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NEW MATERIALS FOR CREATING FLEXIBLE ELECTRONIC DEVICES

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Annotation. This article examines the latest developments in the field of materials for flexible electronic devices. With the rapid development of portable electronics, there is a growing need for flexible and durable materials with high conductivity. The article presents the main materials used in flexible electronics. Their unique properties, advantages and disadvantages, as well as potential future applications, are analyzed and compared in an accessible format.

Keywords: flexible electronics, graphene, conductive polymers, nanowires.

Introduction. In recent years, flexible electronic devices have attracted close attention from researchers and industries alike, driven by their wide-ranging potential applications in burgeoning fields such as wearable technology, implantable medical devices, and innovative folding displays. The ability to create electronic circuits and components on non-rigid substrates opens up entirely new form factors and functionalities previously unattainable with conventional electronics [1].

Unlike traditional electronics that rely on rigid silicon wafers, the fabrication of flexible electronics necessitates materials that can seamlessly combine robust electrical conductivity with exceptional mechanical flexibility, including bending, stretching, and twisting. This dual requirement presents a significant materials science challenge, spurring intense investigation into novel conductive materials capable of withstanding mechanical deformation without compromising their electrical performance. Therefore, the identification and characterization of materials suitable for the manufacture of flexible devices, such as single-layer graphene, various conductive polymers, and networks of metallic nanowires, are becoming an increasingly urgent and pivotal topic for scientific research and technological development [1].

These advanced materials are emerging as promising solutions for creating a diverse array of flexible electronic components, including highly stretchable circuits that can conform to complex surfaces, sensitive flexible sensors for health monitoring and environmental sensing, and ultra-thin, foldable displays that could revolutionize mobile computing and information presentation. The ever-growing global demand for energy-efficient and lightweight electronic devices further underscores the paramount importance of sustained research and innovation in this dynamic area. This article aims to delve into the key electrical and mechanical properties of these prominent flexible electronic materials, explore their current and potential applications across various sectors, and ultimately foster a better understanding of their critical role in shaping the future landscape of flexible electronics [1].

The main part. The development of flexible electronics depends on the emergence of materials that provide both electrical performance and mechanical stability. Three main categories of materials – graphene, conductive polymers, and metallic nanowires – are the most promising candidates. As already mentioned, each of these materials has unique properties, advantages and disadvantages that make them suitable for use in one direction or another, which will become more obvious after a detailed analysis.

1 Graphene. Graphene, which is a monatomic layer of carbon, is considered one of the most important discoveries in materials science. It has extreme lightness, high conductivity and mechanical strength. Graphene is now used in flexible touchscreens (shown in Figure 1), transparent conductive films, and flexible batteries. The high mobility of charge carriers in this material allows for a fast electronic response, making it ideal for the production of high-speed

flexible transistors. The disadvantages include the fact that mass production of graphene without defects remains a difficult task. Modern production methods, such as chemical vapor deposition (CVD) and mechanical separation, require further improvement to reduce production costs [2].

