

# Inkjet printing of perovskite solar cells on flexible substrates using industrial printheads

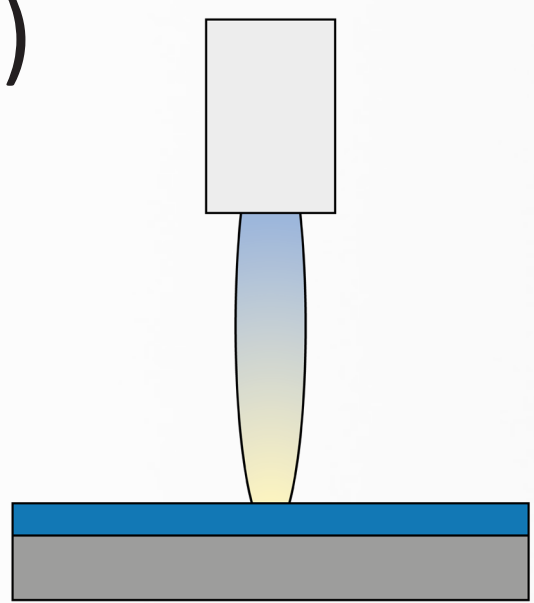
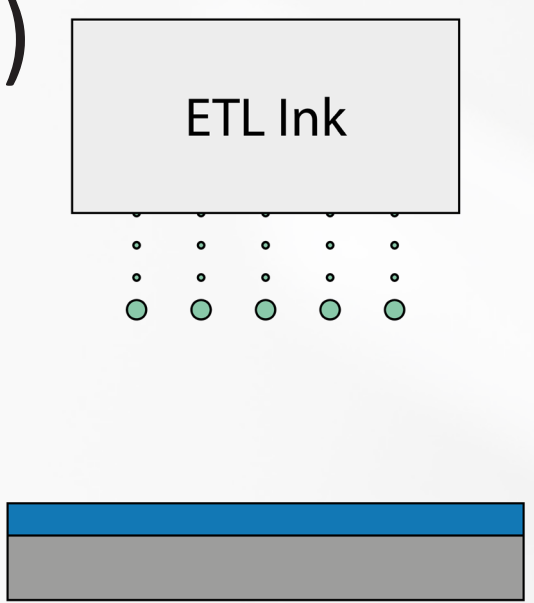
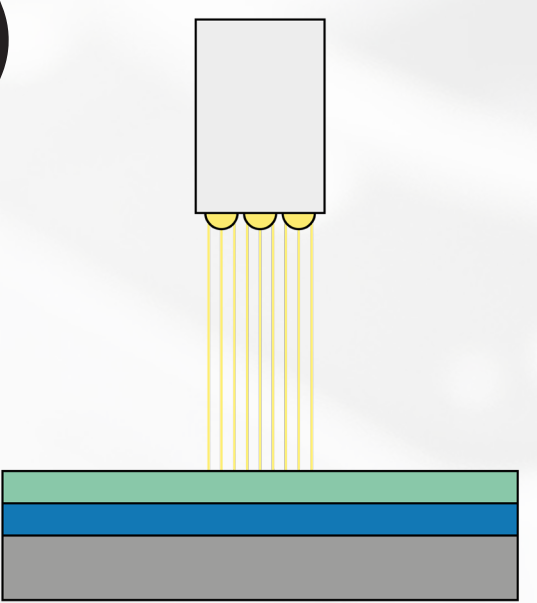
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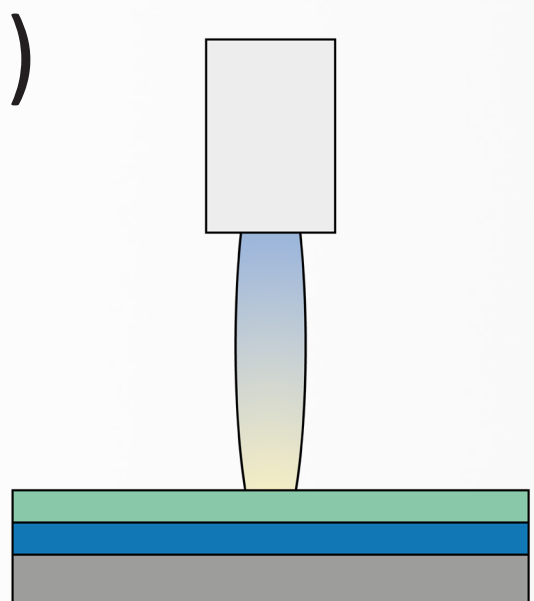
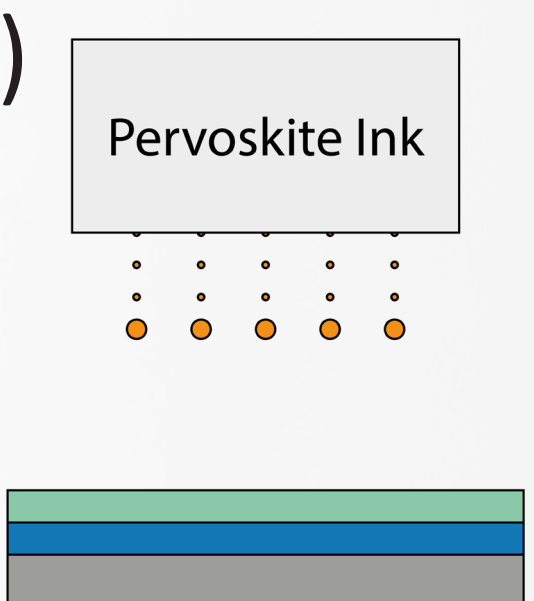
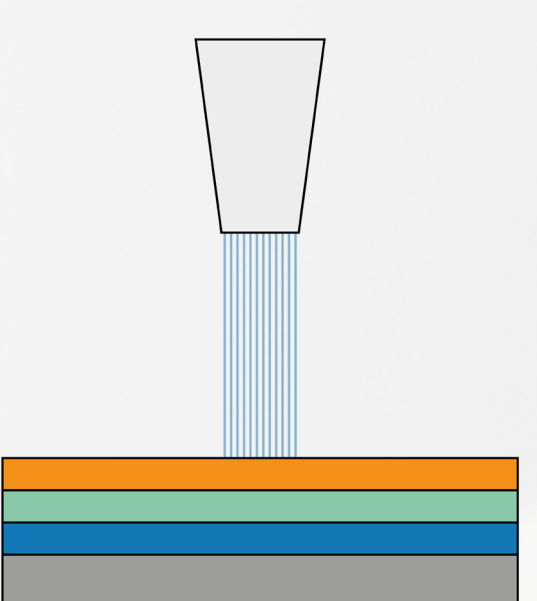
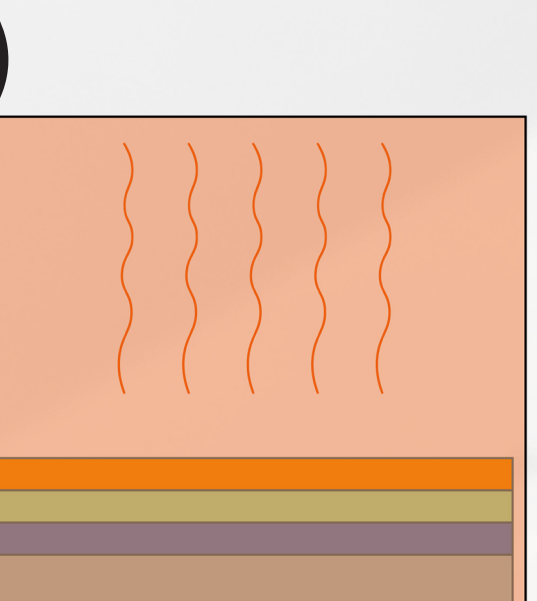
1. iPrint, HEIA-FR, HES-SO University of Applied Sciences and Arts Western Switzerland, Fribourg CH-1700, Switzerland

