

Morphology and topography of Perovskite solar cell films ablated and scribed with ultrashort laser pulses

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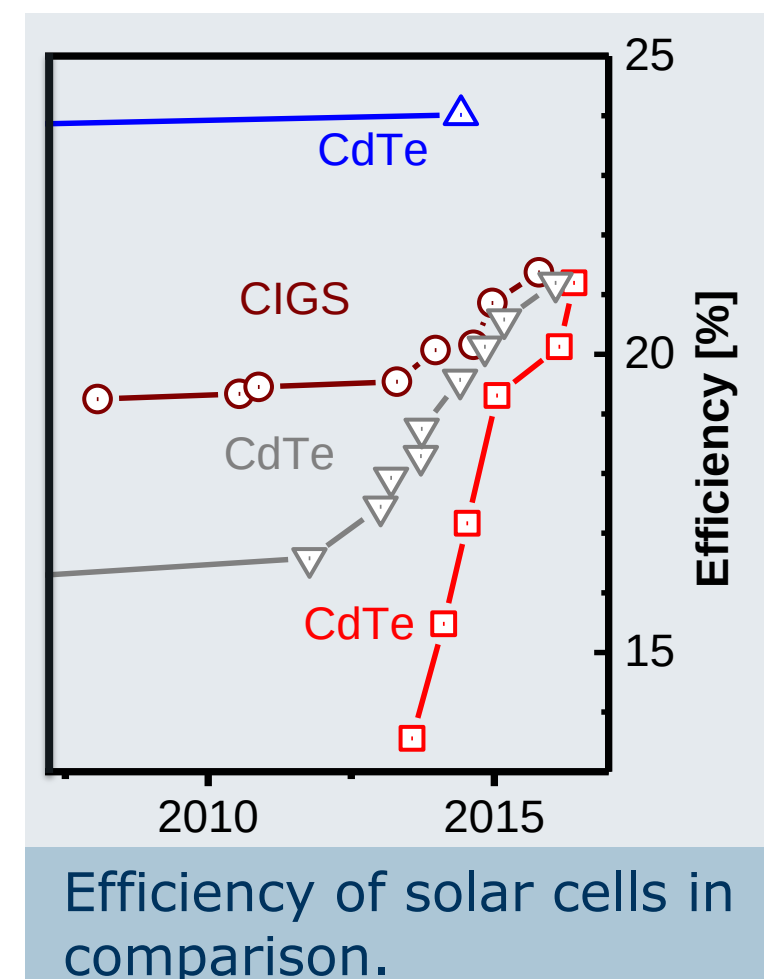
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Introduction

Perovskite thin-film solar cells attract an increasing scientific attention due to the excellent perspectives for commercial applications. In particular, both a high solar cell efficiency and low-cost production can be achieved due to the unique properties of perovskites.

For energy harvesting by modules the solar cell material has to be divided into small stripes of individual solar cells that are interconnected in series by a specific sequence of deposition and patterning steps to reduce ohmic losses. Laser scribing is an industrial-validated technique for thin-film patterning that needs careful optimization to each photovoltaic material system to minimize dead areas, material defects, and additional ohmic losses. Hence, laser ablation and scribing of single as well as thin-film stacks was studied for such Perovskite solar module fabrication ($\text{CH}_3\text{NH}_3\text{PbI}_3$: MAPbI₃).



Solar module

Integrated interconnection of the solar cell thin films is often achieved by a particular sequence of deposition and (laser) scribing steps.



Laser

Excimer laser
 λ : 248 nm t_p : 25 ns
ps Nd:YAG laser
 λ : 1064 / 355 nm
 t_p : 10 ps
fs Ti:Al₂O₃ laser
 λ : 780 nm; t_p : 150 fs

