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Scalable Silicon Nanostructuring for Thermoelectric Applications

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The current limitations of commercially available thermoelectric (TE) generators include their incompatibility with human body applications due to the toxicity of commonly used alloys and possible future shortage of raw materials (Bi-Sb-Te and Se). In this respect, exploiting silicon as an environmentally friendly candidate for thermoelectric applications is a promising alternative since it is an abundant, ecofriendly semiconductor for which there already exists an infrastructure for low-cost and high-yield processing. Contrary to the existing approaches, where *n*/*p*-legs were either heavily doped to an optimal carrier concentration of 10^{19} cm^{-3} or morphologically modified by increasing their roughness, in this work improved thermoelectric performance was achieved in smooth silicon nanostructures with low doping concentration (1.5×10^{15} cm^{-3}). Scalable, highly reproducible e-beam lithographies, which are compatible with nanoimprint and followed by deep reactive-ion etching (DRIE), were employed to produce arrays of regularly spaced nanopillars of 400 nm height with diameters varying from 140 nm to 300 nm. A potential Seebeck microprobe (PSM) was used to measure the Seebeck coefficients of such nanostructures. This resulted in values ranging from -75 μV/K to -120 μV/K for *n*-type and 100 μV/K to 140 μV/K for *p*-type, which are significant improvements over previously reported data.

Key words: Silicon, nanostructures, low doping concentrations, e-beam lithography

INTRODUCTION

Decrease of fossil-fuel resources and increase in energy consumption demands have motivated the research community to seek technologies for the use of alternative energy sources existing in the environment (solar, piezoelectric, and thermoelectric). Although thermoelectric (TE) power generation presents many advantages, the drawbacks of commercially available TE generators include their relatively low efficiency (figure of merit around 1), incompatibility with human body applications due to the toxicity of commonly used alloys, and possible future shortage of raw materials (Bi, Sb, Te, and Se).[1] In addition, these conventional materials and associated processes are difficult to scale up and to recycle.

In this respect, exploiting silicon as an environmentally friendly candidate for thermoelectric applications is a promising alternative since it is an abundant, ecofriendly semiconductor for which there already exists an infrastructure for low-cost and high-yield processing. Although bulk Si is a poor thermoelectric material, recent theoretical[2,3] and experimental results show that nanostructured bulk silicon[4] and nanowires[5–7] have promise as high-performance thermoelectrics since their thermal conductivity is greatly reduced without considerably affecting the Seebeck coefficient or electrical

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