Mechanical Engineering Doctoral Defense

Radiative Heat Transfer with Nanowire/Nanohole Metamaterials for Thermal Energy Harvesting Applications

School for Engineering of Matter, Transport and Energy

Jui-Yung Chang

Advisor: Dr. Liping Wang

abstract

Recently, nanostructured metamaterials have attracted lots of attentions due to its tunable artificial properties. In particular, nanowire/nanohole based metamaterials which are known of the capability of large area fabrication were intensively studied. Most of the studies are only based on the electrical responses of the metamaterials; however, magnetic response, is usually neglected since magnetic material does not exist naturally within the visible or infrared range. For the past few years, artificial magnetic response from nanostructure based metamaterials has been proposed. This reveals the possibility of exciting resonance modes based on magnetic responses in nanowire/nanohole metamaterials which can potentially provide additional enhancement on radiative transport. On the other hand, beyond classical far-field radiative heat transfer, near-field radiation which is known of exceeding the Planck's blackbody limit has also become a hot topic in the field.This PhD dissertation aims to obtain a deep fundamental understanding of nanowire/nanohole based metamaterials in both far-field and near-field in terms of both electrical and magnetic responses. The underlying mechanisms that can be excited by nanowire/nanohole metamaterials such as electrical surface plasmon polariton, magnetic hyperbolic mode, magnetic polariton, etc., will be theoretically studied in both far-field and near-field. Furthermore, other than conventional effective medium theory which only considers the electrical response of metamaterials, the artificial magnetic response of metamaterials will also be studied through parameter retrieval of far-field optical and radiative properties for studying near-field radiative transport. Moreover, a custom-made AFM tip based metrology will be employed to experimentally study near-field radiative transfer between a plate and a sphere separated by nanometer vacuum gaps in vacuum. This transformative research will break new ground in nanoscale radiative heat transfer for various applications in energy systems, thermal management, and thermal imaging and sensing.

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