

# NEW ERA OF ELECTRONIC COMPONENTS: CONCEPT OF BIO-SEMICONDUCTORS

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## ABSTRACT

*One of the most common communication industries needs the new and latest technologies on their fields. As a result, they have already invented various kinds of technologies in this 21st century. But, now we face a big problem. The technocrats are thinking various kinds of new protocols and architectures, but we need the suitable materials to produce that kind of devices and technologies. As a result, we already invented the compound semiconductors earlier. But after the invention of bio-conductors, we are now interested on bio-semiconductors. It is probably easy for developers, engineers, data jockeys to think about the day-to-day running life. This platform of systems can revolute the industry. Still due to some limitations, this technology isn't important for the scientists. They can think about it for a minute to tell about this modern technology. Bio-electric sensors, actuators, and energy sources, to integrate live cells with conventional complementary metal-oxide-semiconductor or CMOS chip technology to form a hybrid bio-semiconductor system offering high signal sensitivity and specificity, but requiring minimal energy. In this paper, we will review about the latest and finest technology: Bio-semiconductors and its future and scope on the electronics and telecom industries.*

**Keywords:** *semiconductor, compound semiconductors, bio-informatics, bio-technology, CMOS, SRC, SSB*

## I. INTRODUCTION

Communication is one Semiconductor Research Corporation (SRC) is one of the world's leading university-research consortiums for semiconductor technologies. In the recent times, they launched the Semiconductor Synthetic Biology (SSB) research program on hybrid bio-semiconductor systems. Their main goal is, to provide insights and opportunities for future information and communication technologies. The program is initially fund research at six universities: MIT, the University of Massachusetts at Amherst, Yale, Georgia Tech, Brigham Young and the University of Washington. SSB concentrates on synergies between synthetic biology and semiconductor technology here. This technology can foster exploratory, multi-disciplinary, longer-term university research leading to novel, breakthrough solutions for a wide range of industries. This research should significantly enhance and accelerate opportunities for advancing properties, design and applications for future generations of integrated circuits [1]

Synthetic biology surely can be used to re-engineer biological materials for useful purposes in the fabrication of advanced semiconductors -- in the short-term, engineering special DNA strands that aid in the self-assembly of chip features. This technology is exceedingly beyond the reach of traditional lithography. However, the long-term goal of the multidisciplinary effort is nothing less than inventing new types of living cells. These living

cells can be integrated into hybrid biological semiconductors. Along the way the SSB program aspires to discover new properties, methodologies, and applications for hybrid bio-semiconductors [2]

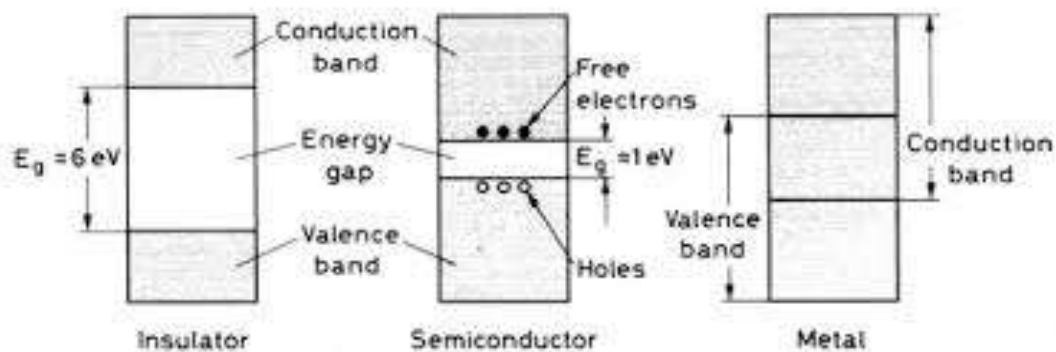
In this paper, we will review about the latest and finest technology: Bio-semiconductors and its future and scope on the electronics and telecom industries.