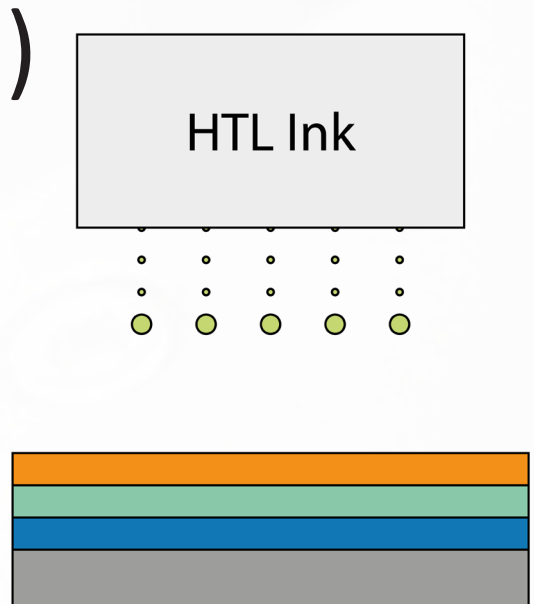
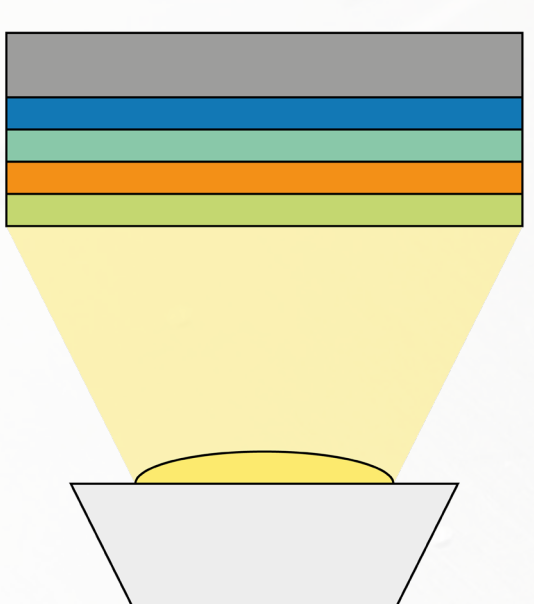
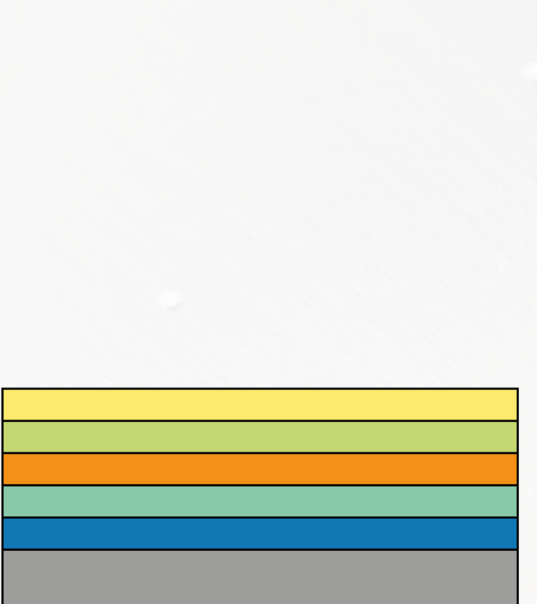
2. GMF, EPFL-Valais, Sion CH-1951, Switzerland

