Circular photogalvanic effect due to quantum interference in the terahertz radiation absorption

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***Abstract*—We report on the observation of the circular (radiation helicity dependent) and linear photogalvanic effects in MOSFETs with n-type inversion channels fabricated on vicinal silicon surfaces. The photocurrents are excited in unbiased transistors across the source and drain contacts by terahertz radiation at normal incident. We developed the miscroscopic theory of the circular photogalvanic effect demonstrating that the helicity-dependent photocurrent in silicon structures is of pure orbital nature originating from the quantum interference of different pathways contributing to the free carrier (Drude-like) radiation absorption.**

I. Introduction And Background

THE photogalvanic effects have been proved to be a very efficient tool to study nonequilibrium processes in semiconductors and semiconductor structures yielding information on their point-group symmetries, details of the band spin splitting, processes of momentum, energy, and spin relaxation, etc. [1-3]. In this work we report on the observation of the circular and linear photogalvanic effects in Si-MOSFETs. The fact of the existence of the circular photogalvanic effect (CPGE) in Si-based structures is of particular importance. So far, the CPGE has only been detected in materials with strong spin-orbit coupling and described by microscopic mechanisms based on spin-related processes [2-3]. In Si-MOSFETs, the spin-orbit coupling is known to be vanishingly small, therefore, these mechanisms of the CPGE get ineffective. Thus, a new access in explaining the CPGE is required. We have developed microscopic and phenomenological theories, both well describing all observed features of the CPGE and linear photogalvanic effect (LPGE). We show that the CPGE in our structures is due to pure orbital (spin-unrelated) mechanisms originating from the interference of different pathways contributing to the light absorption [4]. We also analyze the LPGE photocurrent which consists of ballistic and shift contributions [1-3].

II. Results

The experiments are carried out on miscut Si-MOSFET transistors with inversion layers and semitransparent gates. For excitation we use terahertz radiation of a molecular optically pumped laser yielding 100 ns pulses of radiation in the wavelength range between 77 and 280 μm [3]. We use normal incidence of radiation. Depending on the temperature and the gate voltage, which varies the separation between size-quantized subbands, the radiation induces intrasubband (Drude-like) as well as intersubband transitions. For each type of the transitions, we detect the photocurrent consisted of both the CPGE and LPGE contributions and investigate it as a function of the radiation polarization (see Fig. 1, top panel), gate voltage (see Fig. 1, bottom panel), wavelength, and temperature (from 4.2 K up to room temperature). In the whole temperature range we observed the CPGE photocurrent, which reverses its sign upon switching the helicity from left to right handed. Variation of the gate voltage at fixed helicity also results in the inversion of the current direction (see Fig. 1, bottom panel).

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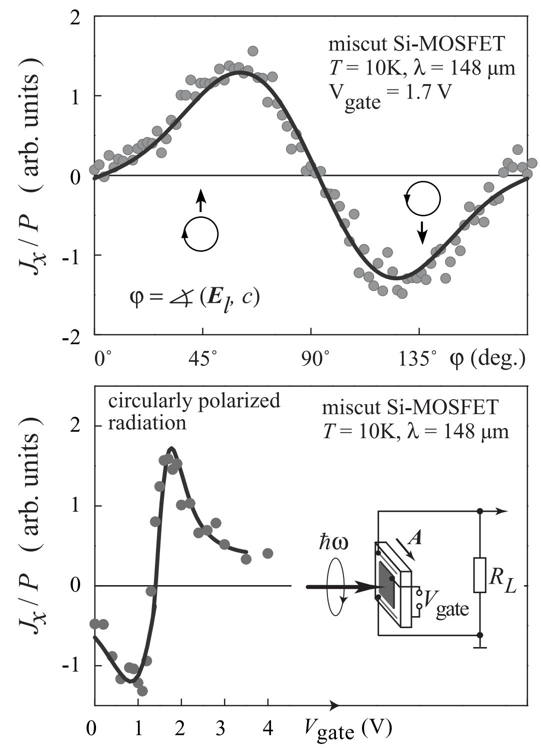

Fig. 1: Photocurrent in Si-MOSFET structures

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