Irradiation

Environment: air
Temperature: RT

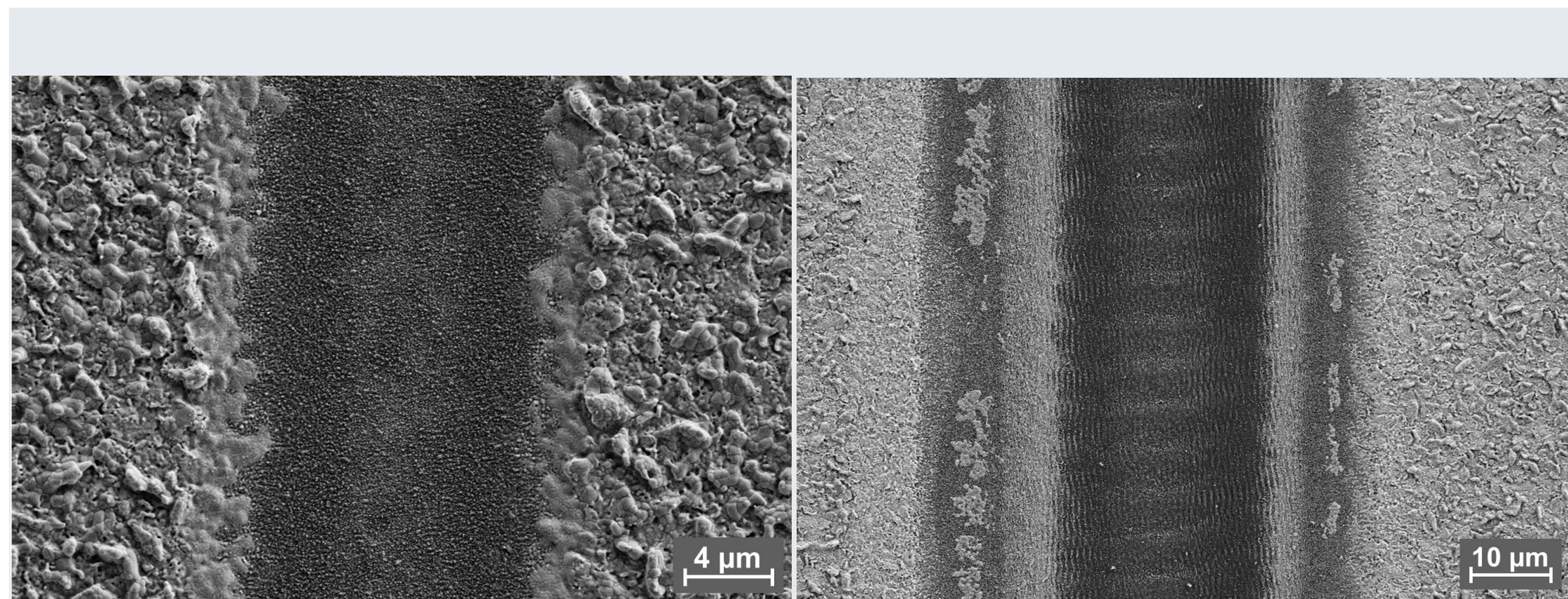
Materials

P2: MAPbI₃/FTO-glass
P3: Au/MAPbI₃/FTO-glass

Results

Removing MAPbI₃ from films (P2)