3. Toyota Motors Europe, Brussels, Belgium

## Three printed layers solar cell process

- a)  b)  c) 
- a) A cleaned commercial ITOPEN substrate was treated with a plasma torch.  
b) The electron transport layer (ETL) SnO<sub>2</sub> was printed .  
c) It was dried by a near-infrared lamp.

- d)  e)  f)  g) 
- d) The ETL coated sample was treated with a plasma torch.  
e) The perovskite layer was printed.  
f) The perovskite layer was dried by an airknife.  
g) The perovskite layer was annealed in a vacuum-oven.

- h)  i)  j) 
- h) The holetransport layer (HTL) Spiro-OMeTAD was printed.  
i) The gold contact layer was evaporated on the stack.  
j) The finished solar cell

## Layers of the solar cell

Back Contact: Gold
Hole Transport Layer (HTL): SPIRO (Inkjet printed)
Perovskite Layer (Inkjet printed)
Electron Transport Layer (ETL): SNO <sub>2</sub> (Inkjet printed)
Front Contact: Transparent Conductive Oxide (TCO) ITO
Transparent Substrate: PEN

## Results

The three printed layers solar cell yielded a photovoltaic energy conversion efficiency (PCE) of 0.6%. The crystallinity of the perovskite layer was too low and ETL layer and HTL layer not optimized. The functionality is checked layer by layer. After improving the ETL layer a solar cell with printed ETL and spin-coated perovskite and HTL-layer had a PCE of 16.76%.

## Printing

The three layers were printed using industrial printheads. Drop watching allowed the tuning of the waveforms to jet the three different inks. The inks are jetted in greyscale mode with several drops merging into one big drop.

