

# One-step electrochemical deposition of Cu-In-Ga mixed oxide thin films for low-cost CIGS solar cells

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## Introduction

Metallic Cu-In-Ga precursors for CIGS solar cells are usually produced by multistep deposition of elemental metallic layers [1]. One step electrodeposition would be of interest in terms of cost reduction, but is difficult because of the highly negative deposition potential of gallium.

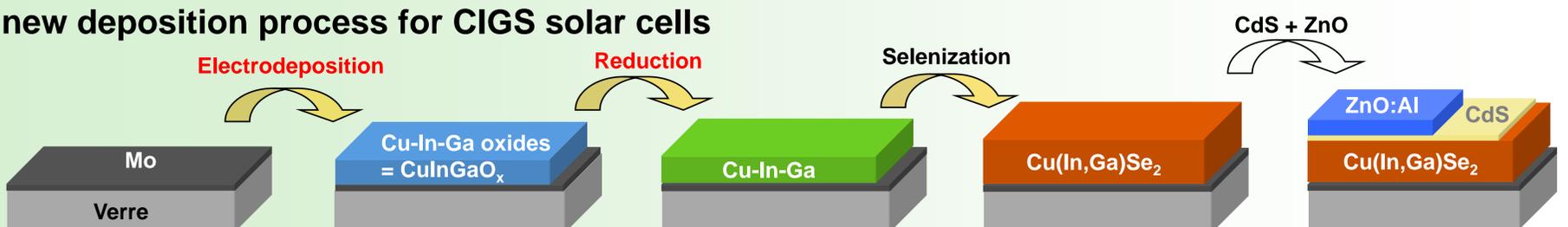
In the present work, we develop a new one-step electrochemical deposition in aqueous solutions of a mixed Cu-In-Ga oxide/hydroxide layer, which is subsequently reduced by thermal treatment under hydrogen atmosphere. This method leads to suitable metallic precursors for CIGS solar cells [2].

## Conclusion

This electrodeposition process enables homogeneous and fast growing oxide precursor deposition in less than 5 minutes. Cu/(In+Ga) and Ga/(In+Ga) ratios are easily adjustable by the ionic species concentrations. The precursor composition is constant over a wide range of deposition potentials.

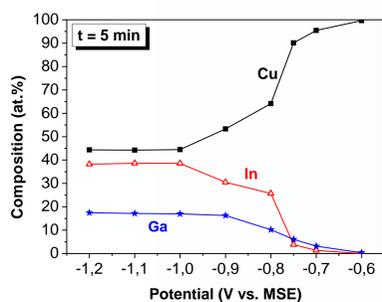
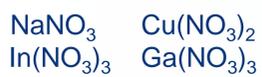
The films are completely reduced into Cu-In-Ga metallic precursor by annealing under Ar-5% H<sub>2</sub> atmosphere. After selenization, very promising device efficiency up to 9.4% was obtained. Selenization process has to be optimized for further efficiency increase.

## A new deposition process for CIGS solar cells



## 1/ Electrodeposition of CuInGaOx precursor

Acidic electrolyte :

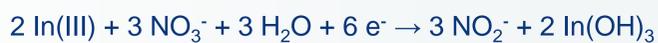


Composition of the Cu-In-Ga mixed oxide films as a function of deposition potential

Proposed mechanism:



NO<sub>3</sub><sup>-</sup> reduction catalyzed by freshly deposited Cu :



- Simple and stable electrolyte
- High deposition rate (< 5min)
- Homogeneous composition and easily adjustable
- Deposition of Cu initiates the whole process

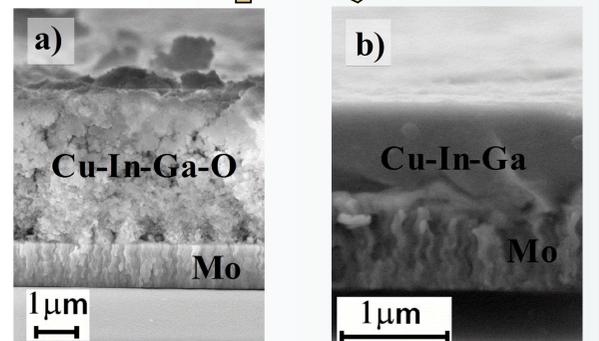


CuInGaOx precursor after electrodeposition (2.5 x 2.5 cm<sup>2</sup>)

