Increased Sustainability of Printed Circuits

Flexible Circuits Using Organic Materials

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Inspiration

While it is difficult to predict scale of the future adoption of any technological advancement, there is an abundance of evidence that the use of flexible electronic circuits is likely to increase with rapid succession, similar to the growth pattern of semiconductors used in flat panel displays during the 1990's and 2000's. [1]

In 2013, the global flexible electronics market was only valued at a few billion dollars, but was predicted to increase to a $60-billion dollar valuation by the end of 2020, according to industry estimates. Experts felts that the United States was not in a position to capitalize on the potential market share, and R&D was being monopolized abroad, creating an unhealthy long-term strategy. [1]

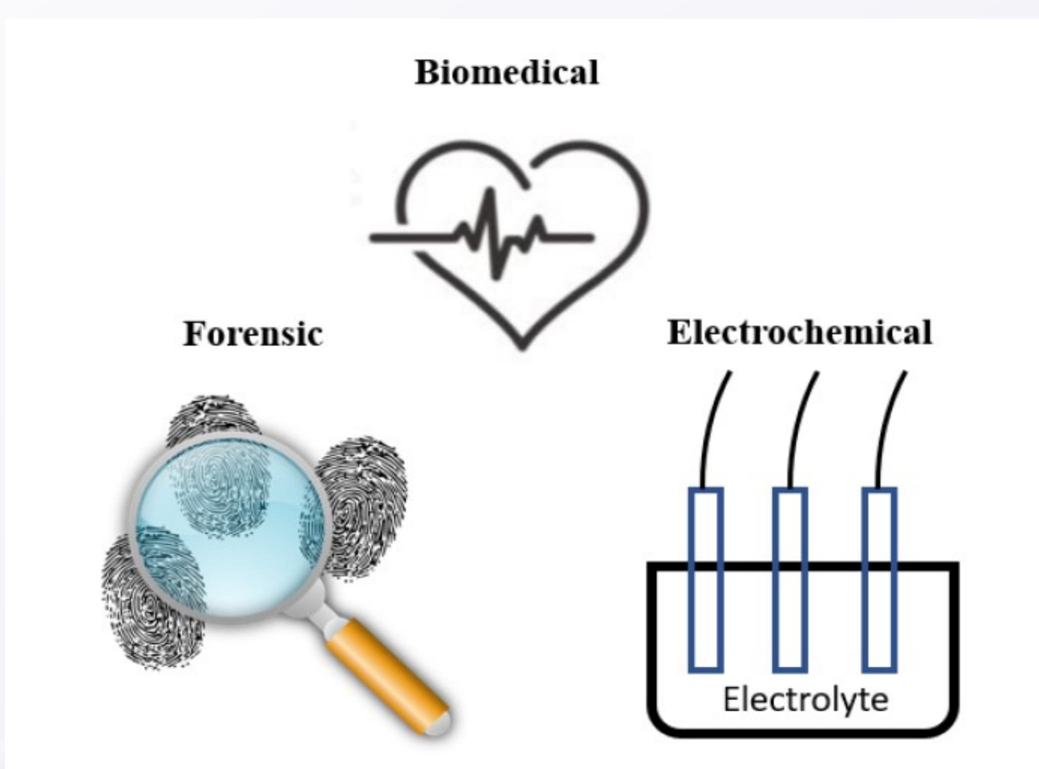
Issue

Flexible circuits are ones that can be bent, stretched, compressed, or undergo other types of deformation while still maintaining their ability to flow current like that of a standard, rigid substrate. The materials and manufacturing methods utilized for fabricating flexible electronic circuits is of substantive interest for a scalable solution to be implemented. Inorganic semiconductors have been proven to outperform their organic counterparts in traditional rigid circuits, and it is assumed that they will retain their role in the future with flexible circuits as well. [2]

As the availability of products and escalation of competition in the market increases, the price and barriers to access are likely to decrease for people seeking to purchase flexible electronic devices. The traditional methods of manufacturing such devices, using inorganic materials is likely to have a large environmental impact in such a case. By further testing the feasibility of organic substrates in comparison to their inorganic counterparts, we propose to find a solution that can be scaled sustainably.

