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Ge/SiGe Superlattices for Thermoelectric Devices Grown by Low-Energy Plasma-Enhanced Chemical Vapor Deposition

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Ge/SiGe multiple quantum wells are presented as efficient material for room-temperature thermoelectric generators monolithically integrated onto silicon. We have deposited and characterized 10-μm-thick heterostructures engineered for lateral devices, in which both heat and current flow parallel to the multilayer. In this paper we investigate in detail the structural and interface quality by means of x-ray diffraction and transmission electron microscopy. Thermoelectric measurements, giving a figure of merit of 0.04 to 0.08, together with mobility spectra and defect analysis suggest possibilities of even higher efficiency. Nevertheless, the high power factor of 2 mW/K^{2}m to 6 mW/K^{2}m is promising for applications.

Key words: Silicon germanium, multiple quantum well, thermoelectrics

INTRODUCTION

Thermoelectric devices are presently used for both power generation and cooling. The efficiency of a thermoelectric material is evaluated by the figure of merit $ZT = \alpha^2\sigma T/\kappa$, where α is the Seebeck coefficient, σ is the electrical conductivity, κ is the thermal conductivity, and T is the absolute temperature in Kelvin.[1] For bulk materials the Wiedemann–Franz law prevents effective enhancement of ZT since charge carriers also efficiently carry heat.

Low-dimensional systems such as superlattices (SLs) have been proposed[2] to overcome the ZT bulk limit, and several experimental results with various materials have been reported in the last two decades, confirming the potential of such an approach.

Compared with Bi_2Te_3/Sb_2Te_3, the material system with the best performance at room temperature at present,[3] Ge/SiGe devices constitute an interesting option, driven by a mature growth technology, and featuring materials which are sustainable and compatible with complementary metal–oxide–semiconductor (CMOS) micropower systems.

We have deposited and characterized Ge/$Si_{1-x}Ge_x$ multiple quantum well (MQW) structures on Si substrates for microfabricated thermoelectric generators monolithically integrated on silicon. The MQW structure is intended for lateral transport in which quantum confinement effects are expected to enhance σ and α. In this work we present results from p-type structures.

HETEROSTRUCTURE AND GROWTH

The structures are p-type modulation-doped Ge/$Si_{1-x}Ge_x$ MQWs in which heat and current flow occur along the in-plane direction. The two-dimensional (2D) density of states featured by quantum-confined carriers is expected to increase the Seebeck coefficient.[2] Furthermore, in modulation-doped QWs, carrier mobility and hence electrical conductivity are

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