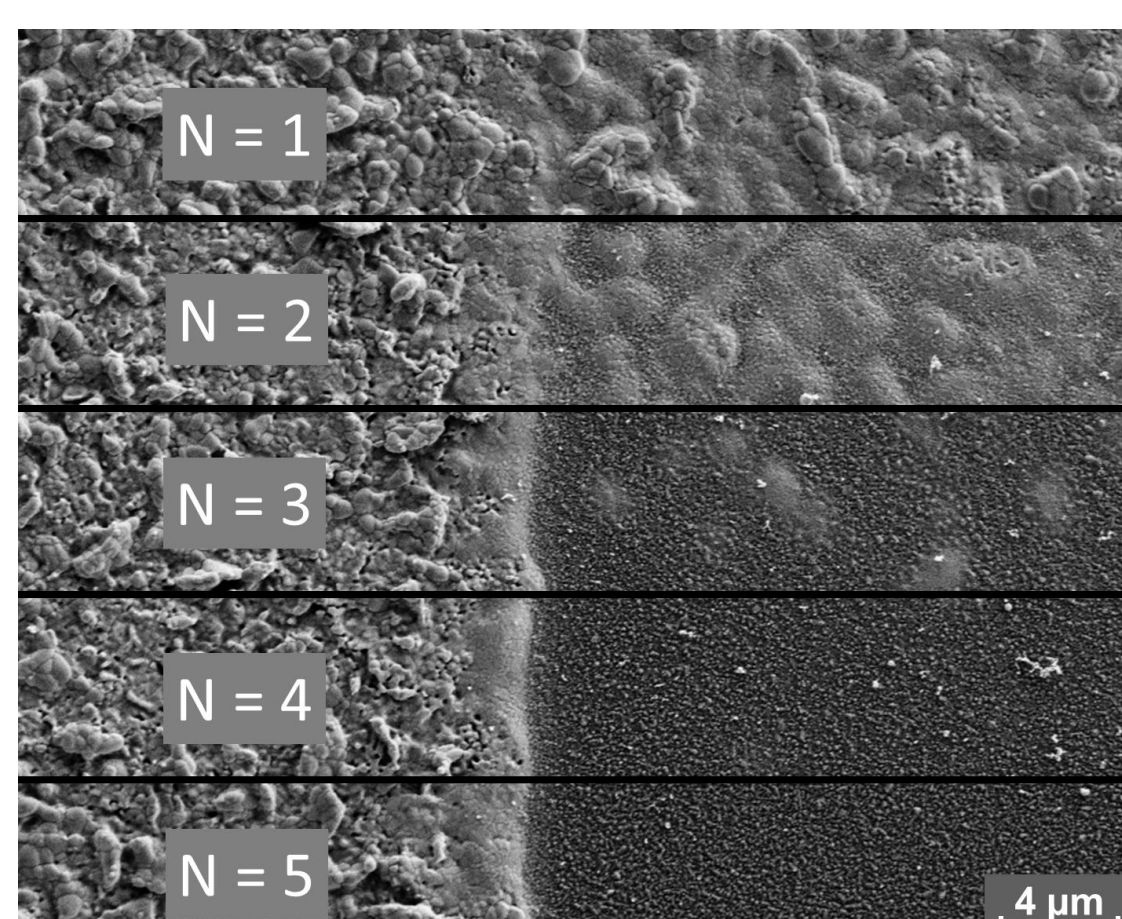
LASER ABLATION



SEM image of P2 scribes due to front side ablation, left: picosecond pulses, right: femtosecond pulses.

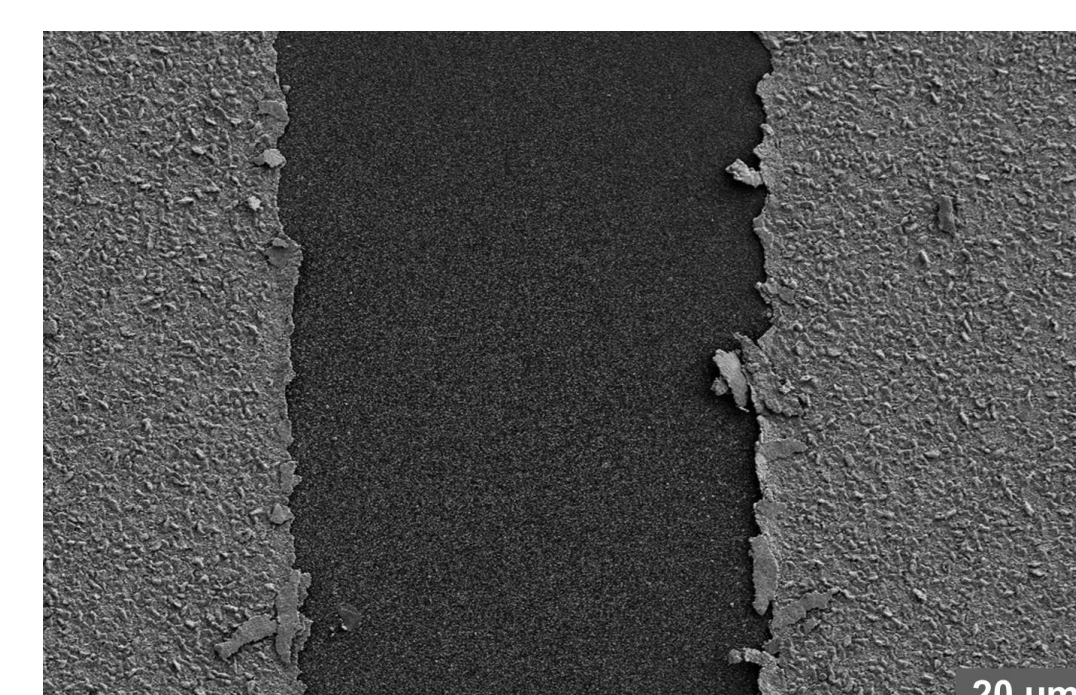
Low damage, well defined pattern by ablation

