VIRTUAL CHALCOGENIDE PV CONFERENCE (vCPVC 2020)

Thursday, May 28, 2020

Grain boundary band bending in polycrystalline materials; A Kelvin Probe Force Microscopy study

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University of Luxembourg - Luxembourg

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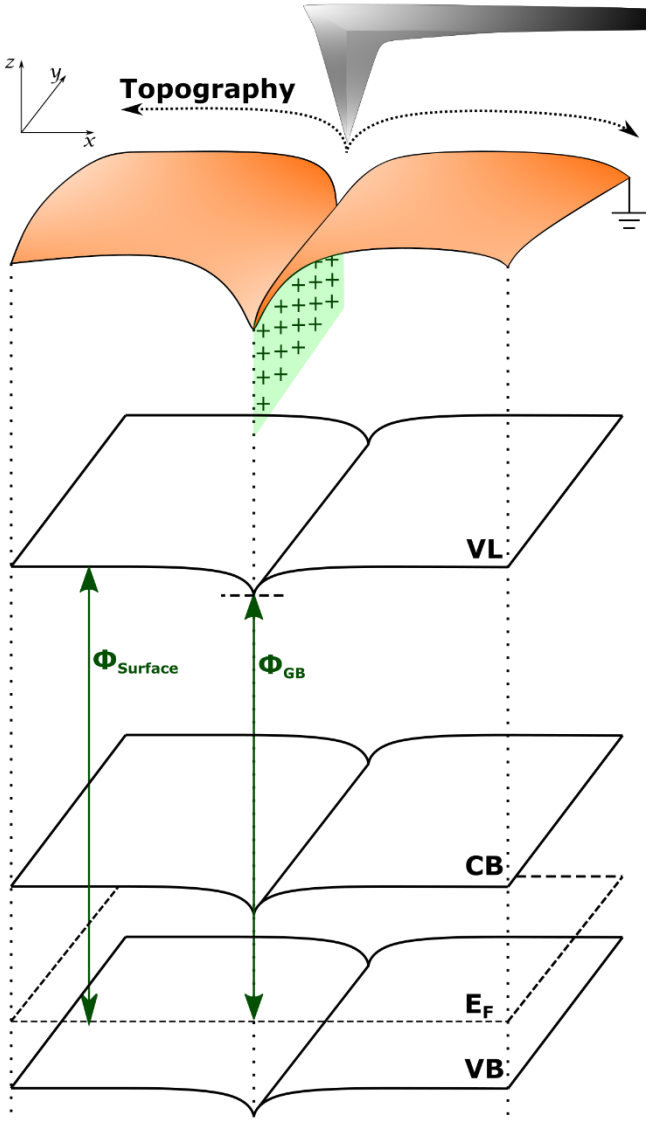
Kelvin probe force microscopy (KPFM)

Grain boundary application



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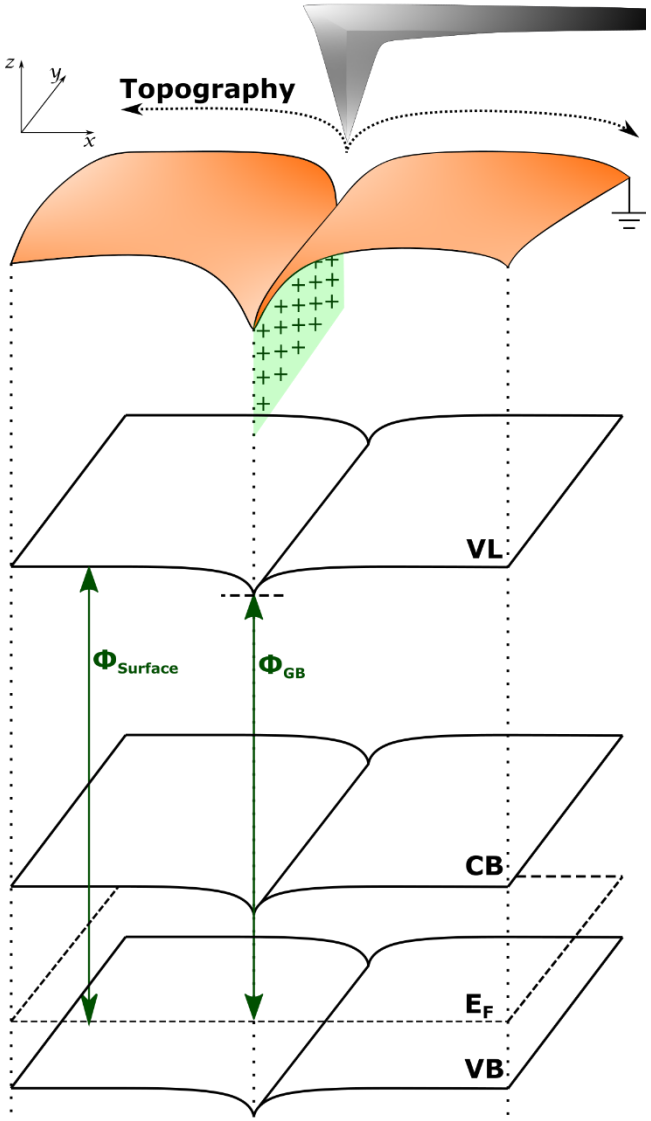
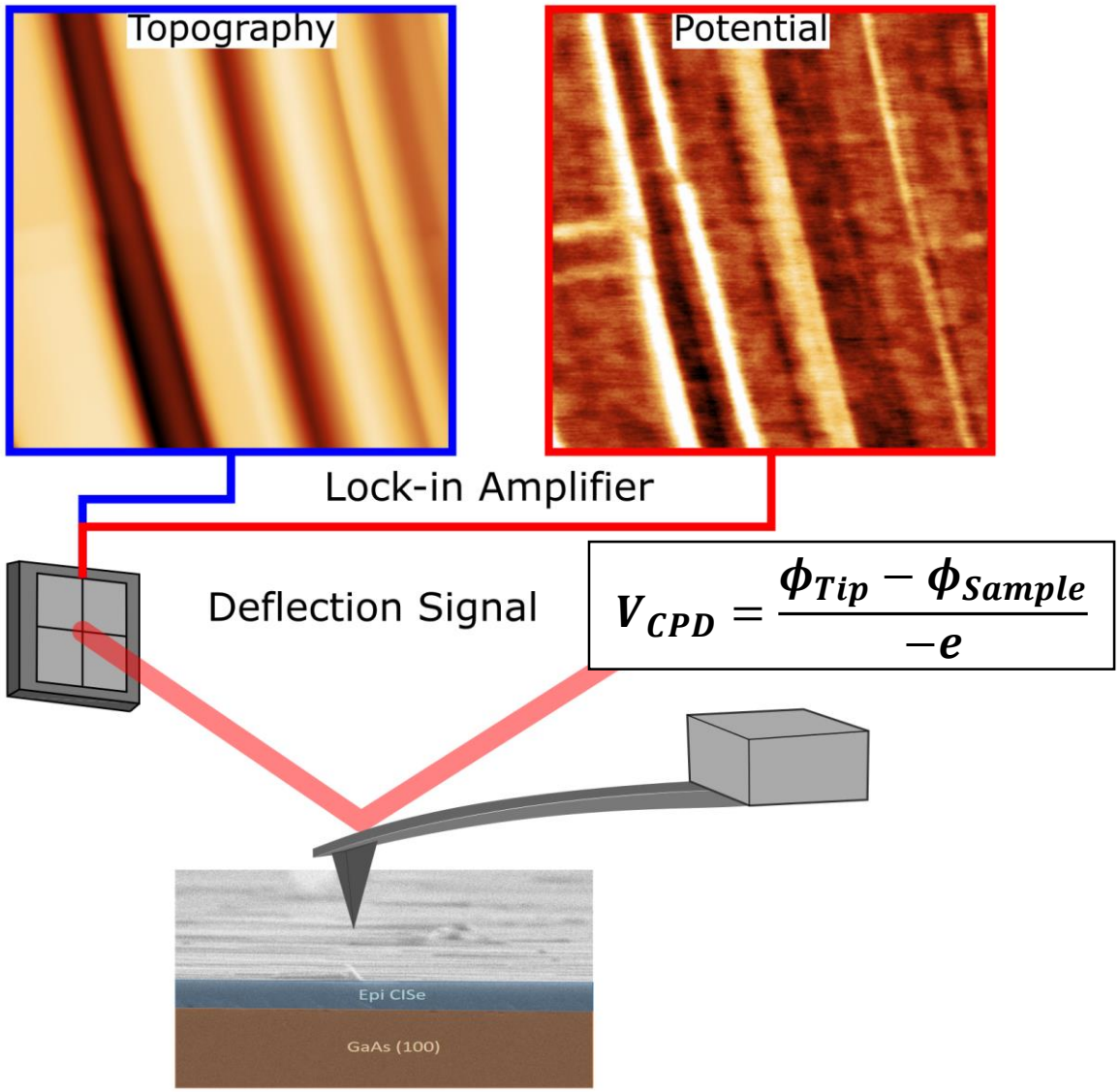


