Solution processed manganese-based thin films for photovoltaic applications.

Fabio Butrichi[a,b], Vanira Trifiletti[a,b], Giorgio Tseberlidis[a,b], Berenice Elena Gaia Colombo[a,b], Fabiana Taglietti[a], Marzio Rancan[c], Lidia Armelao[d,e], Simona Binetti[a,b]

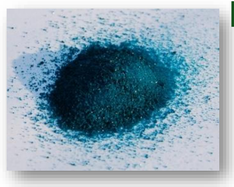
[a] *Department of Materials Science, University of Milano-Bicocca, 20125, Milano, Italy*
[b] *Solar Energy Research Center (MIB-SOLAR), University of Milano-Bicocca, 20125, Milano, Italy*
[c] *Institute of Condensed Matter Chemistry and Technologies for Energy (ICMATE), National Research Council (CNR), C/o Department of Chemical Sciences (DiSC), University of Padova, Via F. Marzolo 1, 35131, Padova, Italy*
[d] *Department of Chemical Sciences (DiSC), University of Padova, Via F. Marzolo 1, 35131, Padova, Italy*
[e] *Department of Chemical Sciences and Materials Technologies (DSCTM), National Research Council (CNR), Piazzale A. Moro 7, 00185, Roma, Italy*

Thin film photovoltaic devices are increasingly developed to be low-cost and eco-friendly. Cu_2MnSnS_4 (CMTS) is a promising candidate thanks the abundance, low cost and low toxicity of its constituents. This work focuses on the development and characterisation of CMTS thin films using a wet synthesis method. The goal is to improve material quality and photovoltaic performance by controlling oxidation states and minimizing defectivity.

Previously, we have grown CMTS thin films through metallic precursors sputtering followed by high-temperature annealing in a sulphur atmosphere. These devices demonstrated a conversion efficiency of 1.13% sustained for over a year from the initial photovoltaic measurement. However, a high level of defectivity in the material has been detected.**[1]**

To address this, we transitioned to a sol-gel-based method to enhance material quality. CMTS films have been obtained in stannite structure. Manganese oxidation was effectively prevented and no oxygen was present. Beneficial effect of post deposition treatments and ageing of the device was confirmed and record efficiency for wet-CMTS was reported. Buffer layer optimisation was identified as key factor to further increase performances of the devices. **[2]**

Preparation



$Cu(CH_3COO)_2 \cdot H_2O$

$Mn(CH_3COO)_2 \cdot 4H_2O$

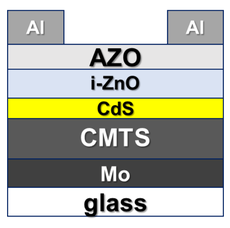
$SnCl_2 \cdot 2H_2O$

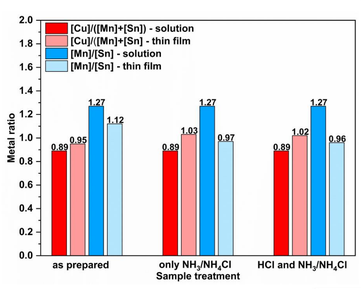
Thiourea

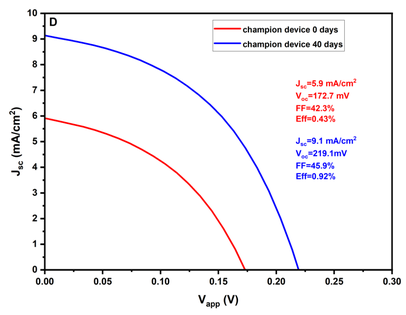
- **Solution preparation**: metal acetates and thiourea dissolved in dimethyl sulfoxide (DMSO) with a potassium chloride (KCl) additive.
- **Deposition:** Blade-coating technique on molybdenum-coated soda-lime glass substrates.

- **Annealing:** Conducted at 550°C in an argon atmosphere without external sulfurizing agents.

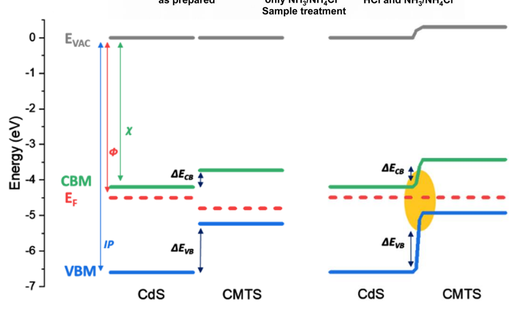
Device







A record efficiency of 0.92%: post-deposition treatments and device ageing positively affects performance.