Morphology of damaged MAPbI₃ films



SEM images of Excimer laser ablated spot edges: $\Phi = 110 \text{ mJ/cm}^2$
N = 1 - 5

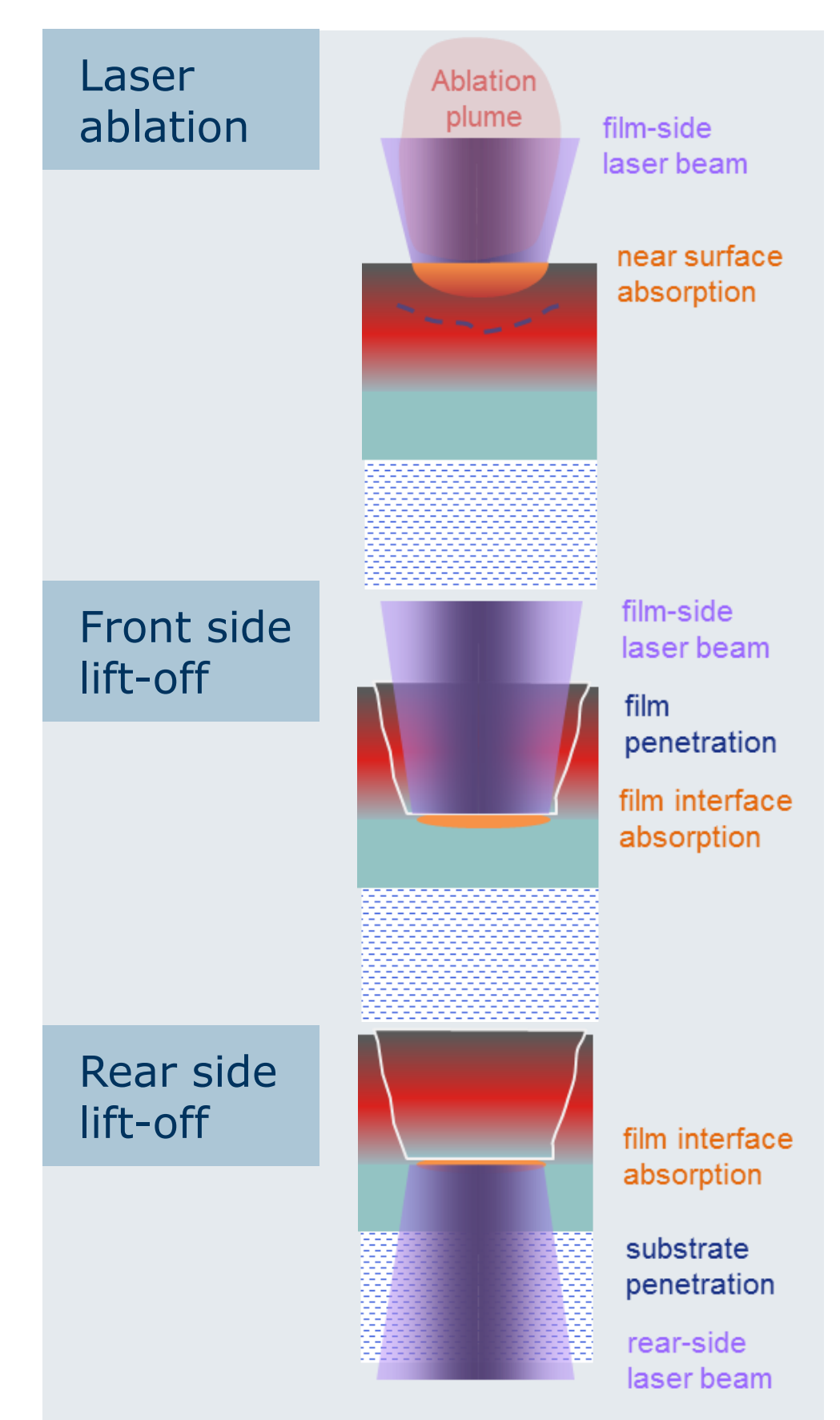