Simplified Schematic



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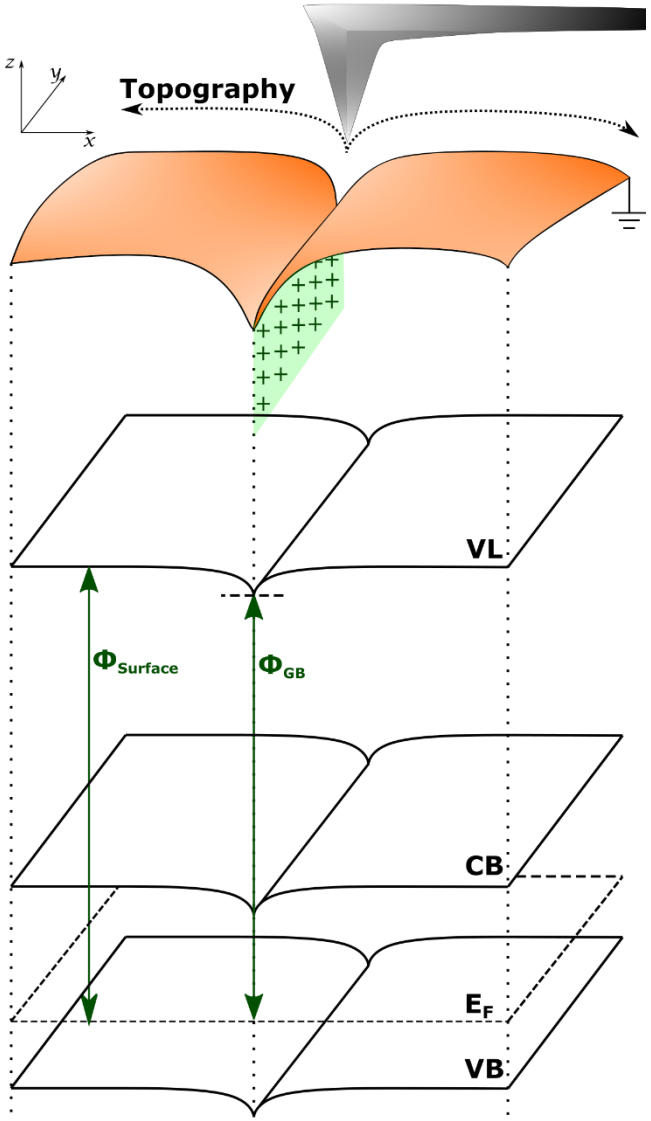
Grain boundary application



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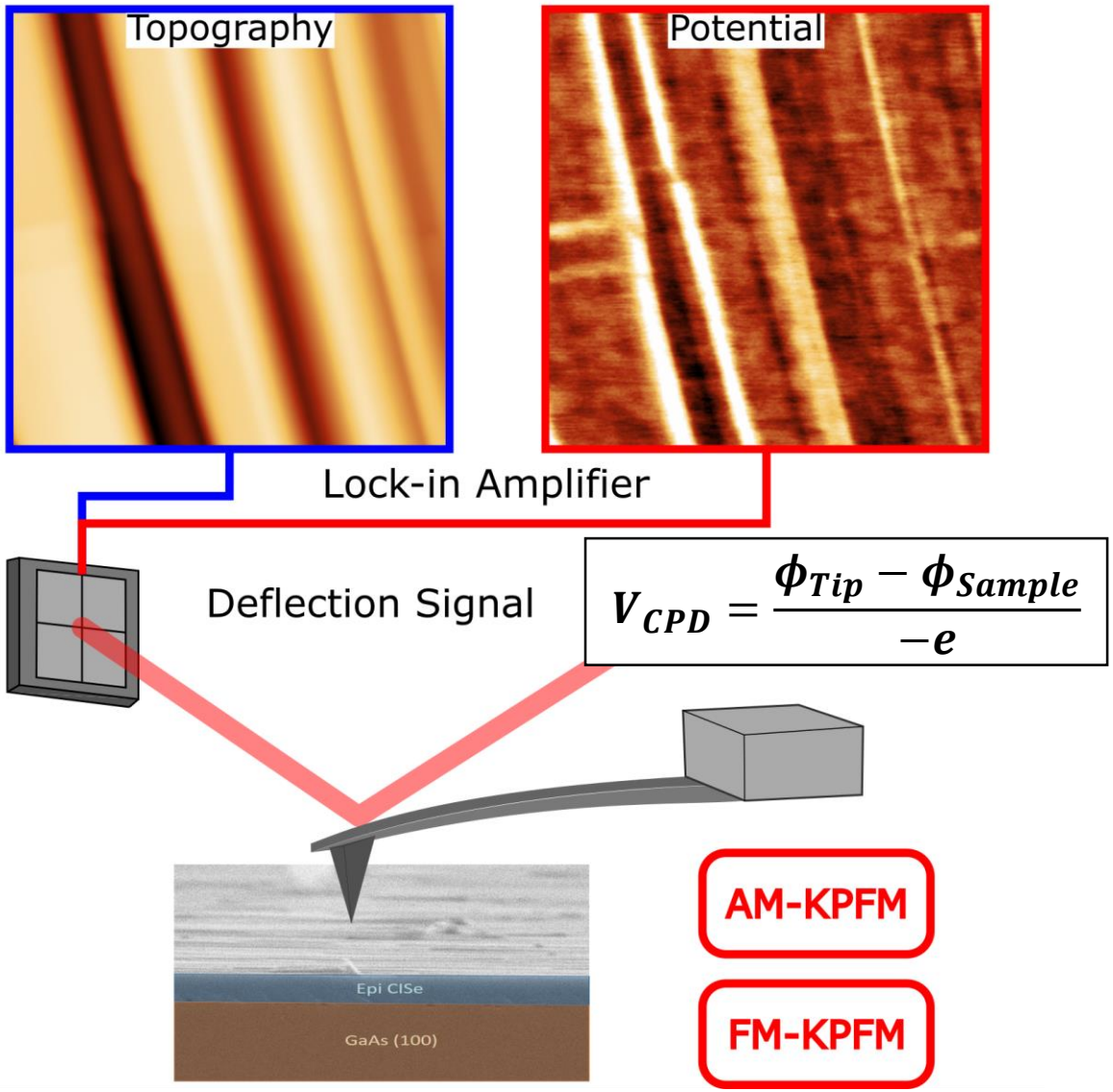

AM-KPFM vs FM-KPFM

In this work:

AM-KPFM in double pass (most used)	FM-KPFM sideband (most accurate)
under ambient conditions	under UHV conditions

Applied to:

2 PV Samples
Perovskite and CIGS

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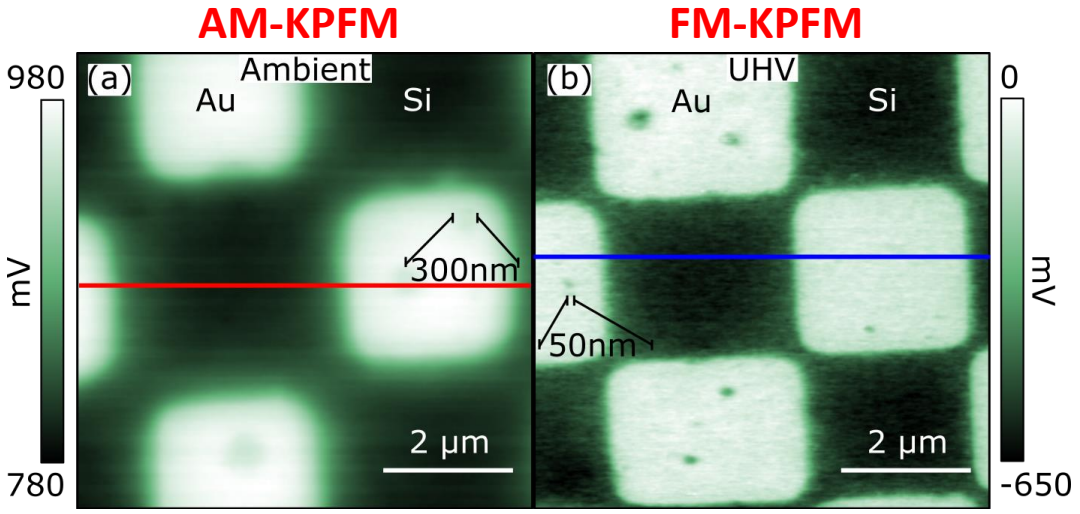

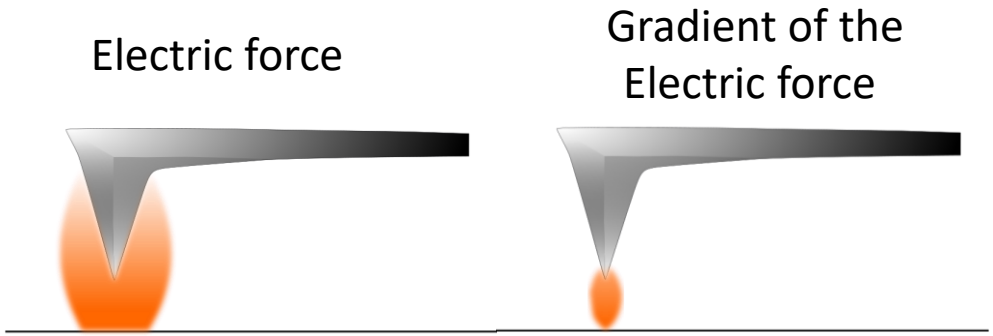

J. Colchero, A. Gil, and A. M. Baró Phys. Rev. B **64**, 245403 (2001)

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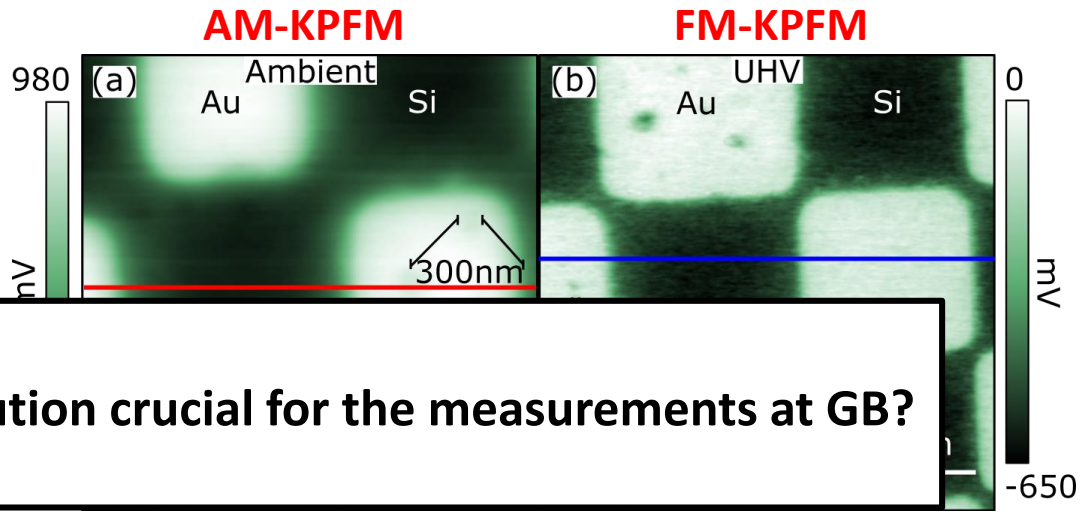


