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On chip micro-batteries: a giant leap towards miniaturization

Abstract

On chip batteries refer to miniaturized version of powerhouse embedded on a chip. This versatile powerhouse can efficiently deliver tiny medical device without being reliant on external sources. The fabrication process of such on-chip batteries is totally different from conventional batteries. Miniaturization as well as efficient delivery of prudent magnitude of potential are some real challenges. This communication briefly overviews on-chip batteries and their potential in future technologies—aided by a concise appraisal on fabrication.

Keywords: on-chip batteries, miniaturization, fabrication

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Introduction

Gone are the days when a computer had to be accommodated in one single room leaving little vit of space for others. Even, the storage devices used to very bulky with very little capacity of storing information. Likewise, the computing powers were minimal. Thanks to the recent developments in Science and Technology.[1-5] The semiconductor industry has been going through radical changes in the context of space, high computing power, faster response and many more. Consequently, with the advent of ultra-large-scale integration, the current mobile phone can do almost all tasks with augmented computing power that a laptop or computer can perform. This has happened because of tremendous advancements in miniaturization. So much progress has been achieved in this field that developers have been able to build a microcomputer having less than the size of thumb tip. In synchrony with this, miniaturization has led to realization of tiny sensors aided by flexibility as well as wearability. However, there is a word of caution. This would not have been possible if computers and batteries had not been miniaturized. Accordingly, there arises one segment known as smart dust applications which basically includes microelectronic devices being small in dimension. Another important characteristic feature is that their size is as small as a dust peck. The upsurge in this direction has prompted many biocompatible sensors.

Background

So far, the growth of smart dust applications has been impeded by two factors—one is the inadequacy of on-chip power sources to be operable 24/7 and other is the challenges in producing microelectronic batteries. However, the future is not so obscure. In a pioneering work by Yang et al.,[1] these problems seem to be solved. They developed the world's tiniest micro-battery and improvised it as an application prototype. They discuss howbattery- powered smart dust applications can be realized in the sub-millimetre-scale and present the world's smallest battery by far as an application-oriented prototype. In general, submillimetre scale computer are powered by mcirobatteries or harvesting methods for yielding electricity. In case of harvesting methods, the power is sourced directly from triboelectric generators or micro-thermoelectric generators. The first drives transduce friction to electricity whereas the latter converts heat to electricity.[2-5] However, the power delivered by them are so smaller in magnitude they cannot drive this dust mote chips. Here, photovoltaic cell as well as mechanical vibrations can alternatively power these minuscules. Nonetheless, the unavailability of solar energy as well as vibrations always worsen the case. As for instance, the implants as well as sensors require uninterrupted power. In such cases, only micro batteries can act as saviour.

Fabrication

Meanwhile, tiny batteries involve a different strategy corresponding to production as compared to their conventional counterparts. Even though, wet technology engaging electrode materials as well as additives yields significant energy and power density for on-chip batteries, it is far from achieving a dimension smaller than sub millimetre. As such the immediate need is to shrink the dimension; thereby maintaining the optimal power density. While stacked thin films, electrode pillars or interdigitated microelectrodes may be viable options; but they are unable to be reduced to less than one square millimetre. Yang's group has so far been able to attain this feat. They developed the tiniest battery down to size of sub-millimetre which could be integrable on a chip. The battery churns out a decent energy density of 100 microwatt hours per square centimeter.

The fabrication was accomplished via Swiss-roll technology as adopted by Tesla for making batteries of e-vehicles. Successive coating of thin layers of polymeric, metallic, and dielectric materials onto a wafer surface leads to inherent tension-embodied layered structure. While shedding the thin layers, mechanical tension is released enabling the system to roll up into a Swiss-Roll architecture without the assistance of external energy. This self-wound cylinder micro-battery thus bears a great potential for futuristic endeavours. It is found to be compatible with standard chip manufacturing process delivering high throughput. The researchers have been able to drive computer chips for 10 hours.[1] This Swiss-roll technology driven on-chip microbatery has huge potential. It will pave way for newer dimensions in the sub-square- millimeter scale. There is still a huge optimization potential for this technology, and the future adaptations in the coming years will prove its worth.

Concluding remarks

On-chip batteries possess a huge potential. They can drive myriad of appliances depending on the magnitude of potential required. A sizeable portion of medical devices can utilize these on- chip batteries. Even though they offer huge merits, there are certain aspects where there is scope of improvements. The fabrication of such batteries must be via a cost-effective as well as efficient procedure. Swis-roll technology can be a game changer in this direction providing lot of scope in the fabrication procedure. Equally important is the synergistic

adaptation of alternative power modes such as solar, triboelectric nanogenerator along with these batteries which can lead to greater height in efficient delivery of uninterrupted power.

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