LASER LIFT-OFF



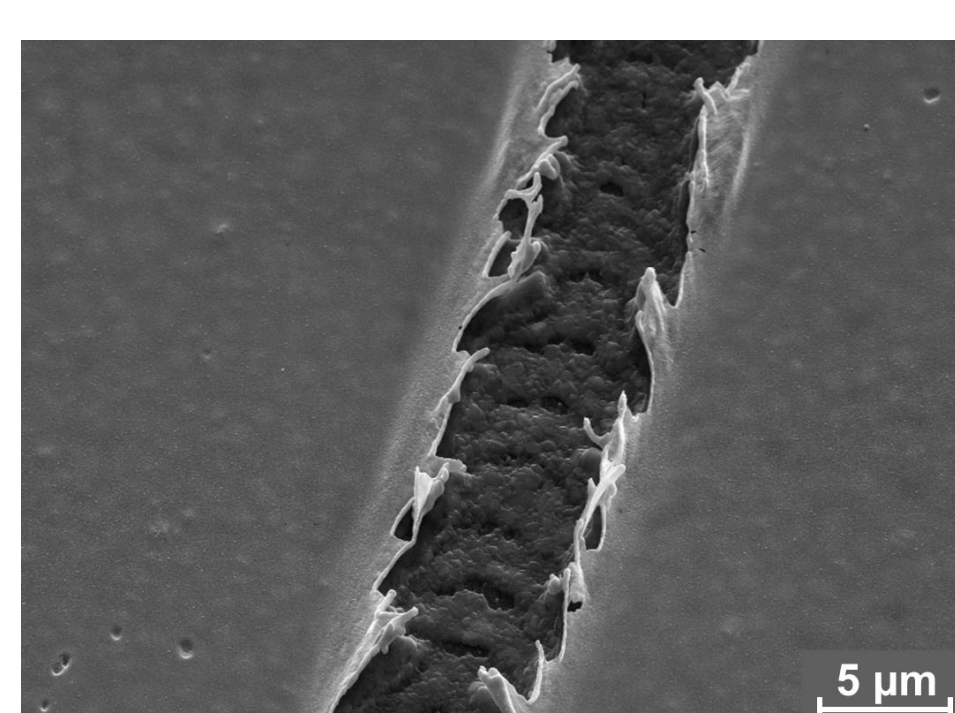
SEM image of a P2 scribe (lift-off) due to rear side ps irradiation (355 nm).