## II. WHAT IS SEMICONDUCTOR

To Electrical conductivity/ resistivity are the parameters to measure of a material's ability/ inability to conduct an electrical current [3]

A semiconductor is that material which has electrical conductivity to a degree between a conductor and an insulator. E.g.: silicon, Germanium, carbon etc. [4]

Semiconductors are very important because, they have find applications in almost all branch of industries and many others areas of daily life. The study of semiconductors provides an opportunity to apply and test much of theory of solids and to obtain information transport properties which could not be obtained from the study of metals alone. Semiconductors have two mainly important properties, that's why the observations and interpretation of electronic processes is easier in semiconductors than in metals and other crystals [5] Firstly, the semiconductor crystals can be grown with purity for in excess of what has been achieved in the case of metals and insulators. Secondly, the mobile carrier concentrations in semiconductors are low, so that the corners can be treated as distinguishable, non-interacting particles like molecules of an ideal gas. [6]



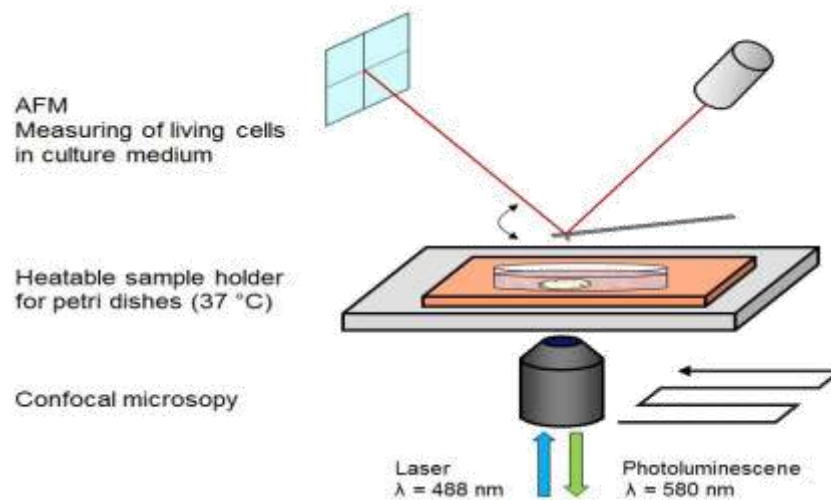
**Fig: 1 Basic Band Theory Diagram of Semiconductor**

## III. CONCEPT OF BIO-SEMICONDUCTOR

University researchers welcome this academia-industry partnership to do long-term research,” said Professor Rahul Sarpeshkar of MIT. “Living cells can offer ground-breaking solutions to some hard problems faced by the semiconductor industry because they solved similar problems more than a billion years ago. Controlled chemical reactions and molecular flows in cells are the ultimate miniaturization of electronics to the atomic and molecular scale.”

We can see that a semiconductor membrane made of two thin layers of opposite (*n*- and *p*-) doping can perform electrically tunable ion current rectification and filtering in a nanopore. Our model is based on the solution of the 3D Poisson equation for the electrostatic potential in a double-cone nanopore, combined with a transport model. It predicts that for appropriate biasing of the membrane-electrolyte system, transitions from ohmic

behavior to sharp rectification with vanishing leakage current are achievable. Furthermore, ion current rectifying and filtering regimes of the nanopore correspond to different charge states in the  $p-n$  membrane which can be tuned with appropriate biasing of the  $n$ - and  $p$ -layers [20]



**Fig: 2 Basics of Bio-Semiconductor**

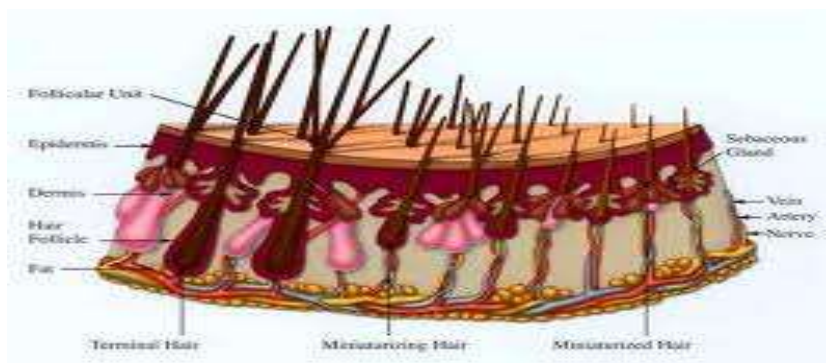
#### IV. POSSIBLE WORKING OF BIO-SEMICONDUCTORS

One Melanin – the pigment that colors skin, eyes and hair – could soon be the face of a new generation of biologically friendly electronic devices used in applications such as medical sensors and tissue stimulation treatments.

