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Microwave response in two-dimensional electron gas in rolled nanomembranes

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Abstract

Magnetoresistance in a high-mobility two-dimensional electron gas contained in a GaAs quantum well on a cylindrical surface exposed to microwave radiation has been measured. The responses to microwave radiation in the magnetotransport of two-dimensional electron gas are shown to be different on planar and cylindrical surfaces. Qualitative explanations to the latter difference are given.

Keywords: two-dimensional electron gas, magnetic field gradient, microwave response, cylindrical surface, rolled nanomembrane

(Some figures may appear in colour only in the online journal)

Introduction

More than a decade ago, various responses of the magnetoresistance of two-dimensional electron gases (2DEG) to microwave radiation were observed for the first time in studying the properties of such gases in magnetic fields, including the Microwave Induced Resistance Oscillations (MIRO) [1], the damping of Shubnikov–de Haas oscillations [2], zero-resistance states (ZRS) [3], and the absolute negative conductivity [4]. Those effects have been given a comprehensive study, and adequate explanations to them have been advanced [5]. The majority of the studies were performed in uniform magnetic fields. Some studies of 2DEG performed under conditions with a magnetic field gradient and microwave radiation were devoted to the observation of spin resonances in hybrid semiconductor-ferromagnetic structures [6, 7].

A high gradient of effective magnetic field can be implemented using non-planar samples. Since only the surface-normal magnetic field component acts on two-dimensional electrons, then, in a nanomembrane rolled in a tube and placed in an external magnetic field, there arises a magnetic field gradient directed normally to the generatrix of the nanomembrane cylindrical surface [8]. In such a situation, the energy separation between Landau levels varies in proportion to the cosine of the angle between the magnetic field direction and the radius-vector (figure 1). As a first step in examining the response of the new two-dimensional electron system to microwave radiation, in the present study we measured the dependencies of the resistance of 2DEG contained in rolled nanomembranes versus magnetic field intensity on exposing the nanomembranes to radiation of up to 78 GHz frequency and without such exposure. Also, a comparison of obtained data with data measured on planar samples was performed.

Description of structures and experimental arrangement

The rolled nanomembranes with 2DEG were prepared from multi-layer heterostructures grown by molecular-beam epitaxy on a GaAs (100) substrate. A typical heterostructure contained a 13 nm quantum well sandwiched inbetween two delta-doped GaAs/AlAs short-period superlattices [9] and, also, a 20 nm thick strained InGaAs layer and AlAs sacrificial layer necessary for rolling the heterostructure in a

