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Thermal conductivity of donor-doped GaN – investigations with 3-ωand stationary metods

Gallium nitride due to its unique optical properties and therefore possible applications has been attracting much attention of researchers for over one decade. Thermal conductivity is of interest as a key parameter in the design of high-power devices in which gallium nitride is an important element.

Key words: Thermal conductivity, donor doping.

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Теплопроводность доноров легированного GaN - исследования с 3-ω and стационарным методом

Нитрид галлия благодаря своим уникальным оптическим свойствам и, следовательно, возможности применения привлекает большое внимание исследователей более одного десятилетия. Теплопроводность представляет интерес в качестве ключевого параметра в разработке мощных устройств, в которых нитрид галлия важным элементом.

Ключевые слова: теплопроводность, донор, легирование.

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Қосындыланған GaN донорлар жылуөткізгіштігін 3-ω and стационарлық әдіспен зерттеу

Соңғы онжылдықта галлий нитриді өзінің бірегей оптикалық қасиеттерінің арқасында көп қызығушылық тудырды. Галлий нитриді негізгі рөлді атқаратын қуатты құрылғылардың жылуөткізгіштігі бірінші қызығушылық болып табылады.

Түйін сөздер: жылуөткізгіштік, донор, қосындылау.

Gallium nitride due to its unique optical properties and therefore possible applications has been attracting much attention of researchers for over one decade. Thermal conductivity is of interest as a key parameter in the design of high-power devices in which gallium nitride is an important element.

The investigated here samples were prepared byammonothermal method. The thermal conductivity of bulk crystals was measured over the temperature range 4–300K with stationary state heat flow method while the measurements of the thermal conductivity of GaN thin layers was carried out in the temperature range 50 – 320K by 3-omega method. For the later, on the surface of the investigated sample a special electrically conductive pattern featuring a temperature-dependent resistance is prepared. During the measurement the pattern acts both as a heater to create a temperature oscillations and as a sensor to measure the sample's thermal response. An electric current of angular frequency ω flows through the pattern resulting in heating the surface of the sample at frequency 2ω. The appearing signal of frequency of 3ω is measured with a lock-in amplifier. The thermal conductivity of the investigated sample is being obtained from the frequency dependence of the signal.

The value of the thermal conductivity coefficient of three investigated bulk single crystal samples of n-type gallium nitride with electron density 4.0 $x10^{16}$, 2.6 $x10^{18}$ and 1.1 $x10^{20}$ cm^{-3} depends strongly on the donor doping concentration. The analysis of phonon-electron scattering was done in the framework of Debye model with the use of Callaway method. In considering the effect of the oxygen dopant on thermal conductivity of GaN crystal the following three effects were taken into account and discussed:

• additional scattering of phonons by oxygen atoms which replace the original nitrogen atom in gallium nitride structure (Rayleigh scattering of phonons)

• enhancement of the thermal conductivity due to increase of concentration of electrons in the conduction band

• additional scattering of phonons by the extra free electrons. Additionally, some results of the measurements in the direction of *c* axes obtained with 3-omega method are presented. The 3-omega method was also utilized for the measurements of thermal conductivity of GaN layers on an Al_2O_3 substrate.

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