Led by Professor Paul Meredith and Associate Professor Ben Powell at The University of Queensland, an international team of scientists has published a study that for the first time gives remarkable insight into the electrical properties of this pigment and its biologically compatible “bio-electronic” features.

Semiconductors are arguably the most important modern day high-tech material – they drive all modern electronics,” said Professor Meredith. “The majority of semiconductors are made from inorganic elements or compounds such as silicon or gallium arsenide.”

Organic semiconductors, on the other hand, are a relatively new member of the semiconductor family and are composed of molecules containing carbon, hydrogen and other elements. “There are very few examples of natural organic semiconductors and melanin was thought to be the very first example, demonstrated to be such in the early 70s,” said Professor Meredith.



**Fig: 3 Biological Melanin**

The study – published recently in Proceedings of the National Academy of Sciences – points to a new way of interfacing conventional electronics to biological systems using a combination of ion-and-electron conducting biomaterials such as melanin. “Melanin is able to ‘talk’ to both electronic and ionic control circuitry and hence can provide that connection role,” said Professor Meredith about the study’s finding, the culmination of ten years of research and experiments [19]

There are very few materials that meet these compatible bio-electronic requirements, and an insight into melanin’s important biological functions and properties has been really crucial in this study.”

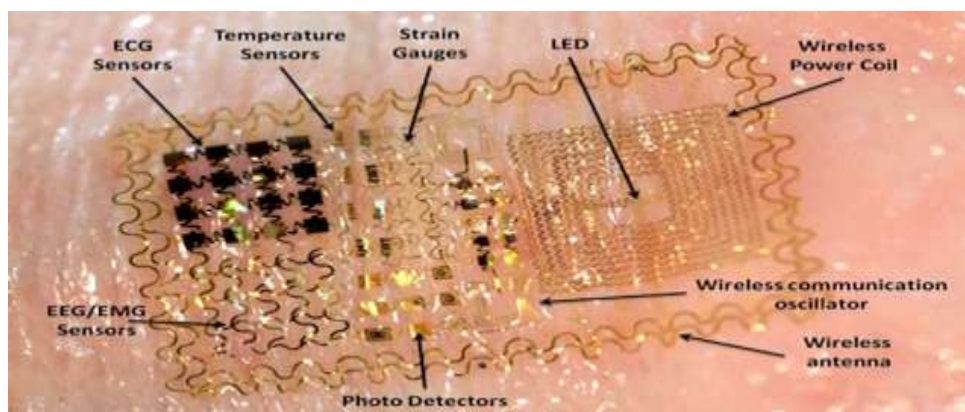
In recent years, the electronics industry has been driven to develop materials and components that are cheaper and more environmentally friendly [18]

## V. FUTURE APPLICATIONS OF BIO-SEMICONDUCTORS

### 5.1 Epidermal Electronics

Existing skin-mounted electronic devices always involve small numbers of bulk electrodes that mount on the skin via adhesive tapes, mechanical clamps/straps and/or penetrating needles, mediated by conductive gels, with terminal connections to separate boxes that house collections of rigid circuit boards, power supplies and communication components. These systems have important capabilities, but they have significant limitations, due to difficulties in establishing long-lived, robust electrical contacts that do not irritate the skin, and in achieving integrated systems with overall sizes, weights and shapes that do not cause discomfort during prolonged use. The materials, assembly and mechanics concepts presented previously allow for a different approach, in which the electrodes, electronics, sensors, power supply and communication components are configured together into ultrathin, low modulus, lightweight, stretchable ‘skin-like’ membranes that conformably laminate onto the surface of the skin by soft contact, in a manner that is mechanically invisible to the user, much like a temporary transfer tattoo. Figure 4 shows a representative device, which we refer to as an epidermal electronic system (EES)[10]

