations in the range of 10^{17} to 10^{18} cm^{-3} for different samples and laser doping conditions.

The laser-metallized tracks exhibit Ohmic or Schottky junction characteristics depending on the laser parameters used to create them. A Schottky diode was fabricated using a laser-metallized track as an Ohmic contact and magnetron-sputtered titanium as a Schottky junction. The titanium layer also acted as an antenna in our subsequent experiments to test the frequency response of the device that responded well at 92.5 GHz which is in the mm wavelength range. The device was also found to act as a frequency mixer. These functions of the device can be used for homeland security, e.g., mm wave imaging to detect hidden weapons or high frequency spectroscopy to identify varieties of chemical species. The device can also be used for nondestructive testing of surface and subsurface defects through mm wave imaging.