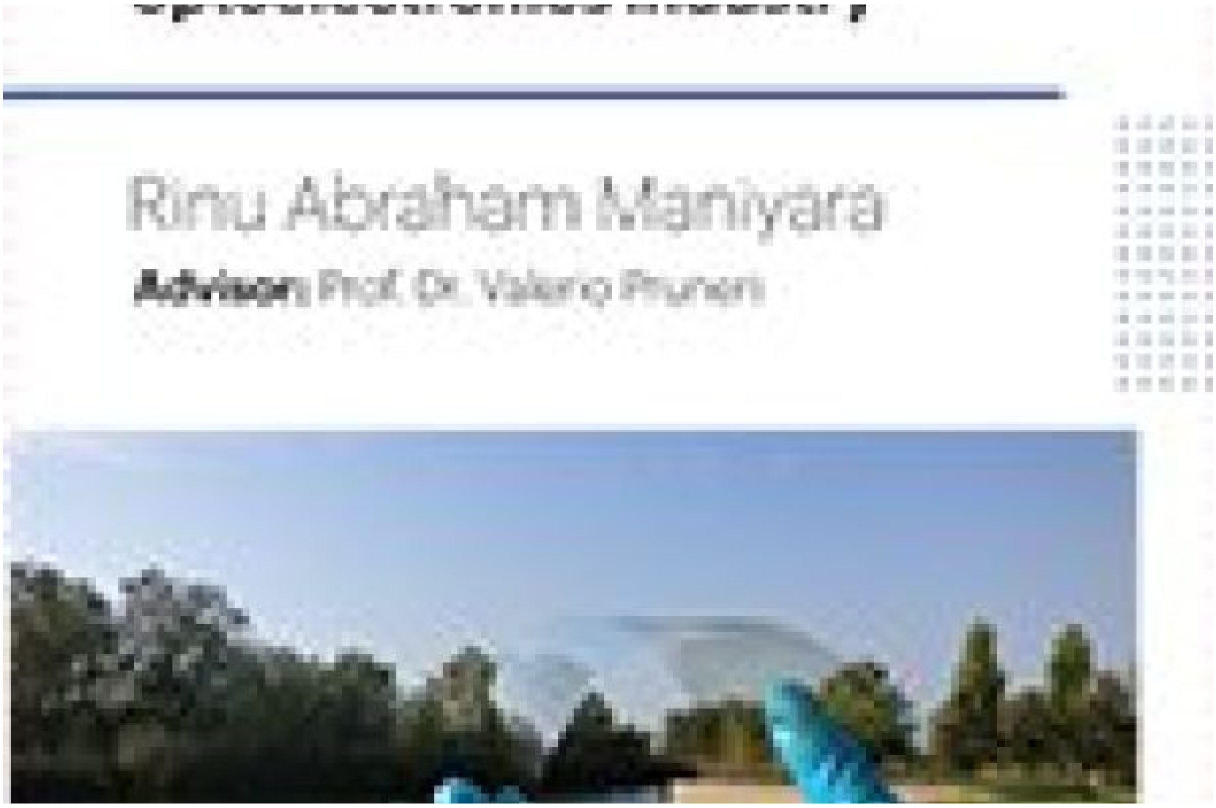

PhD Thesis Defense RINU ABRAHAM MANIYARA 'Nano-structured Transparent Conductors for the Optoelectronics Industry'

RINU MANIYARA

October 07, 2019

Monday, October 7, 11:00. ICFO Auditorium

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Optoelectronics

ICFO

Transparent conductors (TCs) are materials capable of simultaneously transmitting light and conducting electricity. They are an integral part of many optoelectronic devices, including light emitting diodes (LEDs), display screens, solar cells and smart windows. Due to its excellent optical and electrical properties, indium doped tin oxide (ITO) has been the most widely used TC in industrial applications for the past seven decades. However, ITO is no longer ideal for the next generation consumer applications because of its high cost, its scarcity, and its poor mechanical flexibility since mass-produced flexible devices are projected to become more widespread.

Materials like ultrathin metal films (UTMFs), metal oxides, carbon nanotubes (CNTs), graphene, metallic grids, metal nanowires, conducting polymers, and nanoparticles have been widely investigated as alternatives to conventional ITO films. However, there are still many challenges to obtain an ideal TC that integrates multiple properties, especially for consumer applications. For instance, the high contact resistance and the high roughness of metal nanowires and carbon nanotubes limit their practical applications. Additionally, graphene has a comparatively large sheet resistance and its mass production is still a challenge and conducting polymers lack an optimum conductivity and stability. Metal grids are promising in terms of optical transparency and conductivity, but their large-scale manufacturing is complex and the hazing that occurs is not desirable in the final application. Recently, there has been intense research on hybrid TCs that use two or more materials in order to combine their respective properties.
This thesis presents a class of TCs optimized for industrial applications obtained by combining single-component or multi-component material architectures that are already available. The large-scale production of high quality UTMFs is an intensive research area and central to this thesis. In chapter 2, we demonstrate the fabrication of atomically smooth gold (Au) UTMFs by exploiting surface wetting properties. The characterization tests reveal that the proposed structure results in an excellent enhancement of the optical, electrical, and structural properties, which had not been achieved before.

A multilayer architecture comprising ultrathin silver (Ag), aluminum doped zinc oxide (AZO), and titanium oxide (TiO2) is investigated in chapter 3. It constitutes a world record in the trade-off between transparency and conductivity. The destructive interference mechanism in the multilayer films is advantageously exploited, leading to antireflective TCs with an ultra-low optical loss.

Another novel design is presented in chapter 4: UTMFs, their oxides, and their nitrides were used to fabricate TCs with high mechanical resistance. Their mechanical durability and industrial compatibility are tested and confirmed.

The development of TCs with a higher and broader range of transparency along with a higher conductivity is necessary for many near infrared (NIR) and infrared (IR) applications. However, the available state-of-the-art approaches have focused on optimizing the transparency in the visible spectrum while the efficiency in the NIR remained low. In chapter 5, we develop ITO-based NIR-TCs with a high optical transmission that maintain a high electrical conductivity through a controlled and tunable process.

Finally, this thesis successfully demonstrates potential applications for the developed TC architectures with industrial standards. This is achieved by integrating the TC assemblies in plasmonic devices, displays, extreme ultraviolet (EUV) lithography processes, and for energy harvesting applications.

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