Plastic solar cells

Prof.dr.ir. R.A.J. Janssen

Professor of Molecular Materials and Nanosystems

René Janssen has been full professor of molecular materials and nanosystems at the departments of Applied Physics and Chemical Engineering & Chemistry at the TU/e since 2000. His current research focuses on creating, investigating, and applying novel molecular semiconductors with exceptional electronic and photophysical properties. Much of his work revolves around solar cells based on polymers.

Plastic solar cells

Creating a renewable source of clean energy is a prime challenge of today's society. With 100,000 terawatts of sunlight reaching the earth, the potential of solar energy exceeds by several orders of magnitude the requirements of the global population, which will amount to around 20 terawatts in 2050. The energy efficiency with which photovoltaic solar cells directly convert sunlight into electricity exceeds that of other technologies involving biomass, wind or hydroelectric power. In line with this high potential, the photovoltaic market is growing 30-40% annually and is likely to become one of the largest industrial activities worldwide this century.
Obstacles to the widespread introduction of this technology include the cost of materials and production speed. That is why there is a strong drive towards thin-film technologies in photovoltaic research, which is likely to reduce these obstacles. In this regard, polymer solar cells are particularly attractive, because they can reach favorable efficiencies and can be printed in roll-to-roll processes at very high

speeds, possibly exceeding the throughput of any other technology by far. The prospect that lightweight and flexible polymer solar cells can be produced at high speed, in combination with high energy-conversion efficiency, has spurred interests from academia, research institutes and companies. As power conversion efficiency has improved, the field of polymer solar cells has, over the past decade, progressed from being a scientific curiosity to the point where it is now on the brink of becoming a breakthrough technology for the future.

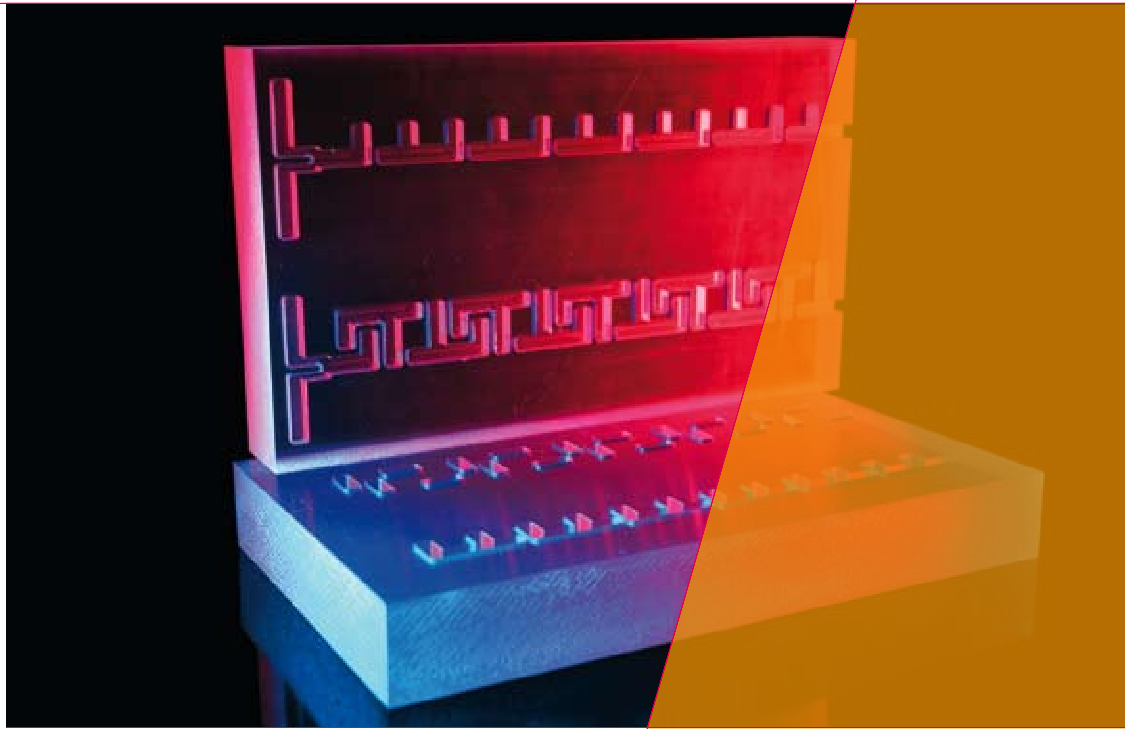
Innovation

The Netherlands has a prominent international position in this area and has contributed significantly to salient improvements in fundamental knowledge, new materials, device architectures, and technology aspects that are moving this area forward at high speed. Comprehensive insight has been gained into crucial materials parameters, including morphology, energy levels, charge transport, and electrode materials. Although there is growing evidence that polymer solar cells may achieve their full potential in future, as sketched above, not all of the attractive properties have yet materialized. New innovations and further scientific insight are required.

At present, state-of-the-art polymer solar cells can achieve power conversion efficiencies of about 6%. Projected efficiencies of 10-12% are within reach and it is expected that efficiency will be even higher in future, when multi-junction solar cells can be employed.

By combining synthesis, processing, and materials science with device physics and fabrication, there is little doubt that these attractive performance levels will be achieved in the near future.

To understand these challenges, one requires fairly detailed insight into the underlying operational principles. Polymer solar cells employ a nanoscopic phase separation or bulk heterojunction between two complementary molecular-based polymer semiconductors to convert sunlight directly into electricity. Their operation relies on a photoinduced electron transfer reaction at the interface of the two semiconductors in a process that mimics natural photosynthesis. Following this event, charges must escape from recombination, separate spatially, migrate to the appropriate electrodes, and finally



be collected. Each of these processes poses intriguing scientific questions and exciting challenges to materials design. The nanoscale morphology of the intermixing between the two components plays a vital role in this complex sequence of events.

The power conversion efficiency of polymer solar cells depends critically on the quantum efficiency of photon to electron conversion that determines the current and the potential energy efficiency, which determines how much of the initial photon energy is preserved at the operating voltage of the cell.

Spectroscopy

Ultrafast spectroscopy studies have clearly established that charge generation can occur within a few tens of femtoseconds. Hence, after absorption of a photon, charge generation can occur with 100% yield. One of the crucial questions is: what happens to the charges after they have been generated? The low dielectric constant of

organic materials creates an energy barrier for charge separation that exceeds the thermal energy. Presently, it is not understood in detail how photogenerated charges escape from the interface where they were created and how they avoid geminate recombination. One of the current hypotheses is that the energy gained in the electron transfer reaction, or excess energy, is used to enable charge separation from the interface. The minimal amount of excess energy needed for full charge separation has direct consequences for the maximum efficiency that can be attained, because it represents a loss factor. Further gain in device performance can be expected by developing materials that create free charges in high yield with minimal energy losses.

Recently, the first multi-junction solar cells, comprising fully solution-processed, transparent intermediate contacts, were demonstrated as a new technology. The novel intermediate contact used in these cells serves to collect electrons generated in the front cell, so that they can be recombined with the gaps created in the back cell, thus closing the circuit. The advantage of a tandem cell – and of multi-junction cells in general – is that photon energy can be collected more efficiently.

In conclusion, by combining synthesis, processing and materials science with device physics and new fabrication technologies, the field of polymer solar cells has made significant progress in recent years, creating a realistic technology platform for abundant, clean energy in the future.