Single pulse, film selective, delamination lift-off scribing with ps laser

PATTERNING MECHANISM



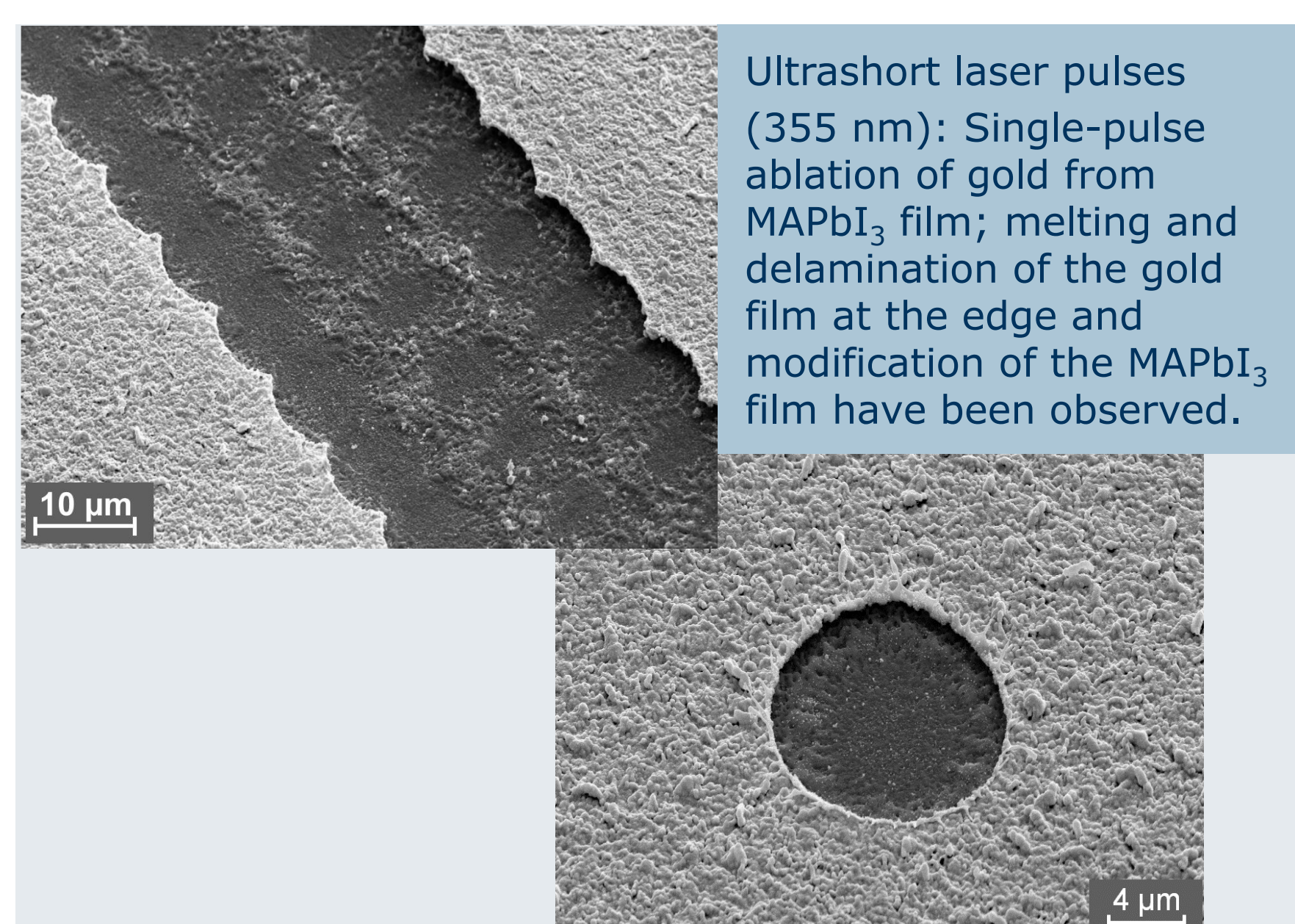
Removing films from MAPbI₃ (P3)



Crude laser scribing conditions cause heavy damage of the gold film and perovskite beneath using ps laser (1064 nm)