Electronic devices like those described here can provide thousands of amplified and multiplexed sensors connected using many fewer wires. These systems can even be mounted onto otherwise conventional balloon catheters, to provide sophisticated devices that combine many different components, ranging from EP, flow, temperature and tactile sensors, to radio frequency ablation electrodes and even micro-scale inorganic light emitting diodes [11]. Related systems can reveal neural processes related to epilepsy [12]. These devices can be used not only to study basic neuroscience but also, in the case of epilepsy, as a tool to enhance the precision of surgical treatments for acute cases.

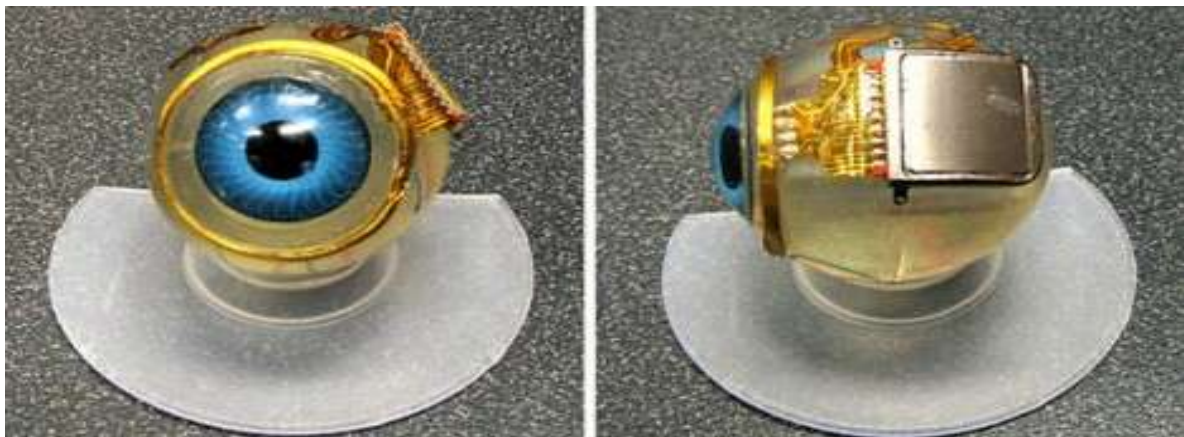


**Fig 4: Epidermal Electronics Application In Our Body**

## 5.2 Electronic Eye Ball Cameras

In addition to bio-integrated devices, the technologies described here can enable bio-inspired device designs. For example, imaging systems in biology are much different from, and in many ways superior to, digital cameras. The mammalian eye uses a detector system with approximately hemispherical curvature whereas man-made devices are constrained to planar geometries, by consequence of their use of semiconductor wafers as the device platform. The fields of view, levels of aberration and illumination uniformity that is possible with the hemispherical design all exceed those achievable with conventional, flat photo-detector arrays when simple imaging lenses are used [13]. The strategies described previously allow silicon detector arrays to be fabricated in planar layouts and then, as a final step, integrated on to controlled stretching. [15].

The fabrication starts with the formation of a planar, interconnected array of silicon photodiodes in an open mesh geometry. Controlled compressive deformation using a shaped, thin elastomeric stamp accomplishes a planar to hemispherical geometry transformation and transfer to the concave surface of a glass support. Mounting the resulting component on a printed circuit board connects it to external data acquisition hardware; coupling a simple, Plano-convex lens fixed in a transparent hemispherical shell completes the camera. Figure 6(right) presents a picture captured with this camera, rendered in the hemispherical geometry of the detector (top), and as a planar projection (bottom); the actual object appears in the right inset.