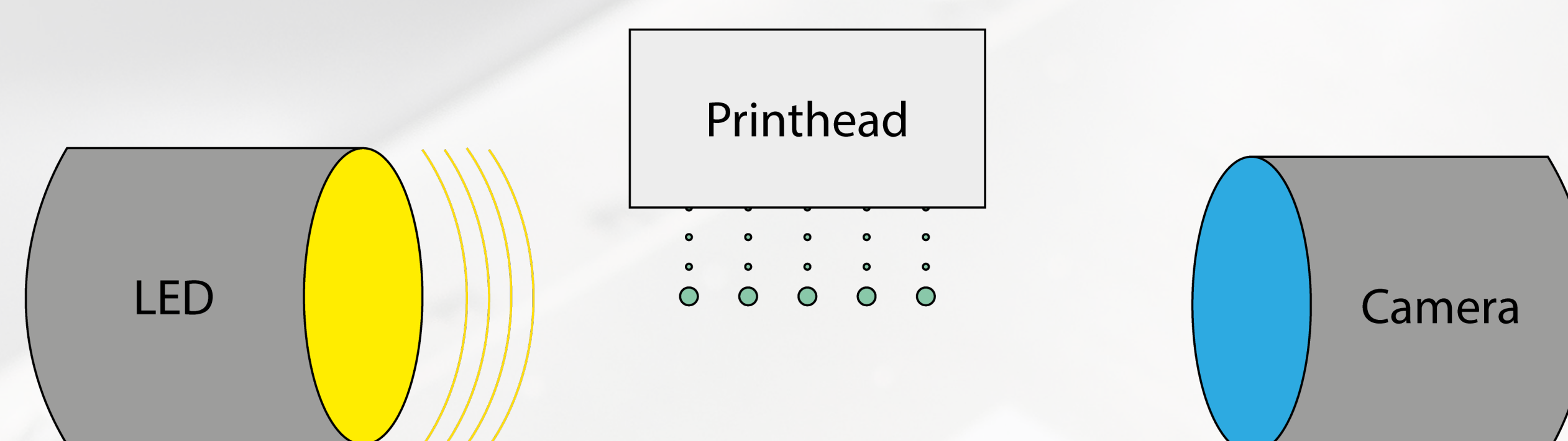


Figure 1: Schema of drop watching setup

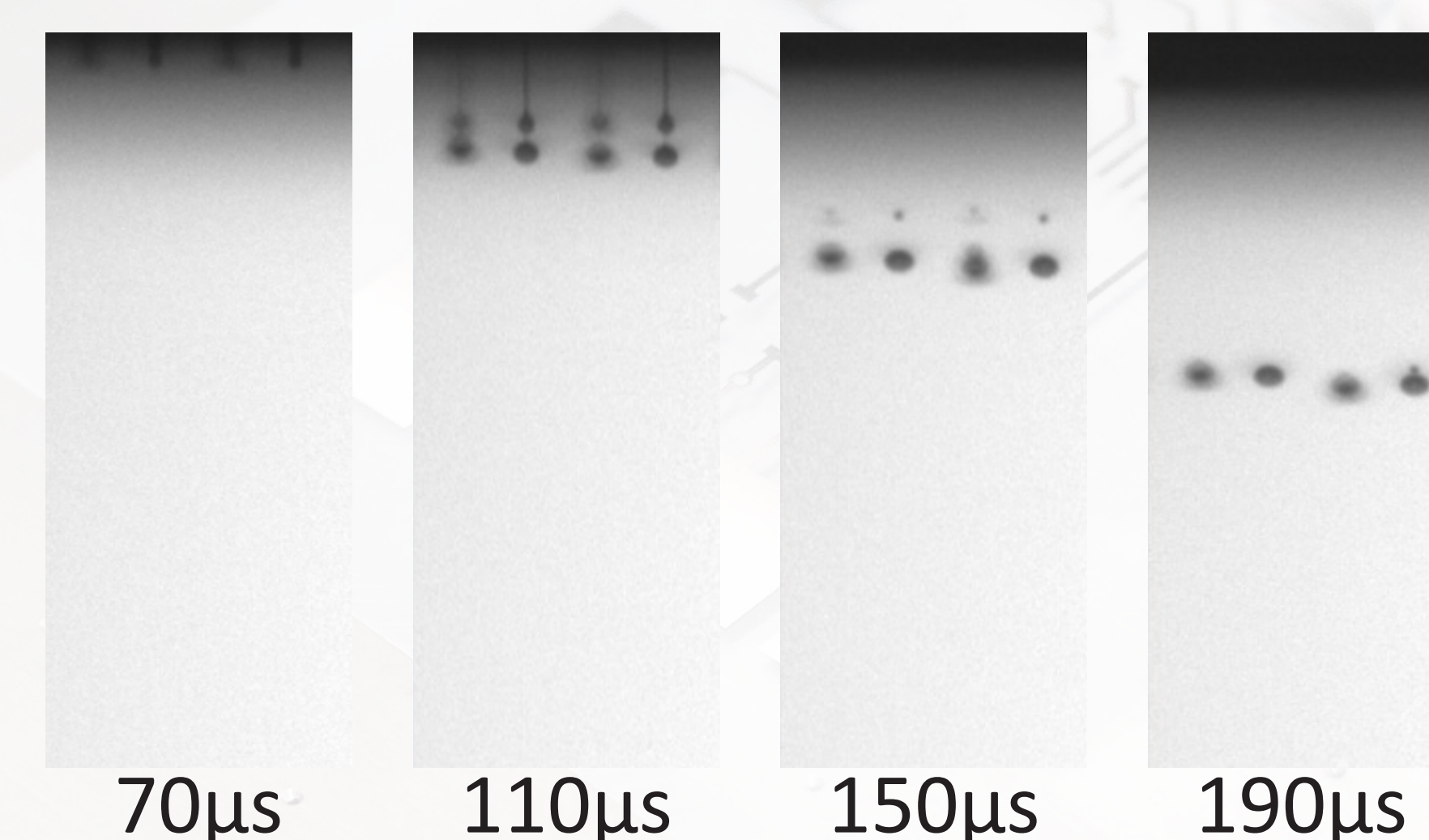


Figure 2: ETL ink drops at different delays after the first pulse