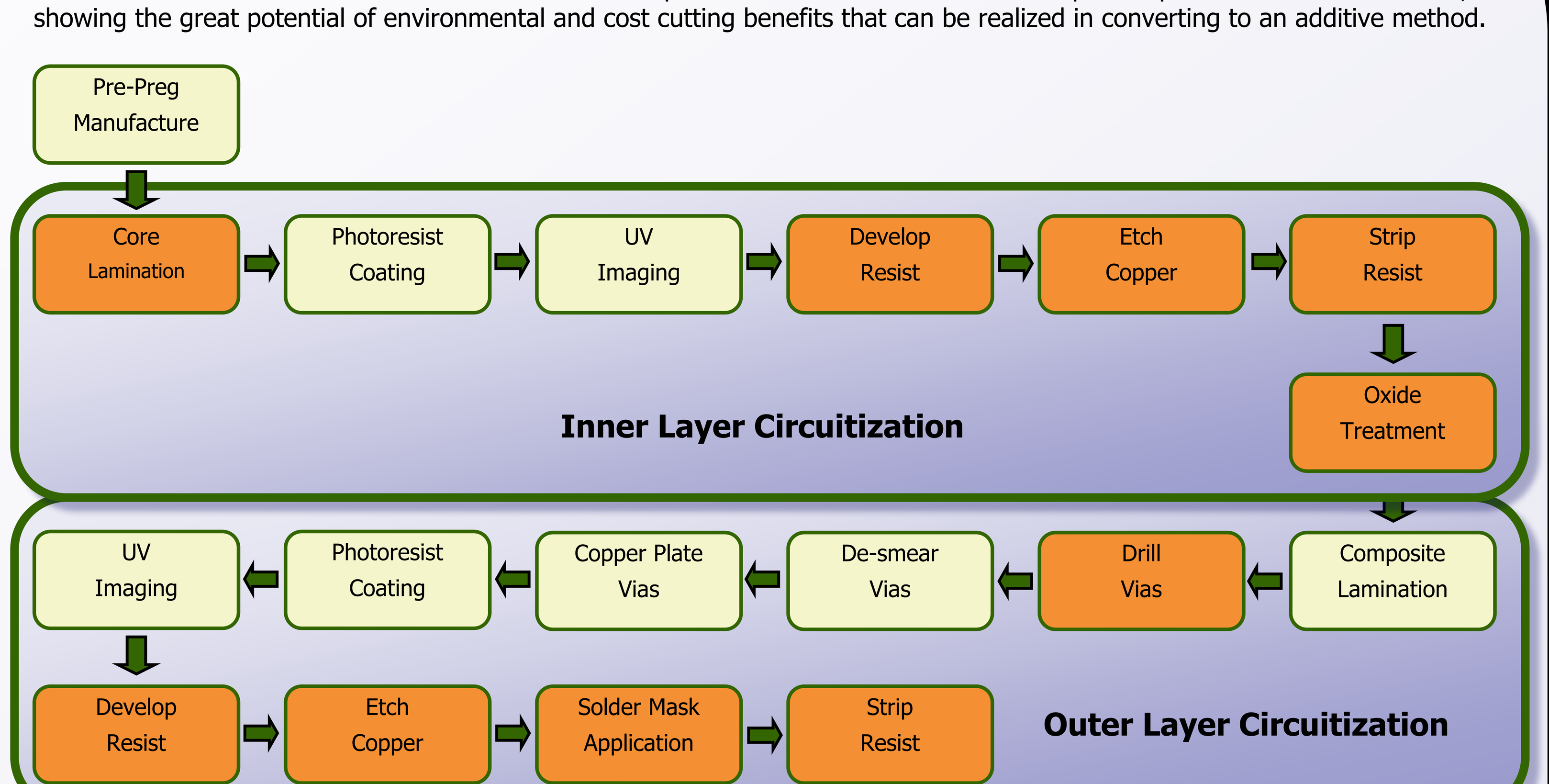
Flexible Circuits Potential Applications

The wide range of potential sectors in which the application of flexible circuits are expected to be adopted in the near future.



Traditional Subtractive Method Waste

The use of the traditional subtractive method to create printed circuits results in several steps that produce hazardous wastes, showing the great potential of environmental and cost cutting benefits that can be realized in converting to an additive method.



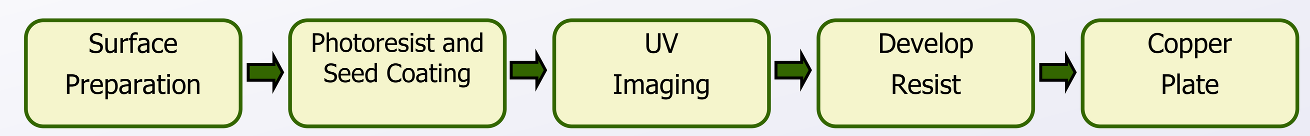
Flow chart depicting the traditional subtractive method of creating printed circuits. Steps in orange create hazardous waste.