AM-KPFM in double pass (most used)

FM-KPFM sideband (most accurate)

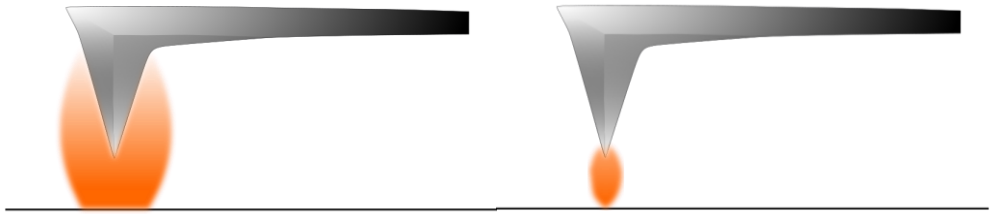
Are these differences in resolution crucial for the measurements at GB?

2 PV Samples

Perovskite and CIGS

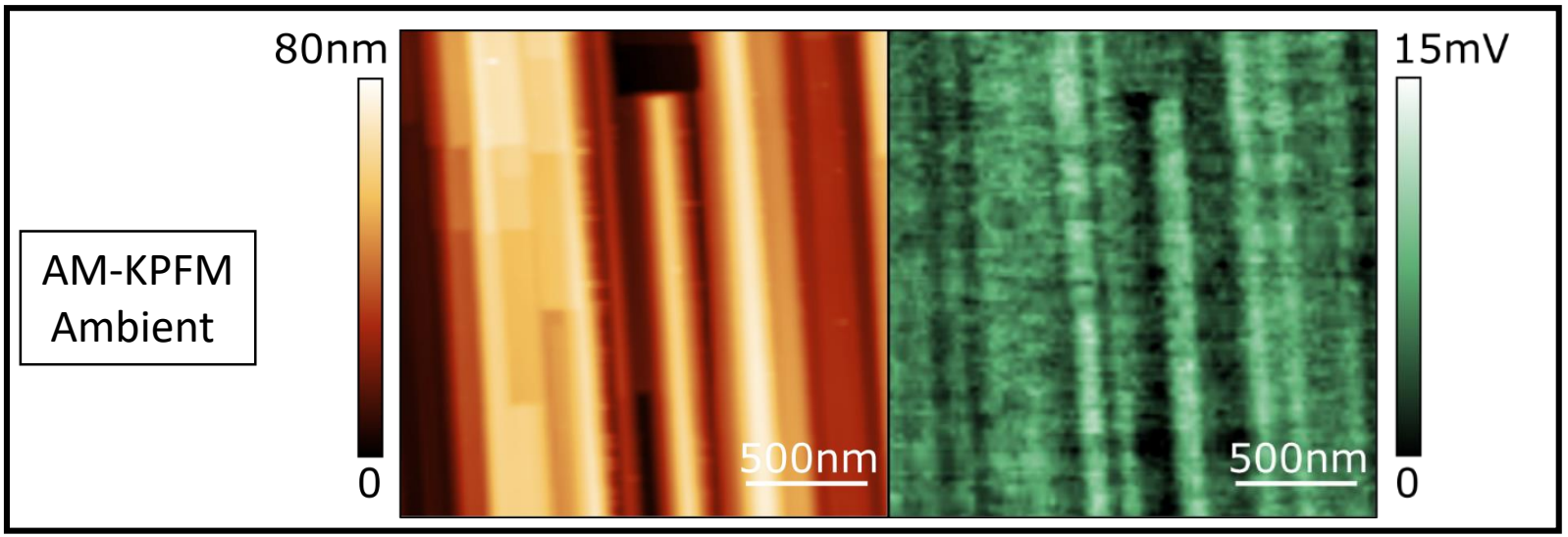
Electric force

Gradient of the Electric force

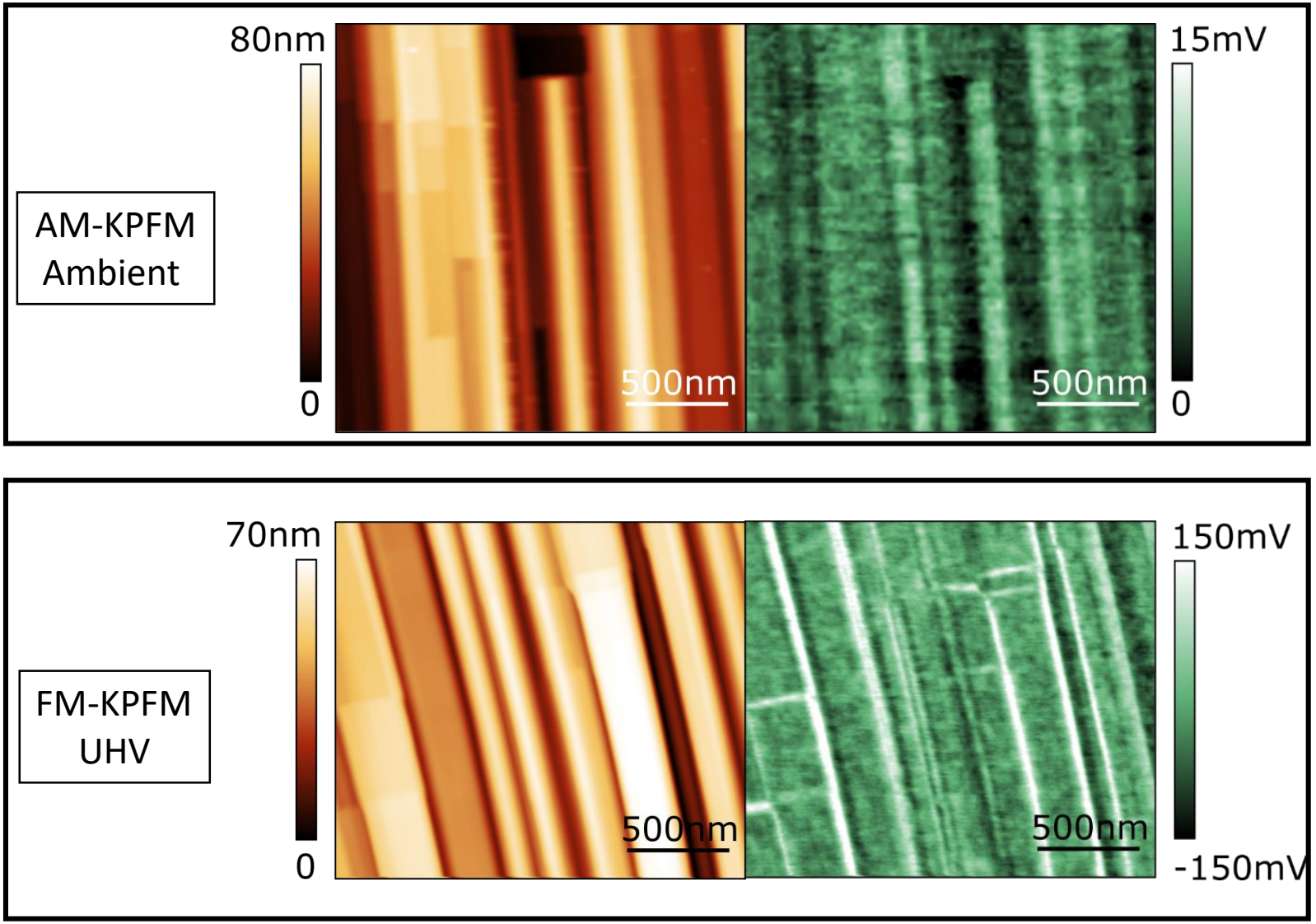


J. Colchero, A. Gil, and A. M. Baró Phys. Rev. B **64**, 245403 (2001)

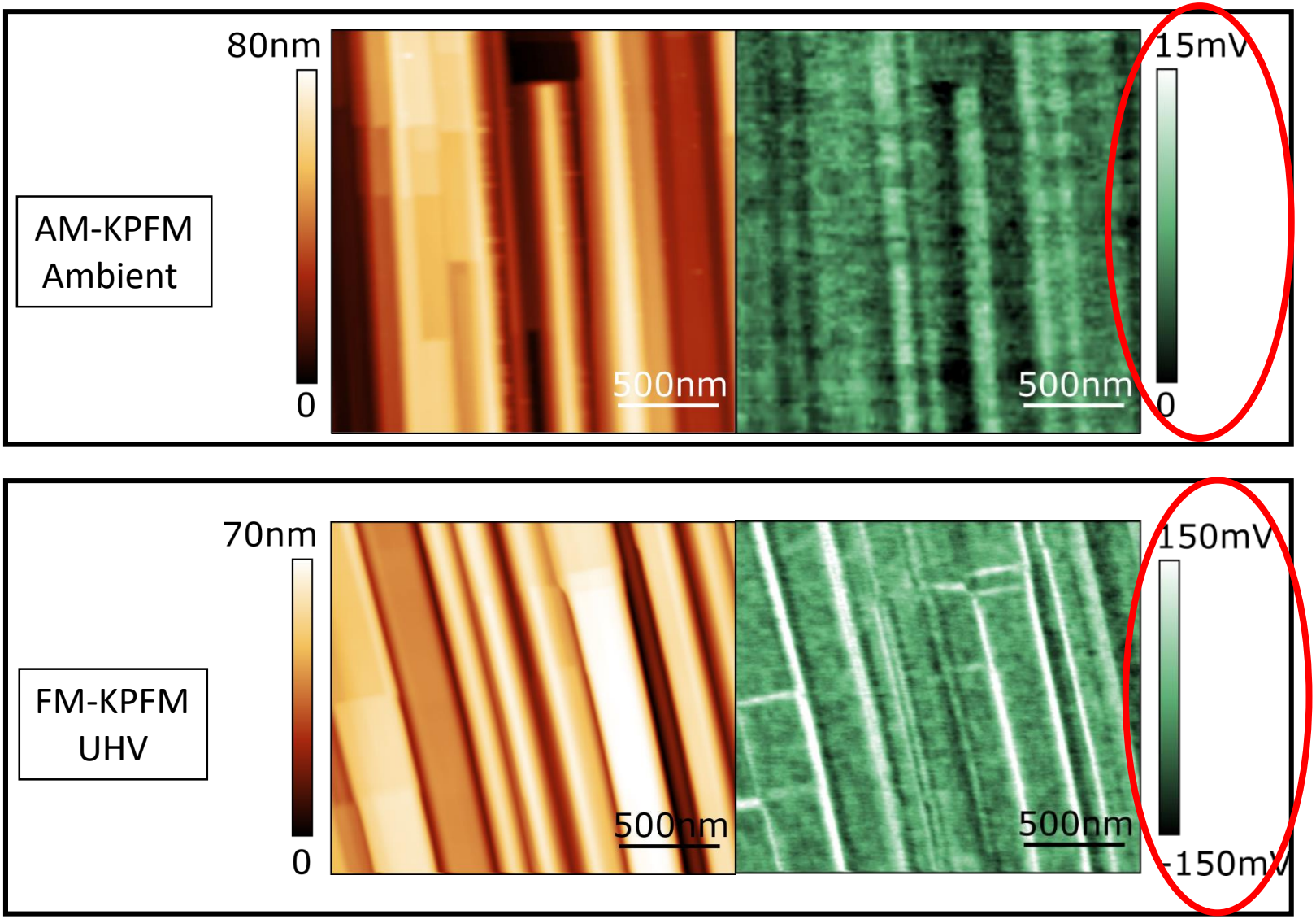