Figure 4: Realised cell array

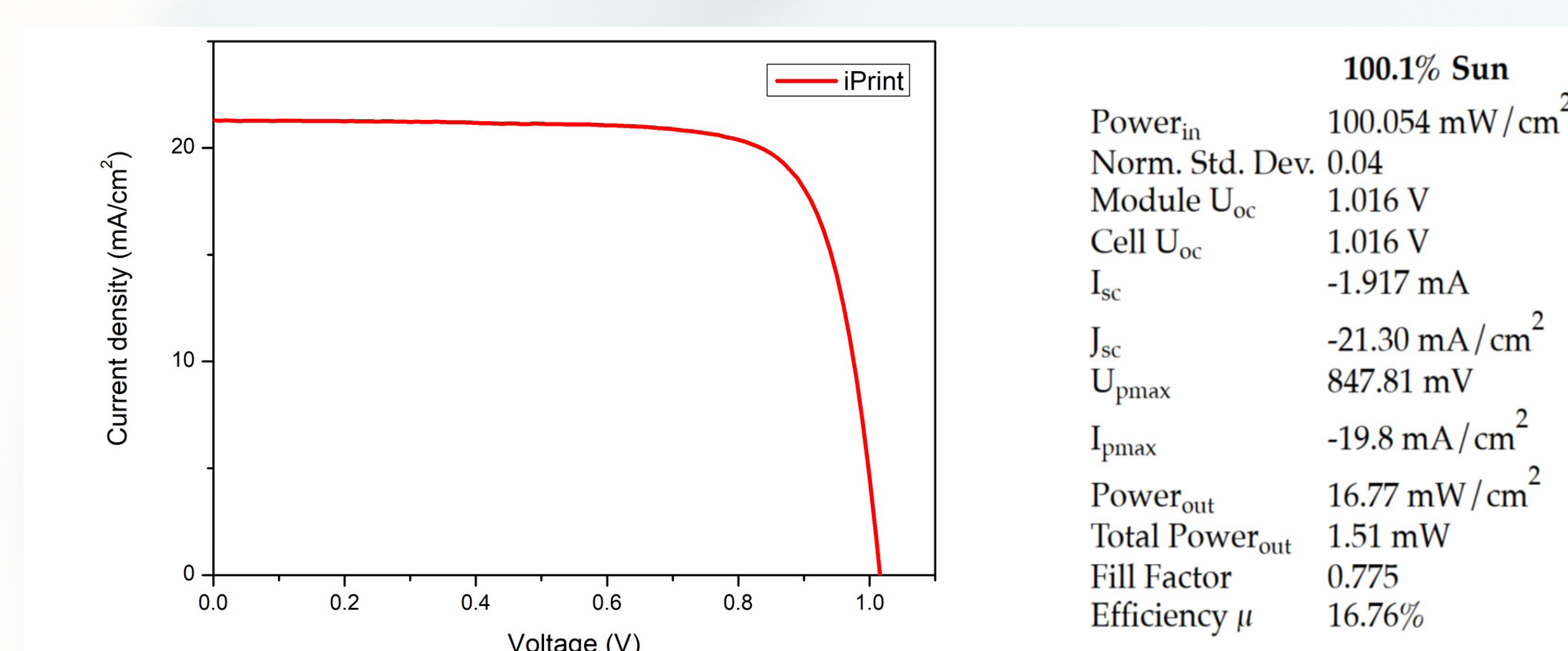


Figure 3: IV curve for cell with printed ETL and spin coated perovskite and HTL layer