Remedy

In order to assess the viability of organic substrates such as graphene, which is a single atomic layer of graphite, it is necessary to first examine the efficacy of the potential electron mobility of the material in different situations. Electron mobility seems to be limited by temperature, showing increased temperature correlating closely with an increase in resistance in single layer graphene applications. These effects can be reduced and even eradicated when pressure is applied, or the graphene is placed upon a substrate. [3]

Additive Process: Less Steps, No Waste

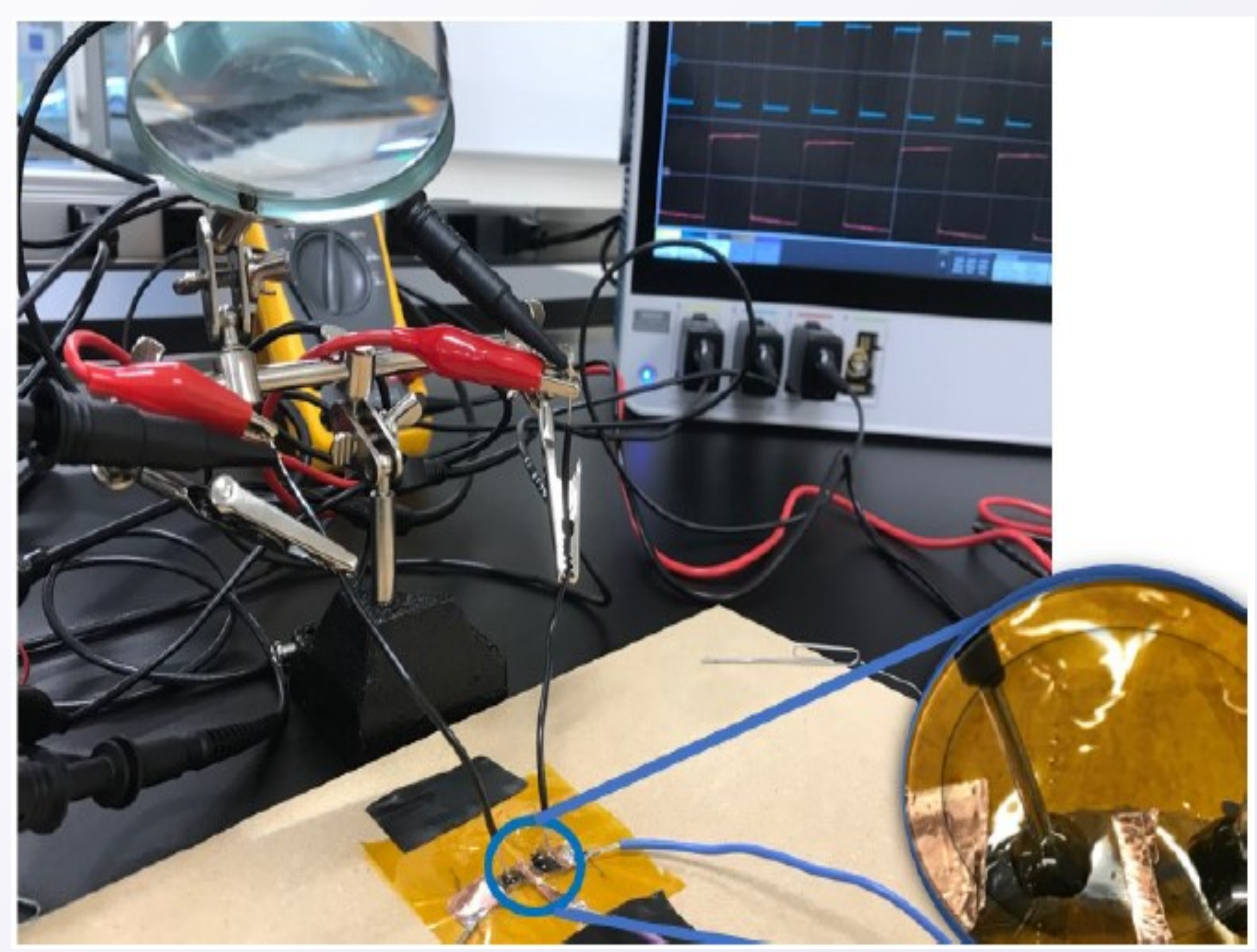
Additive technology shows large potential benefits in reducing the use of chemicals, and resource waste in line with sustainable manufacturing practices. There are no hazardous waste materials that are created, like there are in the traditional subtractive process.



Single layer additive technology process flow chart. A simplified process with no hazardous waste created.

