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Crystalline MoO$_x$ Thin-Films as Hole Transport Layers in DBP/C$_{70}$ Based Organic Solar Cells

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Introduction

Transition Metal Oxides such as Molybdenum oxide (MoO$_x$) have been intensively used as hole transport layers in different organic, inorganic and hybrid technologies, where their presence proves to be beneficial both to the power conversion efficiency, as well as to the operational stability of the devices. Among several different deposition methods available for fabrication of MoO$_x$ thin-films, reactive sputtering arises as an interesting alternative due to its full control over the deposition parameters such as the deposition power, reactive gas partial pressure and the deposition rate.

Methodology

We investigated the differences in performance of the organic solar cells based on DBP/C$_{70}$ containing 30nm of either thermally evaporated (MoO$_{30}$) or reactive sputtered (MoO$_{30}$) MoO$_x$ as hole-transport layer. Furthermore, we compared the two types of MoO$_x$ in dependence of annealing treatment. Although devices with as-deposited MoO$_{30}$ show a rather poor performance, the devices with annealed MoO$_{30}$ show promising characteristics comparable to the as-deposited thermally evaporated films.

Optoelectronic properties

We observed a dramatic change in the optoelectronic properties of the as-deposited DC-sputtered MoO$_x$ films upon tuning the oxygen partial pressure (pO$_2$) during the growth process.

We observe that by increasing the oxygen partial pressure during the formation of MoO$_{30}$ several parameters of the formed film will be affected:

- Stoichiometry of MoO$_x$
- Increase in roughness
- Increase in transmittance
- Decrease in conductivity
- Increase in work function
- Increase of optical band gap

Transport properties

To investigate the effect of annealing on the transport properties of MoO$_x$, we made hole-only devices based on the configuration below, where the different MoO$_x$ layers are used as the hole extracting layer close to the ITO anode. The results demonstrate that the transport properties of the MoO$_{30}$ improve with the annealing temperature, whereas the opposite is the case for the MoO$_{30}$.

Thermal annealing influence on the performance

The influence of different reactive sputtered MoO$_x$ compositions prepared by reactive sputtering (x=3.16), in comparison to those obtained by thermal evaporation (MoO$_x$, x=2.85) and post-annealing in ultra-high vacuum, to the performance of OSC devices has been investigated, where MoO$_x$ was used as hole-transport layer. Interestingly, devices with sputtered MoO$_x$ that has been annealed in ultra high vacuum, exhibits performance comparable to our reference devices containing as-deposited thermal MoO$_x$. Devices made with thermally evaporated MoO$_{30}$ show a consistent drop with the increase in the annealing temperature, while those with sputtered MoO$_{3.16}$ exhibit peak performance when annealed at 350°C.

Conclusion

In this work, we present reactive sputtering as an alternative method for fabricating tunable MoO$_x$ films with a strong positive impact on device performance and potentially on the device stability. Upon vacuum annealing, the sputtered MoO$_x$ films show improved transport properties and work functions, leading to improved device efficiencies.

References