Nanowires for Thermoelectric Devices

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BACKGROUND

Nanowire-based material systems offer a variety of advantages over traditional thin film systems. Thus, nanowire device applications are highly sought after. However, the great majority of existing device applications are based on single nanowires or nanowires operating independently of each other. UCSC’s unique material system, based on randomly oriented and intersecting semiconductor nanowires grown on amorphous substrates, leads to three-dimensional nanowire networks. This allows long-range carrier transport from one nanowire to another. This nanowire network enables nanowire-based devices to be designed with added functionality, and as such includes electrical and thermal transport in directions nominally perpendicular to the surface of a substrate on which the nanowire network is formed. By utilizing nanowire networks that allow electrons and holes to travel over distances much longer than the length of a single nanowire, entirely new device architectures are made possible.

TECHNOLOGY DESCRIPTION

Traditional thermoelectric devices employ a bulk semiconductor formed between two metallic plates through which both electrical charge flow and heat flow enter. The two metallic plates are geometrically in parallel. Each metallic plate concurrently maintains either a high or low temperature. Electrons accumulate on the cold side as they diffuse from the hot to the cold side. These electrons generate an electrical voltage, which appears on an external circuit between the two metallic plates for a given temperature gradient. The electric field counteracts the motion of the diffusing electrons, causing electrons to drift in the direction opposite to the motion of the diffusion. Therefore, at steady-state (i.e. the diffusion and the drift are in balance), the open-circuit voltage and the heat-generated current are limited by the electric field. This causes electrons in a bulk semiconductor to drift in the direction opposite to the motion of the diffusing electrons. Here UCSC researchers use semiconductor nanowires instead of bulk semiconductors; an important feature of this nanowire thermoelectric invention is that the long-axis of the nanowires are not perpendicular to the two metallic plates, and thus, the result is a sizable reduction in the electric field that counteracts the motion of the diffusing electrons. Therefore, the open-circuit voltage and heat-generated current significantly increases.

APPLICATIONS

▶ Thermoelectric semiconductors
▶ New device nanowire architectures

ADVANTAGES

▶ Added functionality including electrical and thermal transport

INTELLECTUAL PROPERTY INFORMATION

Patent Pending

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OTHER INFORMATION

KEYWORDS

Nanowires, nanowire networks
thermoelectric, thermoelectric device,
thermal transport, semiconductor
nanowires, semiconductor, bulk
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CATEGORIZED AS

▶ Energy
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