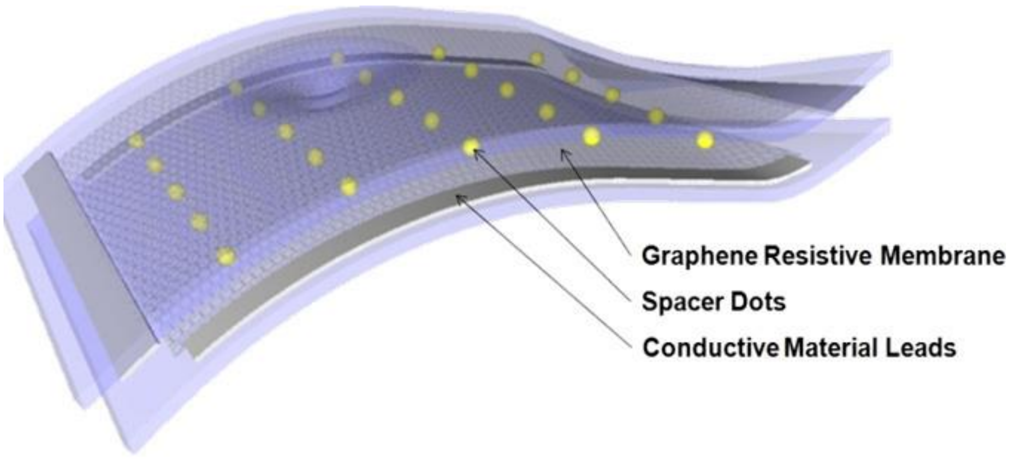

Figure 1 – Structure of graphene-based resistive-type touchscreen

2 Conductive polymers. Conductive polymers such as polyaniline (PANI), polypyrrole (PPy) and PEDOT:PSS provide a balance between conductivity and flexibility. Unlike traditional metal conductors, conductive polymers can be processed using simple and inexpensive printing methods. These materials are widely used in organic light-emitting diodes (OLED) (shown in Figure 2), flexible printed circuit boards (PCB) and bioelectronic devices. Their main advantage is the ability to stretch and bend while maintaining conductivity. Their disadvantage is their lower conductivity compared to graphene or metals. Researchers are working to improve their stability and conductivity through doping (modification of polymers using polymer reactions with electron donors or acceptors) and structural modifications [3].

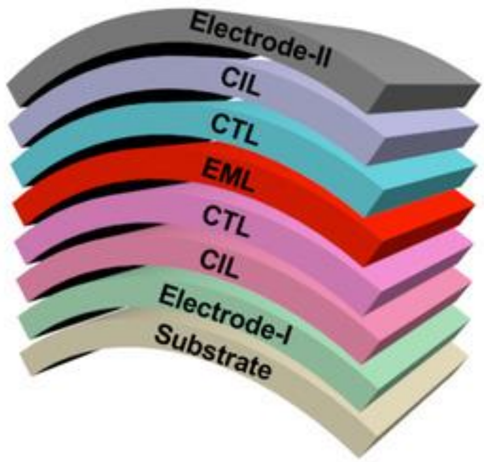

Figure 2 – Diagram of the device structure of flexible white organic light-emitting diodes

3 Metallic nanowires. Metallic nanowires, especially silver and copper, are becoming an excellent alternative to traditional transparent conductors such as indium tin oxide (ITO). The nanowires form a percolation network that retains electrical conductivity even when bent or stretched. They are widely used in flexible solar cells and touchscreens, as well as wearable sensors. However, the main disadvantage of metallic nanowires is their susceptibility to oxidation and degradation over time, especially in a humid environment. To solve this problem, researchers are developing protective coatings and hybrid compositions that increase the durability of metal nanowires [4].

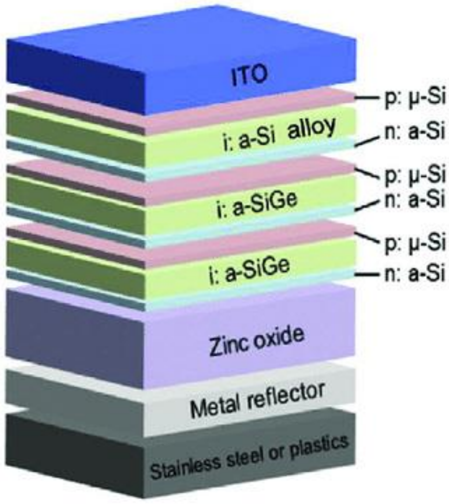

Figure 3 – Illustration of a flexible triple-junction silicon solar cell

The characteristics of the materials considered are presented in the Table 1.

Table 1 – Characteristics of materials used to create flexible electronic devices

Property	Graphene	Conductive Polymers	Metal Nanowires
Electrical Conductivity	Very high	Medium	High
Flexibility	High	Very high	High
Transparency	High	Medium	High
Durability	High	Medium	Low (prone to oxidation)
Manufacturing Complexity	High (labor-intensive production)	Low (simple printing)	Medium (possible conductivity loss)

Since each material has its advantages and disadvantages, it is obvious that the future of flexible electronics depends on combining different materials to optimize their properties. Graphene and polymer-based composites provide improved mechanical flexibility and electrical performance. Similarly, hybrid structures based on nanowires and graphene improve conductivity while maintaining mechanical stability. Future research in materials for flexible electronics will focus on improving technology, reducing production costs, and extending the life of materials.

Conclusion. Advances in materials science are key to creating better flexible electronics, with the greatest potential residing in hybrid structures that integrate diverse materials like graphene, polymers, and nanowires to combine their unique strengths. Future research should prioritize optimizing production methods for scalability and cost-efficiency while also designing novel hybrid materials to achieve synergistic performance gains. The successful development of these advanced flexible electronics is poised to revolutionize industries such as healthcare (wearable sensors), consumer electronics (foldable displays), and communications (flexible antennas), profoundly impacting technology and daily life.

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