Development of a Sunlight-Powered Cardiac Pacemaker

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Today, the lifetime of an implantable cardiac pacemaker is primarily limited by the battery. A contemporary cardiac pacemaker needs to be replaced after approximately 10 years. This exposes the patient to an increased risk of medical complications (e. g. infections, bleedings) and also increases health costs due to multiple surgical interventions.

Introduction

To allow an implantable device autonomously working over long term and avoid repeated device replacements, intracorporeal energy harvesting systems are desired. Sunlight is a virtually unlimited ubiquitous energy source and partially penetrates the skin. This means, that some of the sun's energy may be harvested and converted into electrical energy by subcutaneously implanted photovoltaics cells.

Materials and Methods

The aim of this project was the development of a sunlight-powered cardiac pacemaker which is made out of a photovoltaic module, an energy management system, a storage element and finally a pacing circuit. First, different solar cells were compared theoretically and experimentally. Then, the energy management system was designed according to the choice of photovoltaic cells. The pacing circuit was devloped to be a SOO pacemaker. Afterwards an storage element was selected to supply the system during one month without energy harvesting. A mathematical simulation based on meteorological data was done to calculate the harvestable energy in function of lifestyle. Finally prototypes were build in order to implant them and validate the system in vivo.

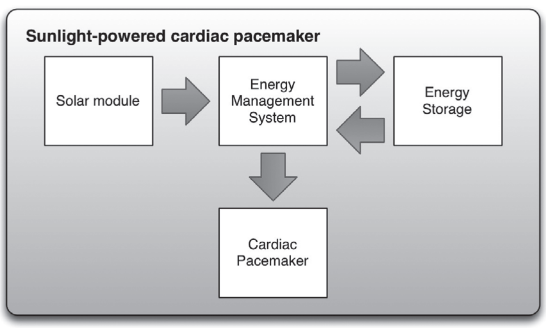
Results and discussions

The solar module was finally composed of three photovoltaics cells in series with an efficency of 22% and a total area of $3.5 cm^2$. Its output power reaches aroud 20mW under optimal sunlight conditions (1'000 W/m^2) under 3.5 mm of skin. The power consumption was estimated to be 23.7 µW. Thus, per month, 61.43J are needed. The energy management system was based on a dedicated chip, which allows to harvest more than 80% of the available power provided by the solar module under the skin. A Li-Ion battery dedicated for medical implants was selected in agreement with previous results.

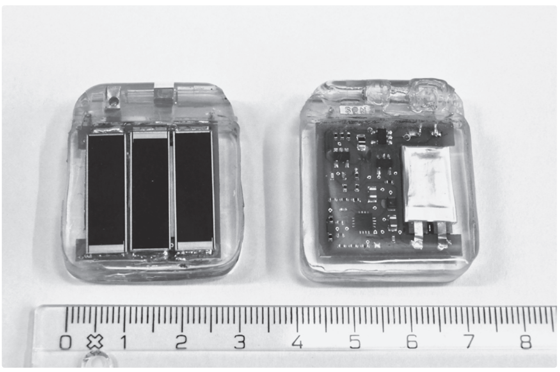
The simulation showed, that the energy harvested during 30 minutes each day in ambient sunlight during wintertime in Bern (80 W/m^2) is sufficient to harvest an average of 69J during the whole month.

Finally, two fully integrated pacemaker prototypes were designed and built to be implanted in vivo in a domestic pig. The first prototype was powered with a capacitor to allow implanting without stored energy (the capacitor can be emptied with a magnet). The second prototype was powered by a Lithium-Polymer battery of 9 mAh. Both prototypes were implanted and successfully paced after irradiation.

Sébastien Walpen



Block diagram sunlight-powered cardiac pacemaker



Fully integrated sunlight-powered cardiac pacemaker