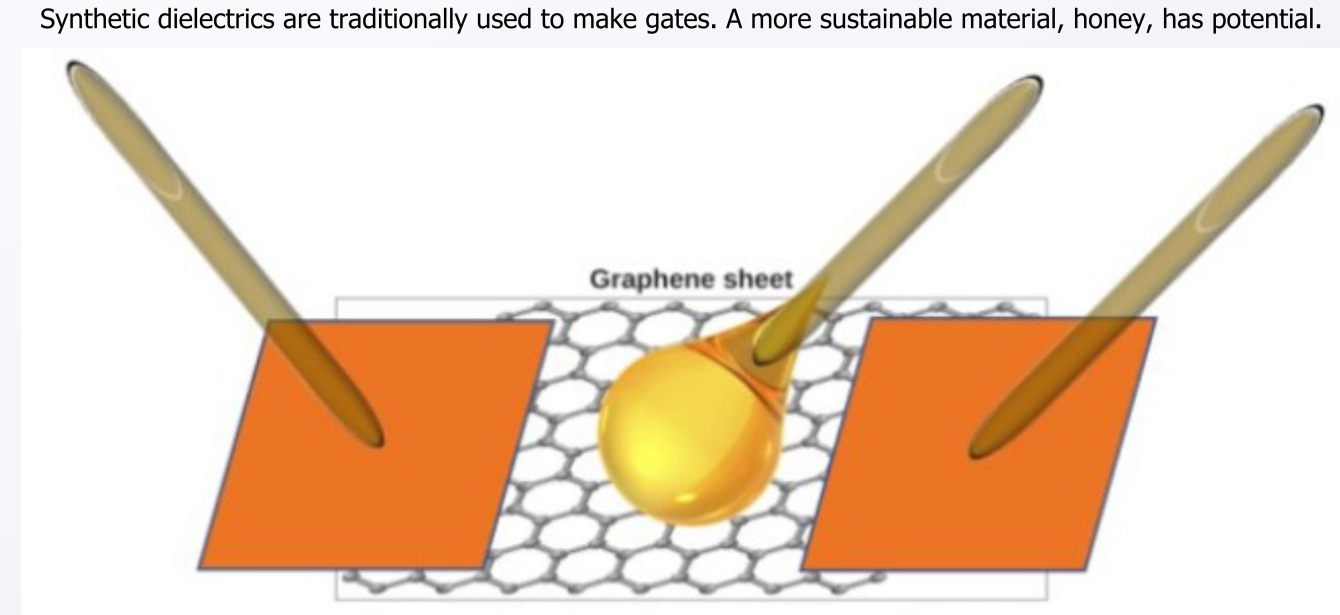
Laboratory Testing and Measurement

A lab created thin film AND gate with graphene transistor being tested and measured for conductivity.



Honey Dielectric Gates

Synthetic dielectrics are traditionally used to make gates. A more sustainable material, honey, has potential.



Real World Applications

A wide variety of real world applications already exist, and more will become available in the future.

Environmental Impacts

This project was conducted in order to acknowledge the lack of environmental considerations in the traditional processes utilized for constructing printed circuits. Through the use of non-toxic, organic material, and processes that do not produce hazardous wastes, the impact of the exponential growth of electronic devices can be reduced significantly, and can be implemented on a large scale without considerable differentiation in product reliability.

Summary

In this analysis, the theoretical application of organic materials where inorganic substances are currently being utilized is realized as being feasible. Further testing is required on a larger scale to ensure that the capability of electronic devices remains constant under a variety of different circumstances and situations, to see if negative or positive comparative correlations can be inferred.

Sources

[1] National, Research Council, et al. *Flexible Electronics for Security, Manufacturing, and Growth in the United States : Summary of a Symposium*, edited by Sujai J. Shivakumar, National Academies Press, 2013. *ProQuest Ebook Central*, https://ebookcentral.proquest.com/lib/csusm/detail.action?docID=3379056.

[2] Yu, K.J., Yan, Z., Han, M. *et al.* Inorganic semiconducting materials for flexible and stretchable electronics. *npj Flex Electron* **1,** 4 (2017). https://doi.org/10.1038/s41528-017-0003-z

[3] Castro, Eduardo V, Ochoa, H, Katsnelson, M I, Gorbachev, R V, Elias, D C, Novoselov, K S, Geim, A K, and Guinea, F. 2010. "Limits on Charge Carrier Mobility in Suspended Graphene Due to Flexural Phonons." Physical Review Letters 105 (26): 266601–266601. https://doi.org/10.1103/PhysRevLett.105.266601.