Alternating current magnetoresistance for determination of electron mobility and concentration under the gate in submicrometer Si and GaN field effect transistors

Rabih Tauk1,2,*, Wojcieh Knap1, Jerzy Łusakowski3, Maciej Sakowicz3, Zahia Bougrioua4, Mohammad Aziz4, Philippe Lorenzini5, Frédéric Boeuf5, and Thomas Skotnicki5
1. Laboratoire Charles Coulomb, Université Montpellier 2, Montpellier, France
2. Laboratoire de Physique Appliquée, Université Libanaise, Fanar, Liban
3. Institute of Experimental Physics, Warsaw University, Warsaw, Poland
4. CRHEA – CNRS, Valbonne, France
5. STMicroelectronics, Crolles, France
* rabih_tauk@yahoo.fr

Abstract

In two dimensional (2D) systems, the electron mobility (\(\mu\)) depends on the electron concentration (\(n\)) showing a bell-like \(\mu(n)\) dependence, observed in many semiconductor structures. The mechanism responsible for this effect is an interplay of scattering by the interface roughness and screening by the 2D electron gas. Investigation of \(\mu(n)\) dependence gives important information about basic processes responsible for electrical conductivity. Such studies are usually carried out on large area devices (Hall bars). It is important to verify theoretical prediction concerning electrical transport in the case of modern nanometer field effect transistors (FETs) which enable generation of extremely high electric fields. Experimental determination of the mobility under the gate of a nanometer FET is a difficult task since the traditional methods fail in this case. Recently, a DC magnetoresistance (MR) method was applied to determine \(\mu\) in nanometer Si MOSFETs and enabled to show an impact of the ballistic motion on \(\mu\) at 300 K [1, 2]. However, the DC MR method is biased by the contact and access resistance which must be carefully taken into account. Here we present an AC MR method based on measurements of FET magnetoresistance with a simultaneous modulation of the gate potential. We show that in the AC MR method one determines \(\mu\) and \(n\) directly under the gate of a FET, even with a gate of a nanometer length; \(\mu\) is determined from a classical MR at low magnetic fields, and \(n\) - from Shubnikov de Haas oscillations at quantizing high fields. We apply the AC MR method to different types of transistors: micrometer AlGaN/GaN HEMTs at 4 K, micrometer and sub micrometer (~ 70 nm) Si MOSFETs at 300 K. We discuss obtained dependencies of the electron scattering times on \(n\), and possibilities of application of AC MR method for investigation of \(\mu\) on a nanometer scale.

References