**Fig: 5 Electronic Eye Ball**

## VI. LITERATURE REVIEW

Funded by SRC's Global Research Collaboration (GRC), SSB concentrates on synergies between synthetic biology and semiconductor technology that can foster exploratory, multi-disciplinary, longer-term university research leading to novel, breakthrough solutions for a wide range of industries. Results from the university research, guided by semiconductor industry needs, should significantly enhance and accelerate opportunities for advancing properties, design and applications for future generations of integrated circuits [1]

With the aim of creating hybrid bio-semiconductor systems that advance the frontiers of information and communications technologies, the Semiconductor Synthetic Biology (SemiSynBio, SSB) program was launched today by Semiconductor Research Corp. (SRC) in Research Triangle Park, N.C. Funded by SRC's Global Research Collaboration (GRC), the initial phase of the project will distribute \$2.25 million in funding over three years to researchers at the Massachusetts Institute of Technology, Yale University, Georgia Institute of Technology, Brigham Young University, the University of Massachusetts, and the University of Washington [2]

The program aims to find synergies between synthetic biology and semiconductors to uncover new properties and designs for integrated circuits, as well as more readily adapt semiconductor technology to biological functions. Steven Hillenius, executive director of Global Research Collaboration, the division funding the initiative, says its projects “will aggressively explore new dimensions for pairing biological activities and semiconductors to benefit society.” [7]

This paper presents an overview of how semiconductor technology is now being used for early detection and therapy of disease. Specifically three areas are described which are currently utilizing CMOS technology with tremendous benefit in healthcare. The first being in mobile health whereby CMOS technology enables implementation of a low power intelligent wireless solution. The second being in Genomics, whereby advances in CMOS based ISFET technology is now allowing implementation of Point-of-Care diagnostic systems as well as genetic sequencing systems which are scalable, miniature and fabricated at low cost, and the final being in bio-inspired prosthetics, whereby low-power CMOS based systems can be designed to replicate biology to provide implantable and portable devices for personalized therapy of conditions such as Diabetes [8]

Biology relies on classes of materials that are soft and elastic, in structures that have complex curvilinear geometries. By contrast, all known high performance electronic/optoelectronic systems are built on the rigid, brittle planar surfaces of semiconductor wafers. Technologies that bridge this gap in form and mechanics create new opportunities in devices that adopt biologically inspired designs or require intimate integration with the human body. This paper reviews concepts for building electronics that combine hard and soft materials in ways that can exploit established semiconductors such as silicon, gallium arsenide, gallium nitride in systems that have the mechanical properties of a rubber band. Due to the central role of mechanics and physical motions in these systems, they can be considered also as a type of MEMS technology. Application examples include (1) bio-integrated systems capable of monitoring and delivering various forms of therapy, and (2) bio-inspired, ‘eyeball’ cameras for wide field-of-view imaging [9]

## VII.CONCLUSION

IC is appropriate. The vast majority of physical science and engineering research in electronics is defined by a development pathway in which functional improvements in performance and capabilities follow from increases in the number densities and switching speeds of transistors, achieved mainly by decreases in their individual sizes. Alternative forms of electronics, configured for driving liquid crystal displays, emerged relatively recently to establish a market presence that now represents a significant fraction of overall sales of semiconductor devices. Here, the primary metric for scaling is overall area coverage, rather than transistor size or speed.

Flexible electronics represents a natural extension of this technology, where motivation derives from unique form factors (e.g. Paper like display) and processing options (e.g. roll-to-roll) that follow from the use of plastic substrates. Here, we review recent research progress that suggests a different class of electronics whose key attribute is that it is capable not only of bending, but also stretching, with reversible, linear elastic responses to large strain ( $\gg 1\%$ ) deformations[16]. Such electronics are mechanically ‘soft’, thereby allowing them to be twisted, folded, and conformably wrapped onto arbitrarily curved surfaces, without mechanical fatigue or any significant change in operating characteristics. This mechanics leads to powerful engineering design options and modes of integration, including direct, seamless mounting on tissues of

the human body in ways that provide unmatched functionality in surgical devices, monitoring systems and human-machine interfaces[17].