Model system (single crystal CIGS)



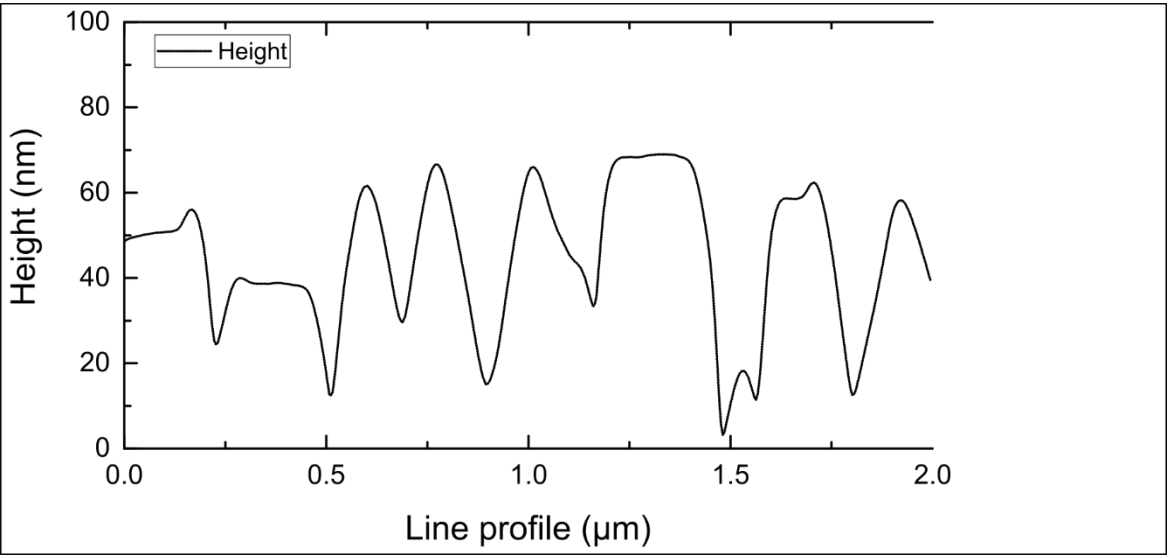
Model system (single crystal CIGS)



Model system (single crystal CIGS)

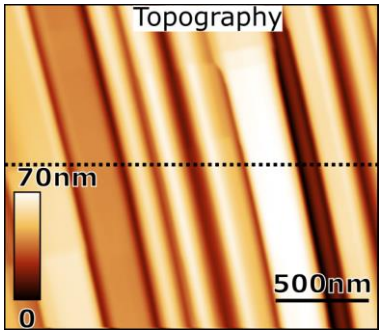


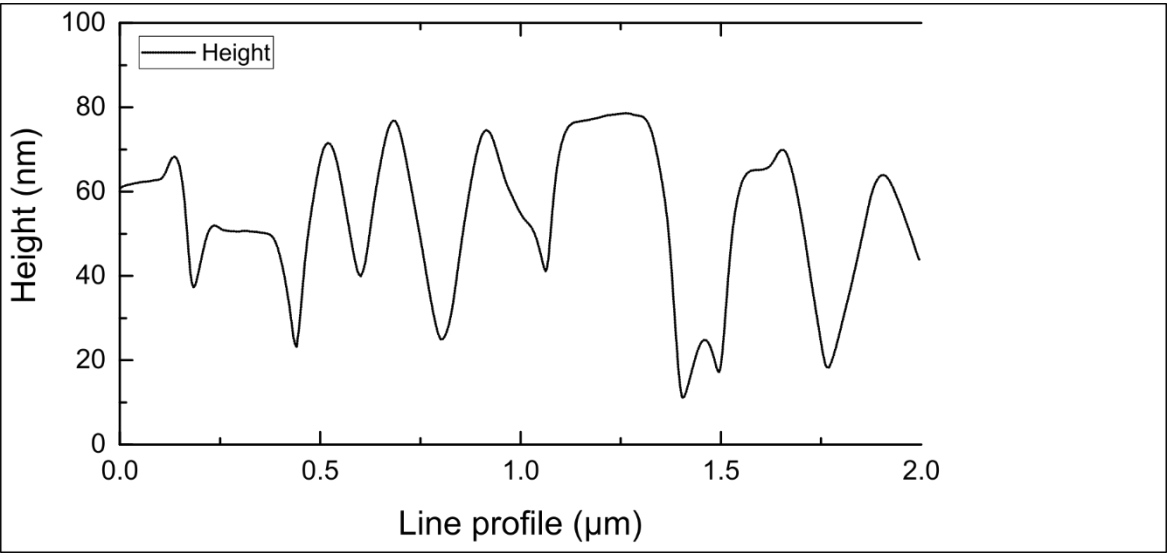
FM-KPFM UHV conditions CIGS



Trace images

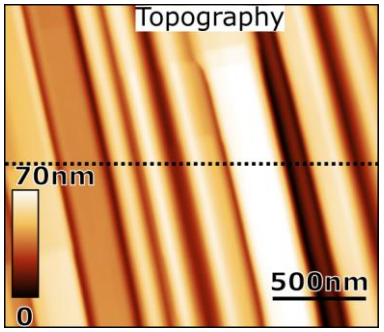
Scan direction





Retrace images

Scan direction



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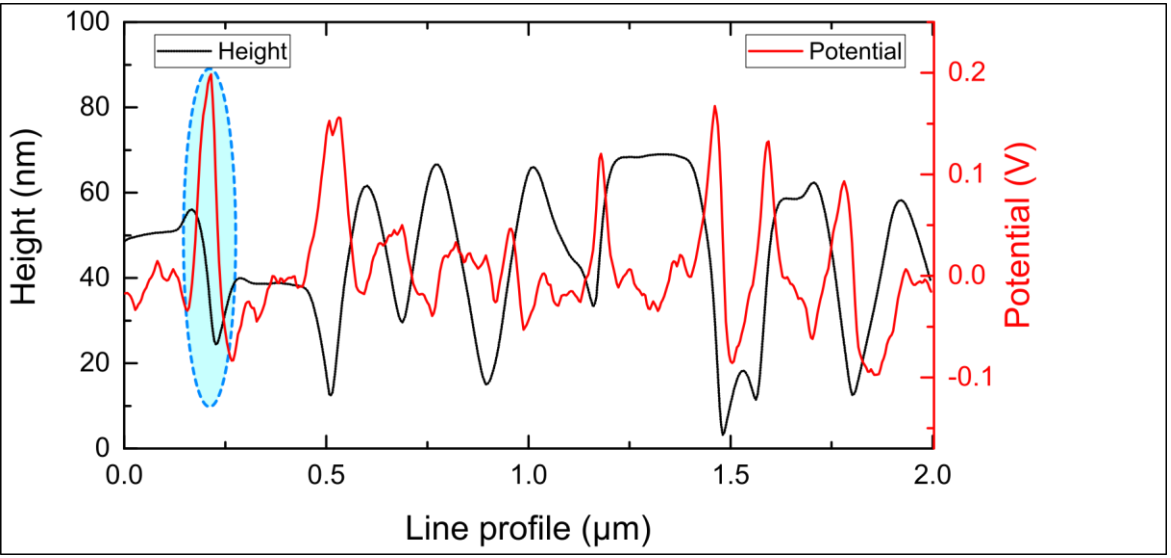

