Seebeck Nanoantennas for Solar Energy Harvesting

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Outline

• Introduction to Nanoantennas (How everything started).
• Antenna-coupled microbolometers.
• Applications to Solar Energy Harvesting.
  • Rectennas.
  • Antenna-coupled thermocouples.
  • Seebeck Nanoantennas.
• Other Applications.
• Conclusions.
Introduction
Bolometers

- Made of materials with very small thermal capacity and large temperature coefficient of resistance so that the absorbed radiation produces a large change in resistance.
- They are operated by passing a bias current through the detector and monitoring the output voltage.

Bolometer Detector Circuit with bridge configuration for dc operation.

AC-coupled Bolometer Detector Circuit
Microbolometers
Antenna-coupled microbolometers

Antenna-coupled microbolometers

Dipole

Square-Spirals

Bowtie

Log-Periodic

Cambridge EBMF 10.5/CS Electron Beam Lithography System

Microbolometer fabricated using EBL
The sensitive element is a NB patch of 800 nm × 200 nm
Liftoff

(a) PMMA
P(MMA-co-MAA)

(b) Bilayer Profile

Finished Device

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Characterization
Characterization
F.J. González, G.D. Boreman,
2D Scan in the Infrared
Integration to ROICs
Integration to ROIC’s
Integration to ROIC’s
Integration to ROIC’s

8x8 Array of Spiral Antennas

8x8 Array of Log-Periodic Antennas
Integration to ROIC’s

Applications to Solar Energy Harvesting
Advantages

Array of nanoantennas can be fabricated on flexible substrates and placed on clothing or rolls that can later be extended for charging portable equipment.
Advantages

Nanoantennas can be tuned to harvest energy at infrared and longer wavelengths, which are not used by PV.
Numerical simulations of the far-infrared antenna-coupled microbolometer were performed using COMSOL Multiphysics.
Material Parameters

$n$ and $k$ values for gold, aluminum, copper and nickel films as a function of frequency obtained using a J.A. Woollam infrared variable angle spectroscopic ellipsometer (IR-VASE).

FEM Simulations
FEM Simulations
FEM Simulations
Detection Mechanism
Harvesting mechanism

Rectennas

MOM Diodes

- Low efficiency
- High impedance, which creates an impedance mismatch with the antenna reducing its efficiency.
- Efficiency in the $10^{-6}$-$10^{-9}$.

Rectification Mechanism $\Rightarrow$ MOM Diodes

Seebeck Nanoantennas

Materials: Ti/Ni (S_Ni = -15, S_Ti = 7.19)

Single element nanoantenna

Array of Nanoantennas

Signal increase by using an array

$\Delta V = 3.6 \mu V$

$\Delta V = 26 \mu V$
Antenna-coupled Thermocouples

- Nanorectennas are actually thermocouples (Reference).

Single-metal nanothermocouples

The hot and cold junctions of the thermocouple are formed between the narrow and wide wire segments. Fabrication complexity is greatly reduced compared to bi-metallic thermocouples, and might point the way to large-scale fabrication.

Seebeck Nanoantennas

Materials:

Ti/Ni (S_Ni = -15, S_Ti = 7.19)

ΔV = 5.74 μV

ΔV = 9.08 μV

Other Applications
Polarization detection

New Fabrication Methods

Nanoimprint Lithography

Electrochemical deposition
Conclusions

• Antenna-coupled microbolometers can be used for infrared detection and can be integrated into ROICs to make IR-FPA.

• Rectennas would probably have extremely low efficiencies making them impractical for energy harvesting applications.

• Nanoantennas can be used to harvest solar energy by using them in a Seebeck-Nanoantenna configuration.

• Measurements will show what would be the real efficiency of this devices and would indicate the possible applications.
Collaborators

Prof. Glenn Boreman (UNCC)

Prof. Javier Alda (UCM)