## REFERENCE

- [1] <https://www.src.org/newsroom/press-release/2013/521/>
- [2] [http://www.eetimes.com/document.asp?doc\\_id=1319874](http://www.eetimes.com/document.asp?doc_id=1319874)
- [3] <en.m.wikipedia.org/wiki/conductivity>
- [4] <en.m.wikipedia.org/semiconductor>
- [5] Electronic Devices And Circuits, Theodore F. Bograt Jr., Jeffrey S. Beasley, Guillermo Rico
- [6] Rishav Choudhary, Susmit Paul “Study of semiconductor Materials and improvement of Compound semiconductors”- SEMSINDIA CONFERENCE-2014
- [7] <http://sciencebusiness.technewslit.com/?p=15847>
- [8] Toumazou, C., Georgiou, P. “Bio-inspired semiconductors for early detection and therapy”
- [9] J.A. Rogers-“SEMICONDUCTOR DEVICES INSPIRED BY AND INTEGRATED WITH BIOLOGY”
- [10] W.M. Choi, J. Song, D.-Y. Khang, H. Jiang, Y.Y. Huang, J.A. Rogers, “Biaxially Stretchable “Wavy” Silicon Nanomembranes”, Nano Lett., vol.7, pp. 1655-1663,2007. D.-H. Kim, J. So
- [11] D.-H. Kim, N. Lu, R. Ghaffari, Y.-S. Kim, S.P. Lee, L. Xu, J. Wu, R.-H. Kim, J. Song, Z. Liu, J. Viventi, B. de Graff, B. Elolampi, M. Mansour, M.J. Slepian, S. Hwang, J.D. Moss, S.-M. Won, Y. Huang, B. Litt, J.A. Rogers, “Materials for Multifunctional BalloonCatheters With Capabilities in Cardiac Electrophysiological Mapping and Ablation Therapy”, Nature Mater., vol.10, pp. 316-323, 2011.
- [12] J. Viventi, D.-H. Kim, L. Vigeland, E.S. Frechette, J.A. Blanco, Y.-S. Kim, A.E. Avrin, V.R. Tiruvadi, S.-W. Hwang, A.C. Vanleer, D.F. Wulsin, K. Davis, C.E. Gelber, L. Palmer, J. Van der Spiegel, J. Wu, J. Xiao, Y. Huang, D. Contreras, J.A. Rogers, B. Litt., “Flexible, Foldable, Actively Multiplexed, HighDensity Electrode Array forMapping Brain Activity In Vivo”, Nature Neuro., ASAP,2011.
- [13] V. Malyarchuk, I. Jung, J.A. Rogers, G. Shin, J.S. Ha, “Experimental and Modeling Studies of Imaging with Curvilinear Electronic Eye Cameras”, Opt.Expr., vol.18, pp. 27346-27358,2010.
- [14] H.C. Ko, G. Shin, S. Wang, M.P. Stoykovich, J.W. Lee, D.-H. Kim, J.S. Ha, Y. Huang, K.-C. Hwang, J.A. Rogers, “Curvilinear Electronics Formed Using Silicon Membrane Circuits and Elastomeric Transfer Elements”, Small, vol.5, pp. 2703–2709,2009
- [15] H.C. Ko, M.P. Stoykovich, J. Song, V. Malyarchuk, W.M. Choi, C.-J. Yu, J.B. Geddes, J. Xiao, S. Wang, Y. Huang, J.A. Rogers, “A Hemispherical Electronic Eye Camera Based on Compressible Silicon Optoelectronics”, Nature, vol. 454, pp. 748-753, 2008
- [16] J.A. Rogers, T. Someya, Y. Huang, “Materials and Mechanics for Stretchable Electronics”, Science vol. 327, pp. 1603-1607, 2010
- [17] I. Jung, J. Xiao, V. Malyarchuk, C. Lub, M. Li, Z. Liu, J. Yoon, Y. Huang, J.A. Rogers, “Dynamically Tunable Hemispherical Electronic Eye Camera System with Adjustable Zoom Capability”, Proc.Nat.Acad.Sci.USA, vol.108, pp. 1788–1793, 2011

- [18] <http://www.uq.edu.au/news/article/2012/06/melanin-considered-bio-friendly-electronics>
- [19] <http://en.wikipedia.org/wiki/Melanin>
- [20] Maria E. Gracheva, Jean-Pierre Leburton “Simulation of electrically tunable semiconductor nanopores for ion current/single bio-molecule manipulation”