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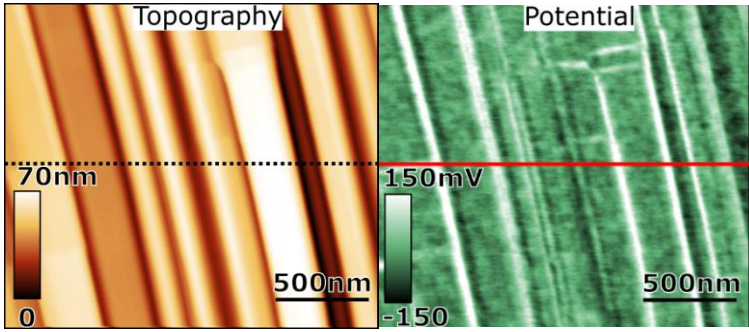

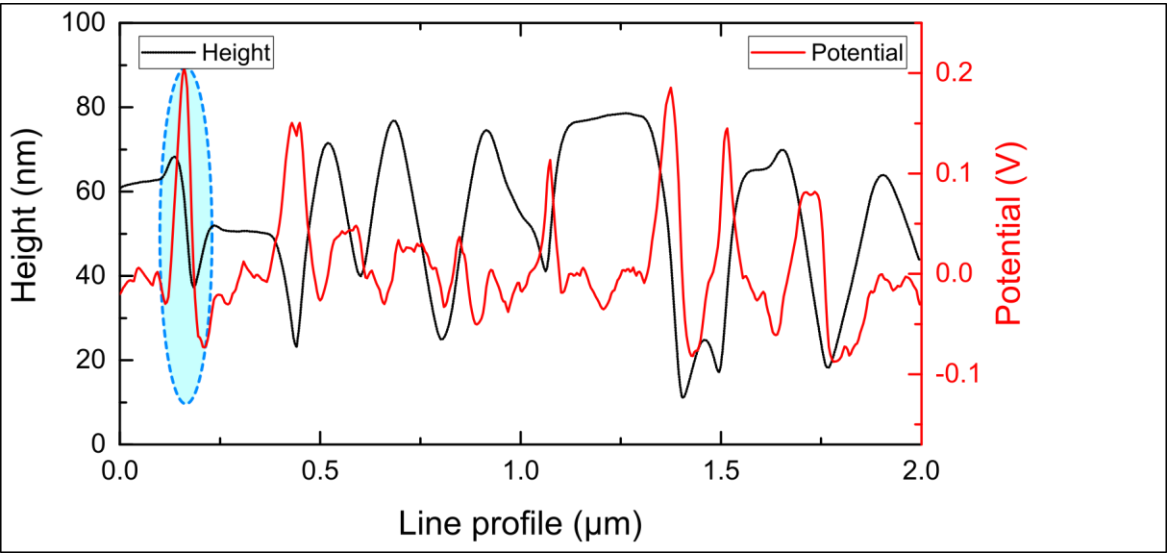

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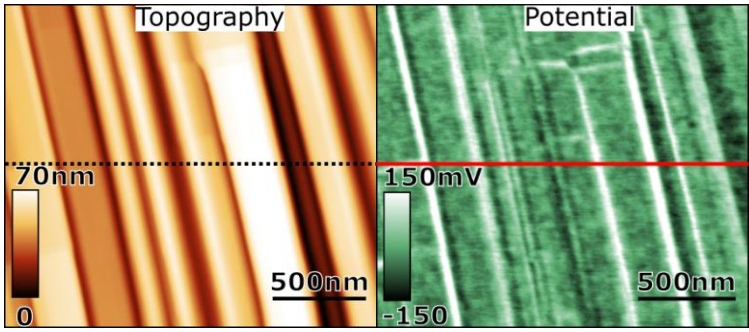

Lanzoni et.al. Proceedings IEEE 46th (PVSC) (2019)
J. Jaffe et.al. PHYSICAL REVIEW B, 64, 241304

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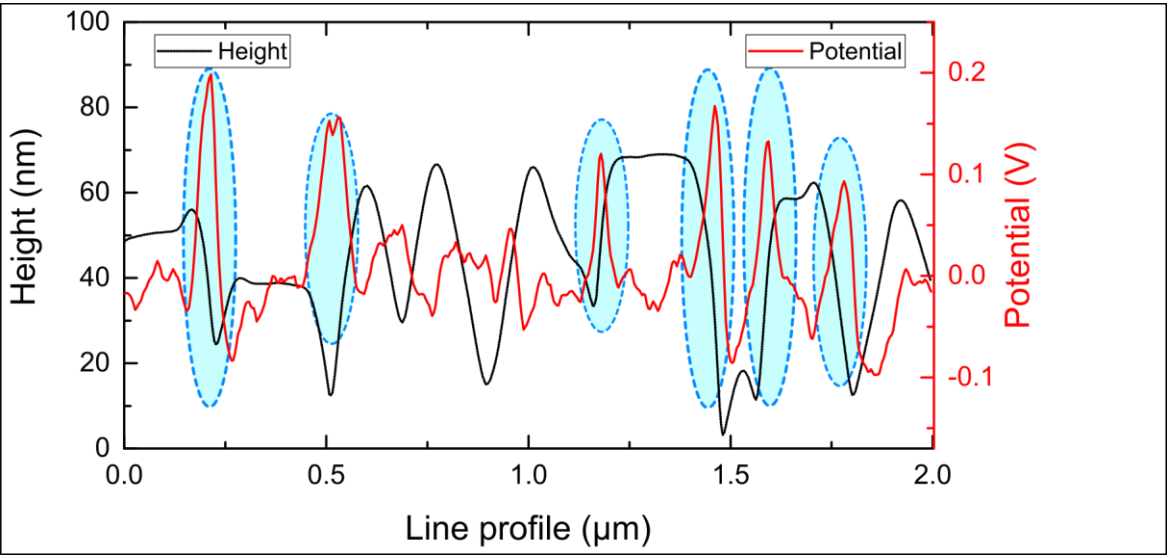

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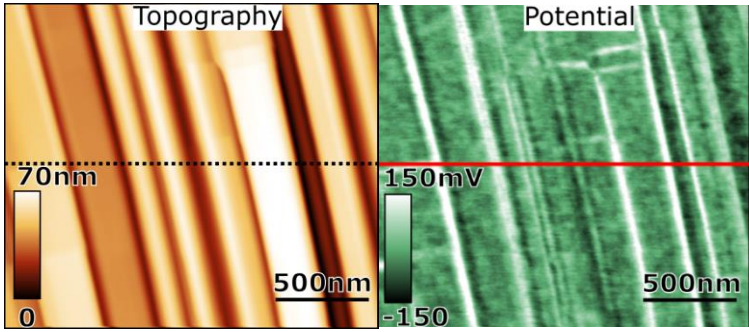

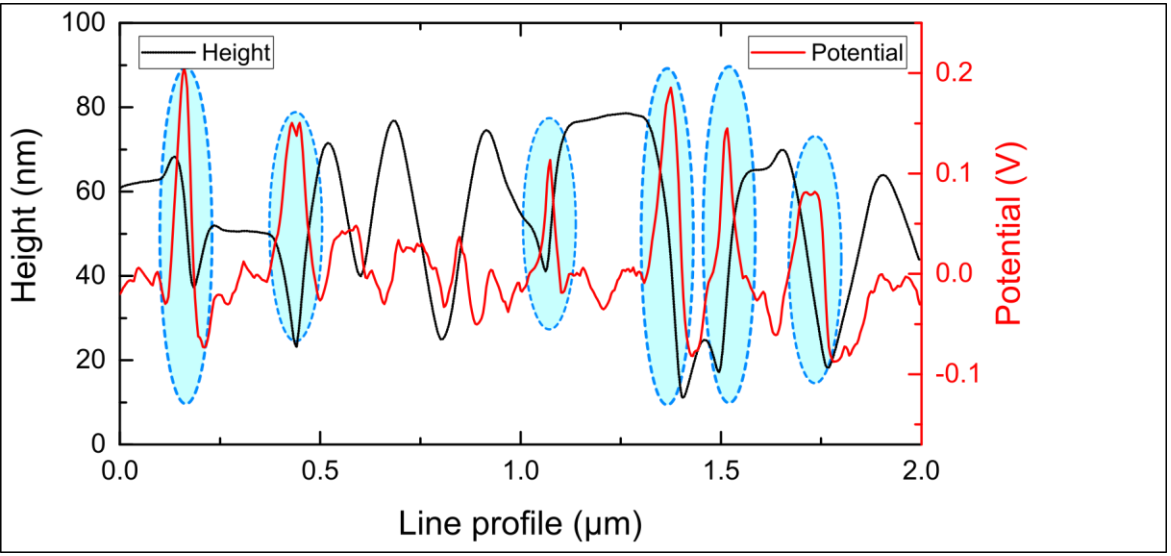

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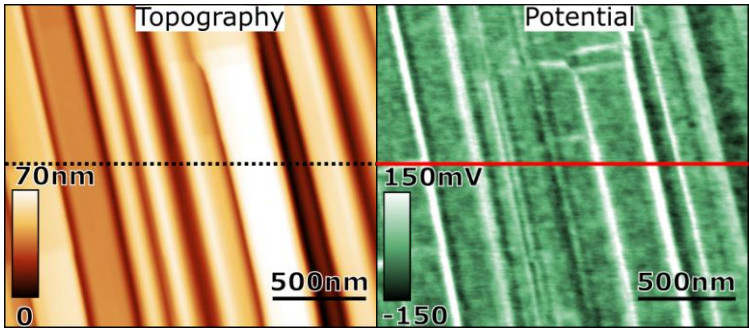