## 3/ Reduction of CuInGaOx by annealing under Ar-5%H<sub>2</sub>

Complete reduction of CuInGaO<sub>x</sub> precursor

Annealing at 600-650°C / 60-90 min



CuInGaO<sub>x</sub> electro-deposited precursor

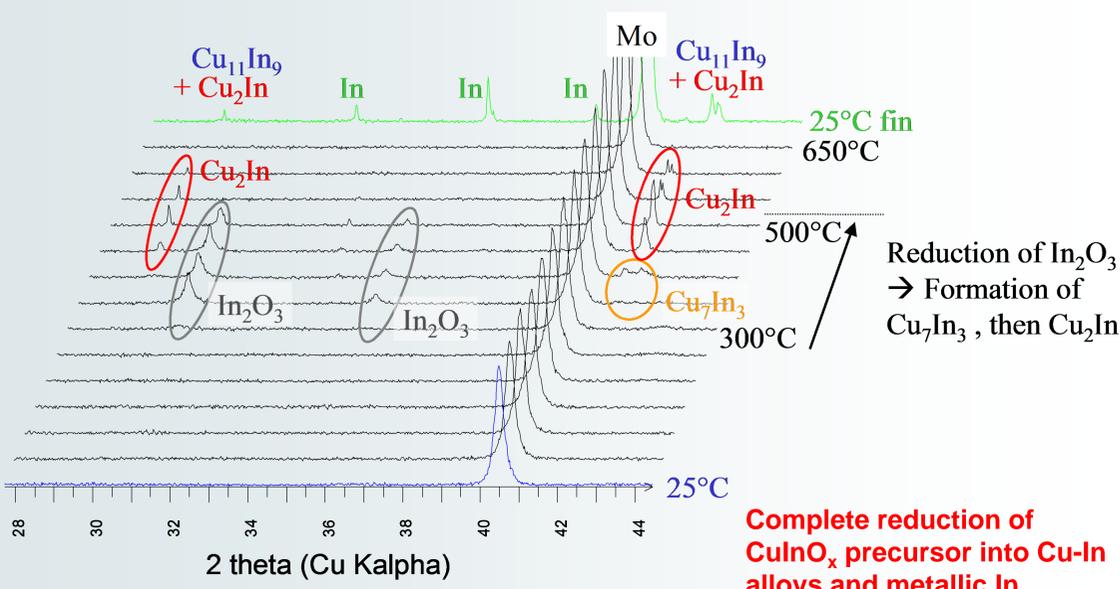
CuInGa metallic precursor

Homogeneous composition

Cu/(In+Ga) = 0.89

Ga/(In+Ga) = 0.35

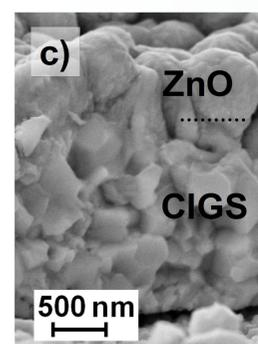
## 2/ HT-XRD reduction of Cu<sub>0.47</sub>In<sub>0.53</sub>O<sub>x</sub> under flowing N<sub>2</sub>-3%H<sub>2</sub>



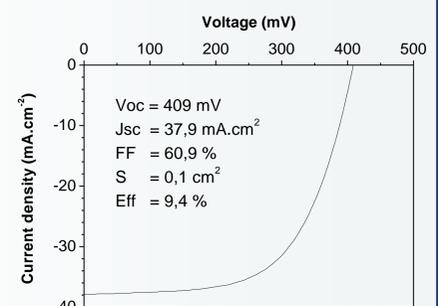
Reduction of In<sub>2</sub>O<sub>3</sub> → Formation of Cu<sub>7</sub>In<sub>3</sub>, then Cu<sub>2</sub>In

Complete reduction of CuInO<sub>x</sub> precursor into Cu-In alloys and metallic In

## 4/ Selenization and best-cell result



CIGS completed cell



I-V characteristics of a 0.1 cm<sup>2</sup> area device

- First cell results are very encouraging
- Ga accumulation near the back-contact
- Selenization process has to be improved for higher efficiency