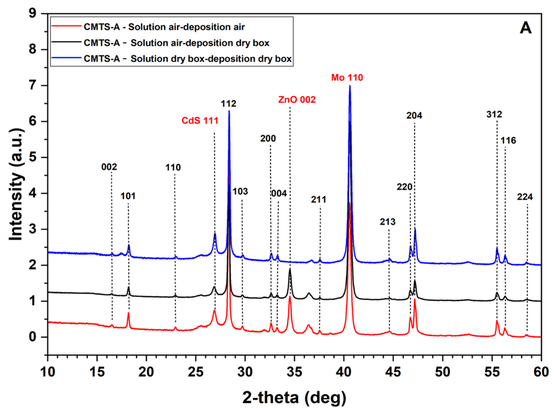


CdS buffer layer was found to impact surface composition and photovoltaic efficiency.

In conclusion, the wet synthesis method developed for CMTS thin films presents a promising route for producing cost-effective and sustainable photovoltaic materials. Further improvements in buffer layer optimization could lead to enhanced device performance.

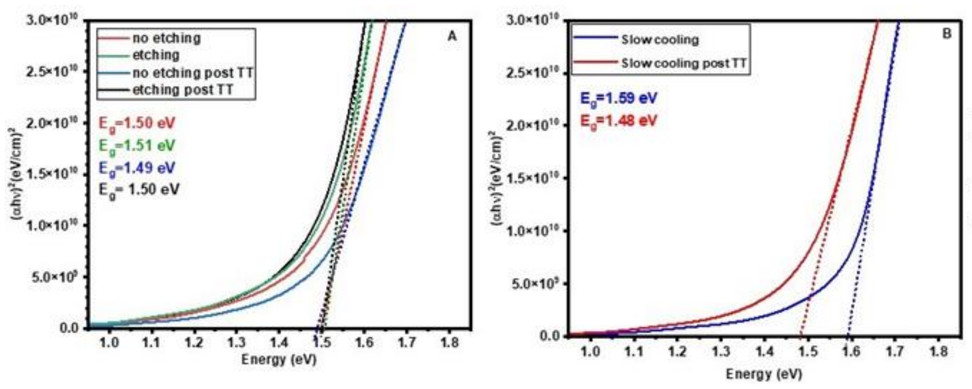
Characterization

X-ray diffraction (XRD)

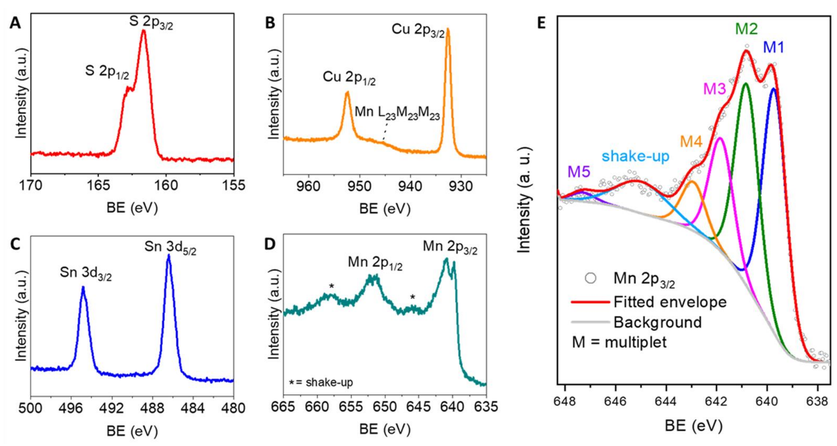


High-quality stannite structure CMTS thin films were obtained.

UV-Vis spectroscopy

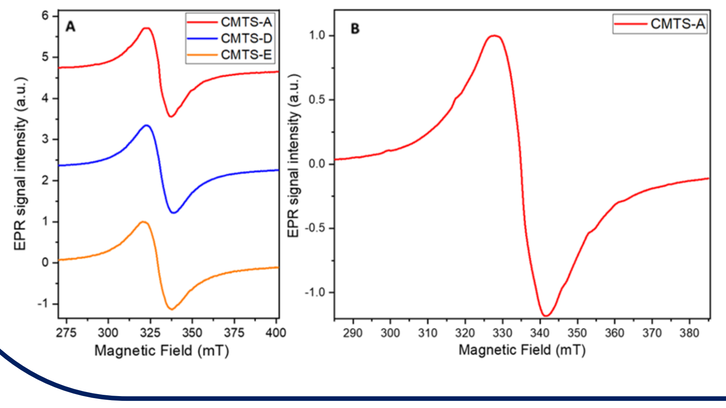


Photoelectron spectroscopy (XPS)



XPS and EPR proved the oxidation of manganese being avoided

Electron paramagnetic resonance (EPR)



[1] V. Trifiletti, L. Frioni, G. Tseberlidis, E. Vitiello, M. Danilson, M. Grossberg, M. Acciarri, S. Binetti, S. Marchionna, Solar Energy Materials and Solar Cells, 254 (2023) 112247.

[2] F. Butrichi, V. Trifiletti, G. Tseberlidis, B.E.G. Colombo, F. Taglietti, M. Rancan, L. Armelao, S. Binetti, Solar Energy Materials and Solar Cells, 272 (2024) 112924.

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