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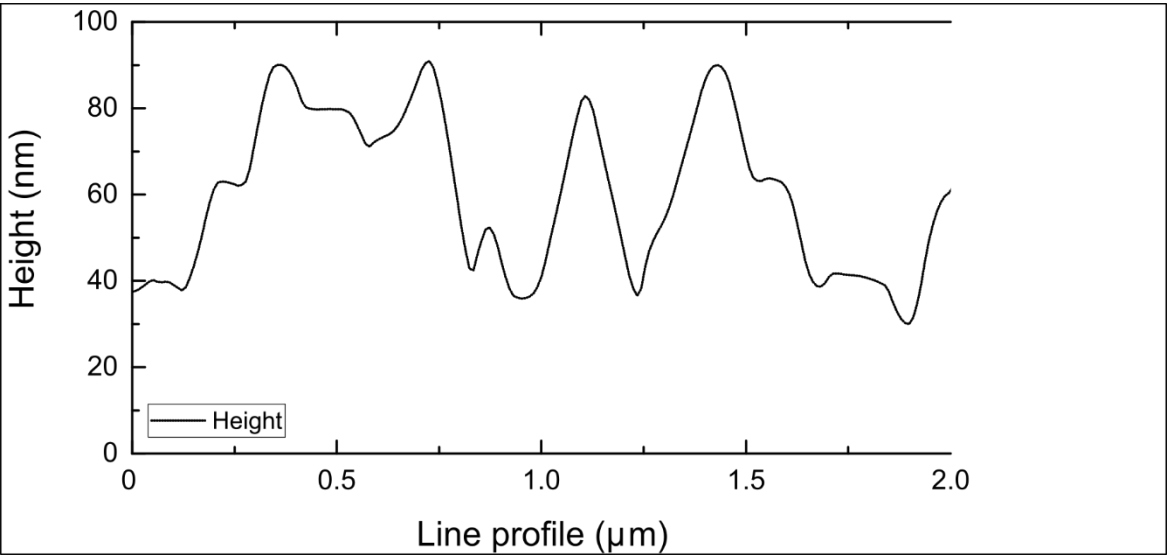
AM-KPFM ambient conditions CIGS



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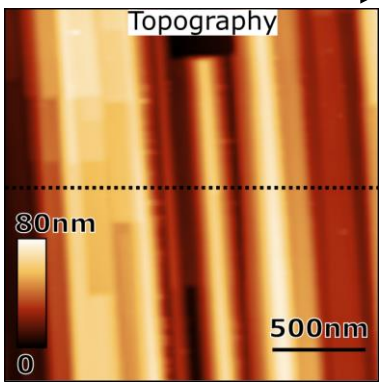

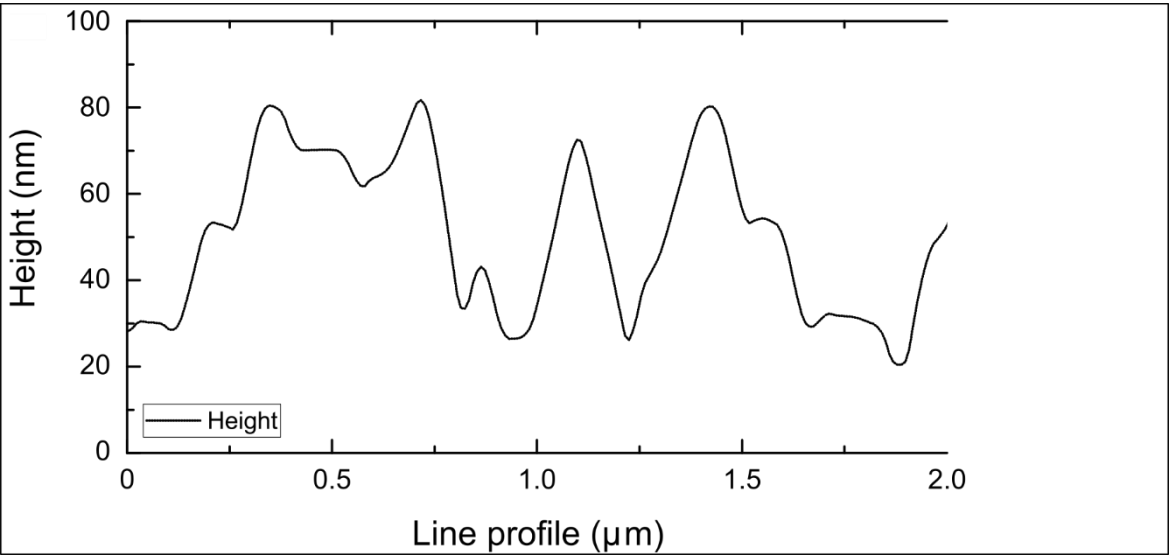

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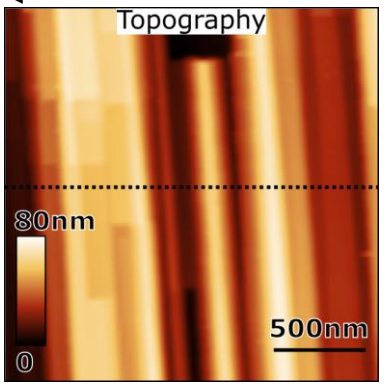

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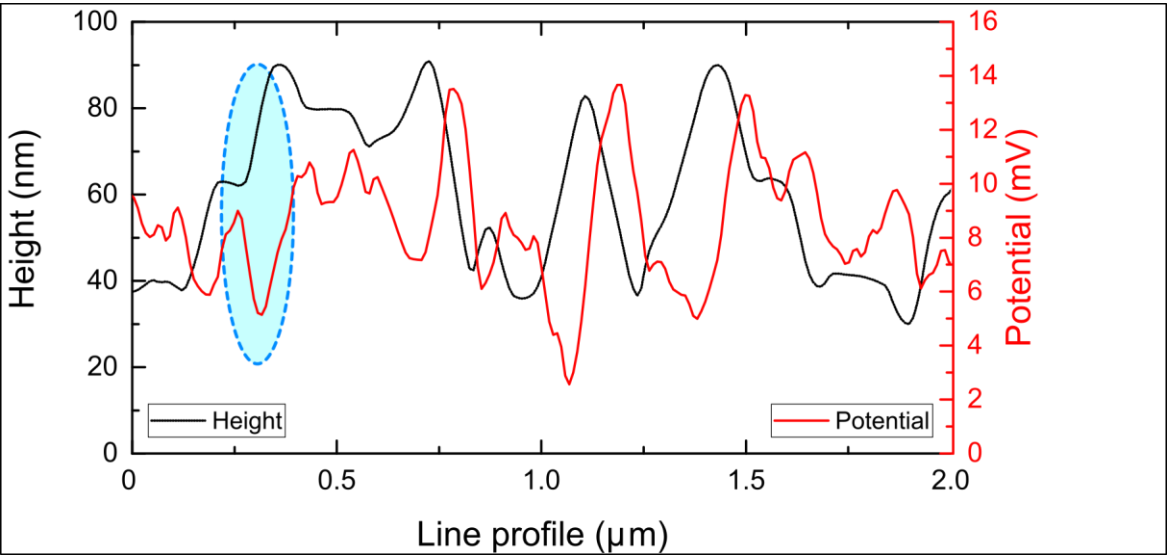

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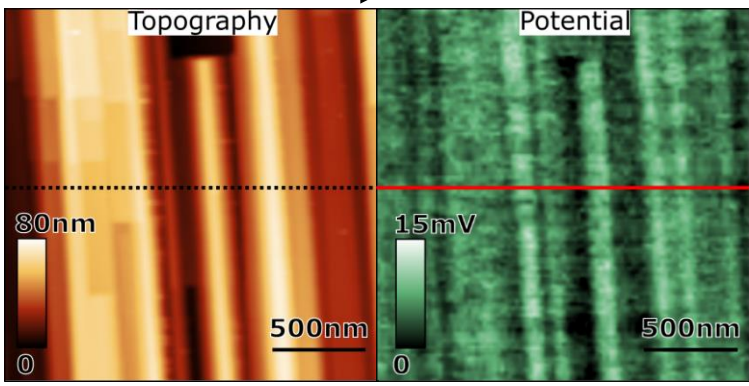

