

## Transparent Electrodes Based on Carbon Nanotubes

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## Overview

The electrical, optical, and mechanical qualities of transparent conductive electrodes (TCEs) make them ideal for electro-optic applications. However, existing TCEs are costly, inflexible, and their performance is inadequate. Considering the exceptional mechanical and electrical characteristics of carbon nanotubes (CNTs), which enhance the properties of composites, polymers, and solvents, we have devised a novel approach for producing transparent electrodes using organic dye/carbon nanotube dispersions. This new method addresses the limitations of current TCEs, offering affordability, flexibility, and improved performance. By utilizing CNT-based materials on transparent substrates, we provide a versatile platform suitable for many applications.

## Background and Unmet Need

Carbon nanotubes (CNTs) are utilized to produce high-quality electrodes and can enhance the properties of different materials, such as polymers. Recent advancements in large-scale production have made multi-walled and single-walled CNTs (MWCNTs, SWCNTs) more accessible and cost-effective. Yet, CNTs have a high tendency for bundling, which impedes their dispersion in liquid (solvents) and solid (polymer) media. This issue hinders the convenient and cost-efficient fabrication of materials with improved properties. Furthermore, transparent electrodes, which are extensively employed in numerous applications, necessitate the development of thin, flexible, and highly conductive systems that can be utilized on various surfaces. Current solutions, such as Indium Tin Oxide (ITO) and Fluorine-doped tin oxide (FTO), suffer from drawbacks, including high cost, brittleness, and poor flexibility.

## The Solution

Prof. Rybtchinski and his team developed transparent conductive materials and electrodes based on CNTs, that can be seamlessly transferred onto different transparent substrates.

## Technology Essence

Transparent conductive electrodes (TCEs) possess exceptional electrical, optical, and mechanical characteristics, making them a versatile platform for electro-optic applications. Using macroscopic electrodes comprising carbon nanotubes in various structural forms, the team developed a transparent conductive material disposed on a substrate forming a transparent conductive electrode. This transparent conductive material incorporates a hybrid of cost-effective aromatic molecules and CNTs, which undergo noncovalent modifications to achieve efficient and stable dispersions across a wide range of solvents, solvent mixtures, and polymers.

## Applications and Advantages

- Fabrication of transparent conductive electrodes, sensors, and composites using CNTs.
- Well-suited for touch screens, electrochromic materials, and as a conductive electrode cover for plastic.
- Superior mechanical and electrical properties.
- Cost-effective solution.
- Maintains conductivity during flexing, bending, stretching, and inflation.
- Easily integrated with various platforms.
- High transmittance in the UV- visible range.
- Extremely low thickness of several nm

## Development Status

The group successfully devised an innovative approach to create transparent conductive materials and electrodes using carbon nanotubes. The team achieved success in producing a hybrid of organic dyes and SWCNTs. They also established a method for manufacturing transparent conductive electrodes on transparent substrates.

## Market Opportunity

The potential for transparent electrodes is vast. Transparent electrodes find applications in various market segments, including Liquid Crystal Displays (LCD), Organic Light Emitting Diodes (OLEDs), and Plasma Display Panels (PDPs). These electrodes contribute to enhancing the color, contrast, and brightness of displays. Moreover, transparent displays represent an emerging market segment poised to revolutionize the display industry. They offer the unique advantage of transparency and flexibility, enabling integration into a wide range of applications such as automobiles, smart homes, wearables, and phones, which have significant market potential.

## Patent Status

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