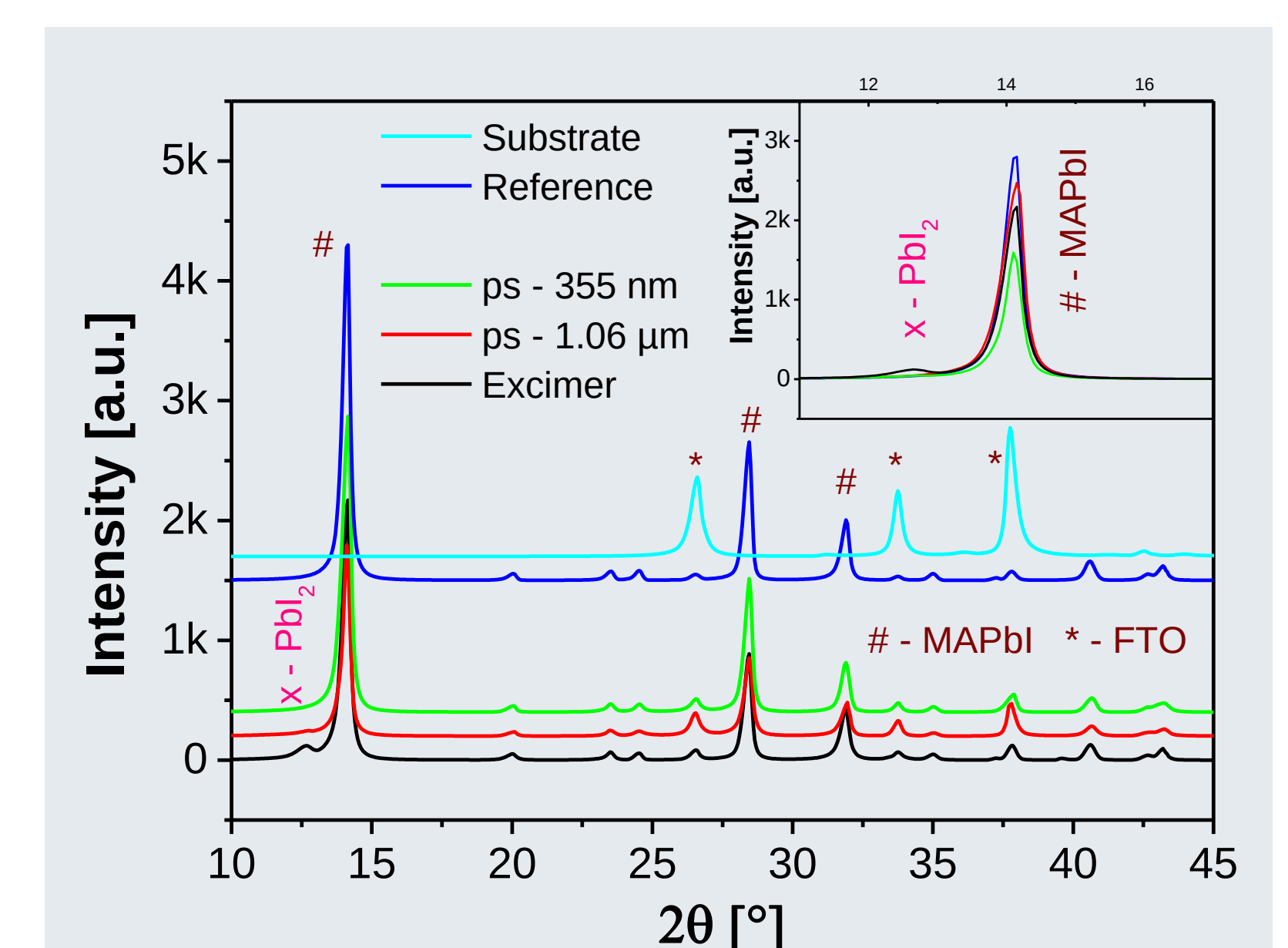
Characteristics to be considered:

- Low adhesion of gold films
- Melting and hydrodynamics of molten gold
- $T_{m,Au} > T_{m,MAPbI_3}$
- Decomposition of MAPbI₃



Ultrashort laser pulses (355 nm): Single-pulse ablation of gold from MAPbI₃ film; melting and delamination of the gold film at the edge and modification of the MAPbI₃ film have been observed.

Low damage, well defined patterning with 355 nm ps-laser pulses



XRD analysis of the Perovskite film modified with the different (single pulse) laser radiation in comparison to the virgin MAPbI₃ and the substrate.

Discussion

- Perovskite thin films can be scribed successfully with ultrashort laser pulses by film and rear side laser irradiation applying different wavelengths.
- Laser thin-film delamination and lift-off processes are mostly observed.

References

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- [2] S. Razza et al., J Power Sources, 277 (2015) 286-291.
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