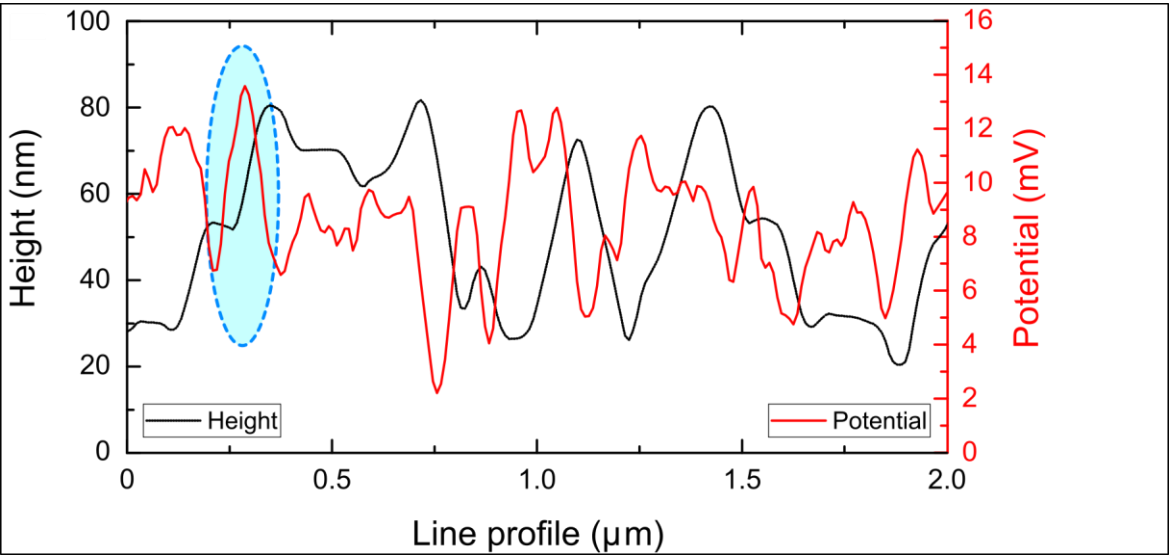

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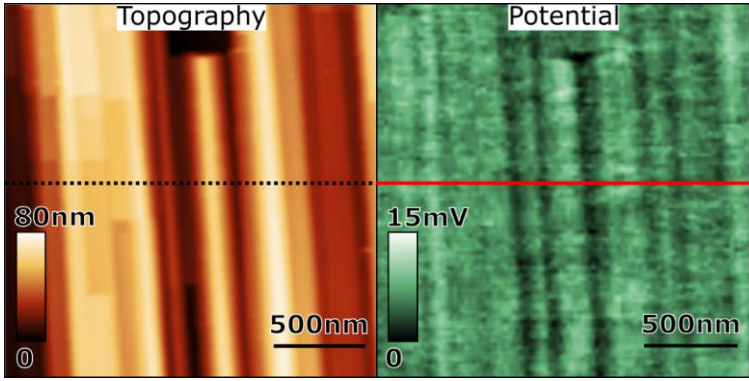

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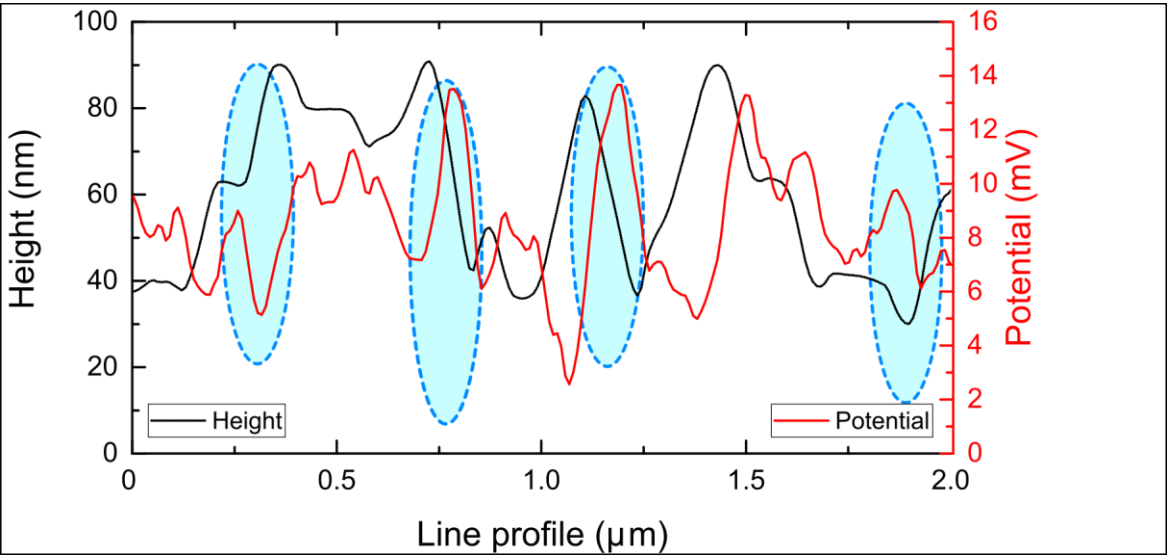

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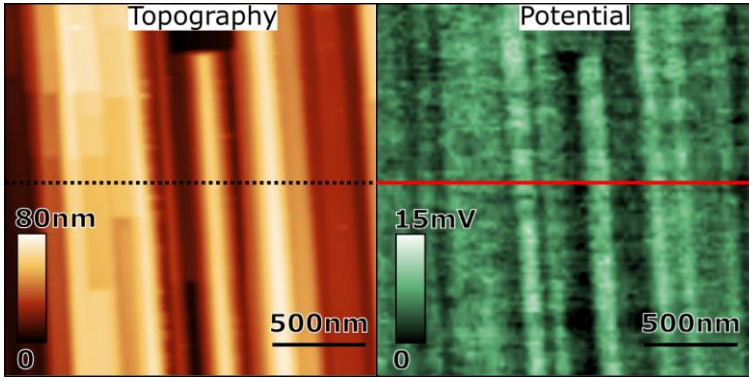

