Optical Nanoantennas for Energy Harvesting

C. Di Garbo[1], P. Livreri[1] and G. Vitale[2]

[1]Dipartimento di Energia, ingegneria dell'Informazione e modelli Matematici, Università di Palermo, Viale delle Scienze, Ed.9, 90128 Palermo (Italy), email: chiara.digarbo(at)unipa.it, patrizia.livreri(at)unipa.it
[2]Istituto di Studi sui Sistemi Intelligenti per l'Automazione (ISSIA), Consiglio Nazionale delle Ricerche (CNR), Via Dante Alighieri, n. 12 - 90141Palermo (Italy) email: gianpaolo.vitale(at)cnr.it

In the last decade, the increasing demand for renewable energy has been leading to the development of new devices, which overcome the disadvantages of the traditional photovoltaic conversion and exploit the thermal radiation created by the Sun, that is transferred in the form of electromagnetic waves into free space and finally absorbed by the surface of the Earth [1-2]. These new devices, called nanoantennas, have only recently been considered thanks to the development of electron beam lithography and similar techniques. Nanoantennas operate at nanometers wavelengths and their dimensions range from a few hundred nanometres to a few microns. They exhibit potential advantages in terms of polarization, tunability, and rapid time response. Furthermore, the nanoscale dimensions, combined with the high electric field enhancement in the antenna gap, enable a small device footprint, making it compact enough to be monolithically integrated with electronics and auxiliary optics [3]. Similar to traditional RF antennas, nanoantennas capture the incident visible or infrared electromagnetic wave causing an AC current onto the antenna surface, such that it oscillates at the same frequency of that of the wave. The movement of the electrons produces an alternating current in the antenna circuit. A proper rectifier coupled with nanoantenna is used in order to produce a DC power [3]. This rectifier contains one or more diodes whose power loss and fast response can influence the whole device efficiency. This circuit is known as rectenna and the typical block diagram and the equivalent circuit are shown in figure 1-2 [3-4]. Infrared nanoantennas are also coupled to a metallic thermocouple. The rectification mechanism is based on the Seebeck effect, a thermoelectric voltage generation due to the infrared irradiation induced currents in the antenna. Figure 3 shows the electric equivalent circuit of the antenna-coupled thermocouples [5]. The purpose of this contribution is to critically compare advantages and disadvantages of new optical nanoantennas for energy harvesting, focusing on the state of the art and its perspectives. Nanoantennas for visible radiation reveal better upper bound limits in terms of efficiency and available power density, table 1 [4]. Infrared nanoantennas can work even in the absence of solar radiation, but the efficiency is still very low. Some technological issues have to be taken into account before these commercial devices are put on the market. They mainly regard the circuits between the antenna and the load. Nonetheless, they show a greater efficiency than traditional PV solar cells and could be an alternative to the latter in the energy harvesting process in the next future.

References

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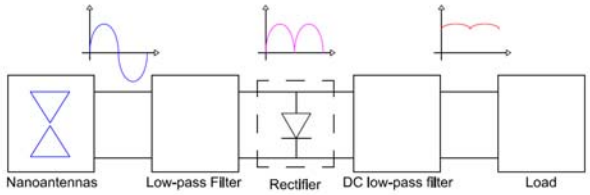

Figure 1: Block diagram of infrared nano-rectenna.

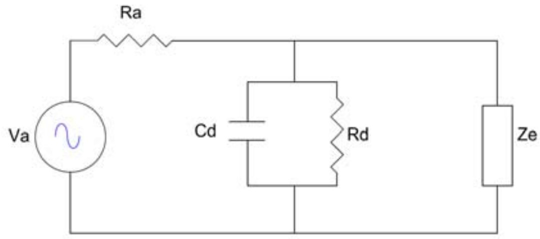

Figure 2: Equivalent circuit of a solar rectenna.

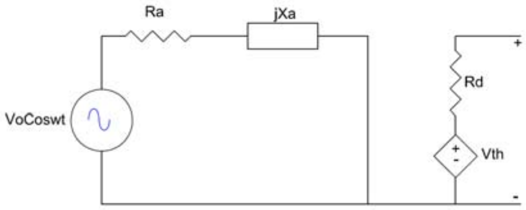

Figure 3: Electric equivalent circuit of the antenna-coupled thermocouples.

Table 1: Power density values for dipole nanoantennas.

Dipole length [nm]	Power density [W/m^2]
100	**379.49**
150	**505.59**
200	**517.97**
250	**508.73**
300	**486.39**
350	**488.16**