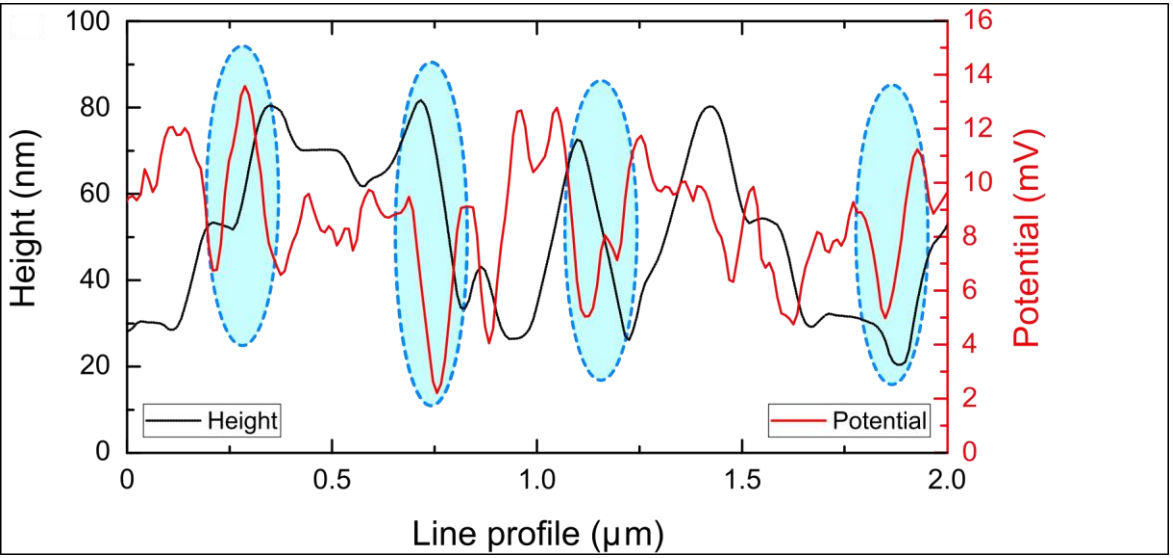

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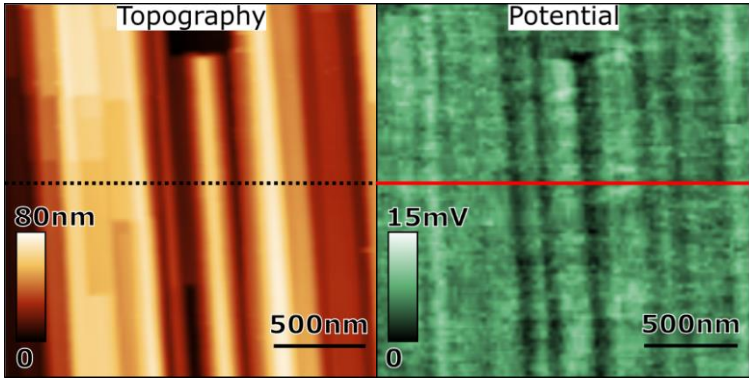
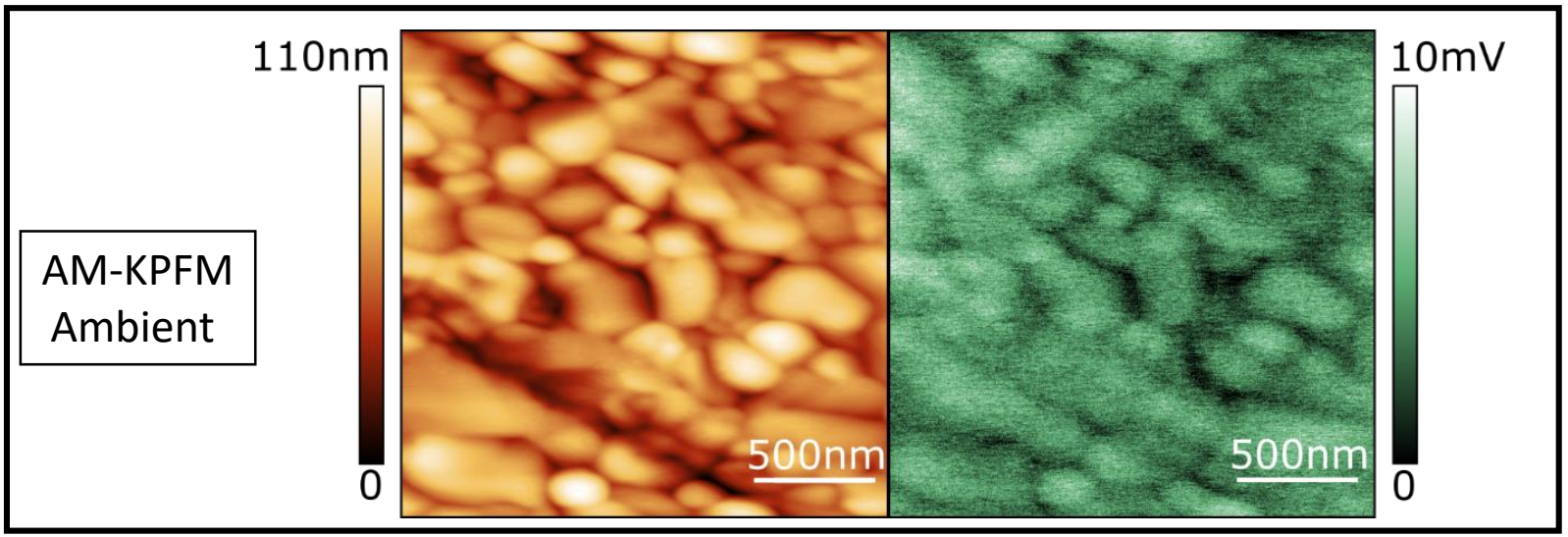


Perovskite sample



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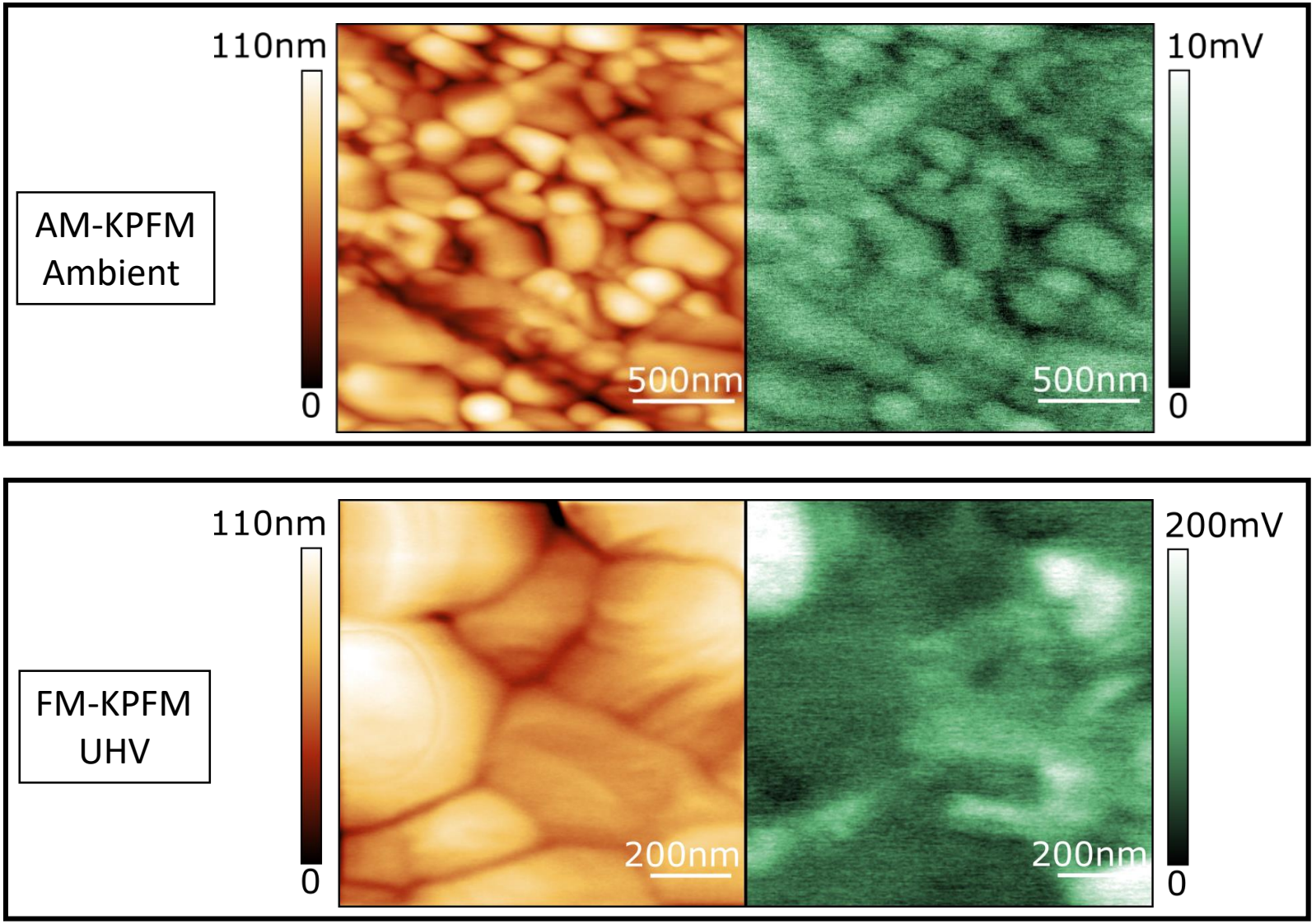

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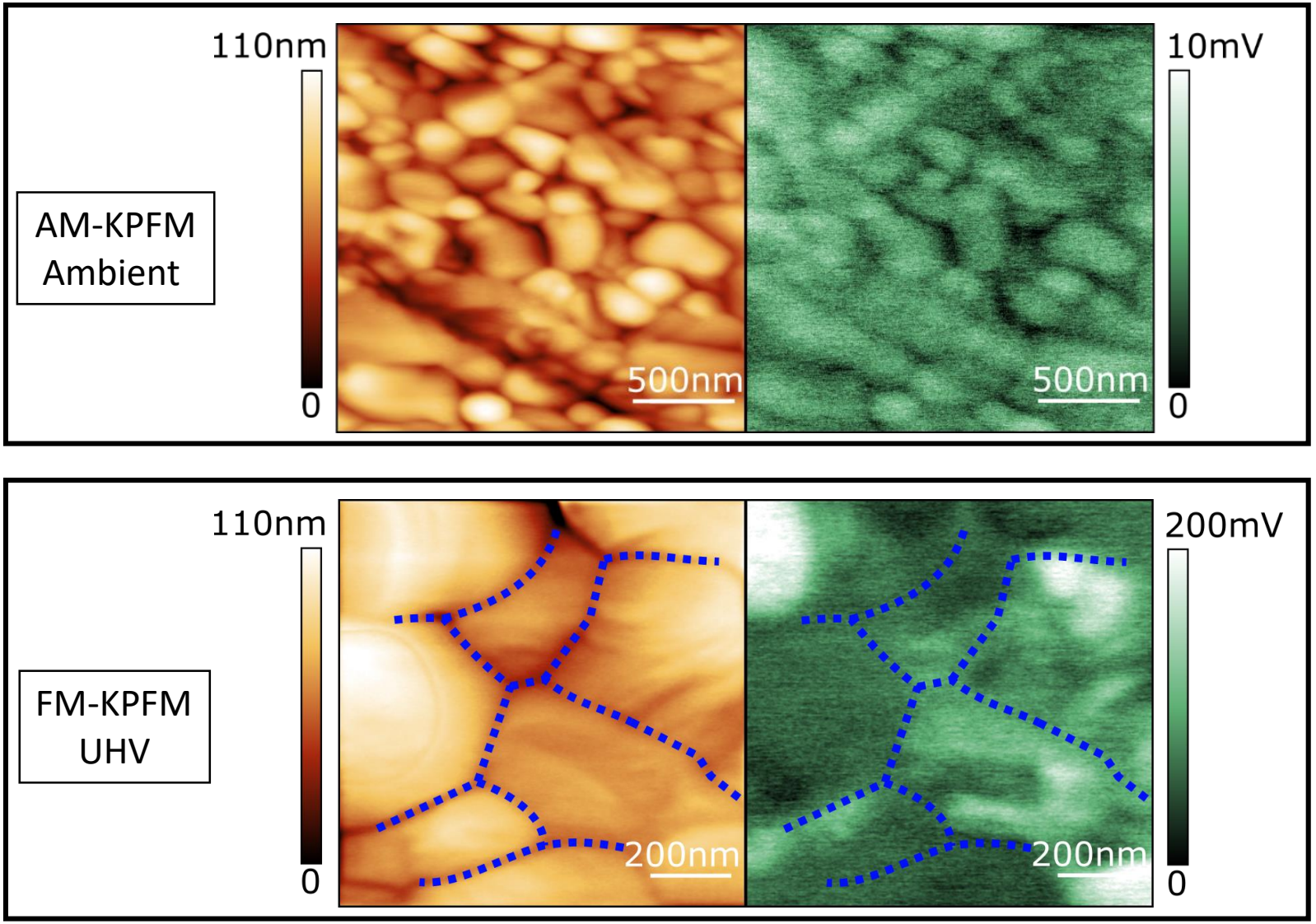
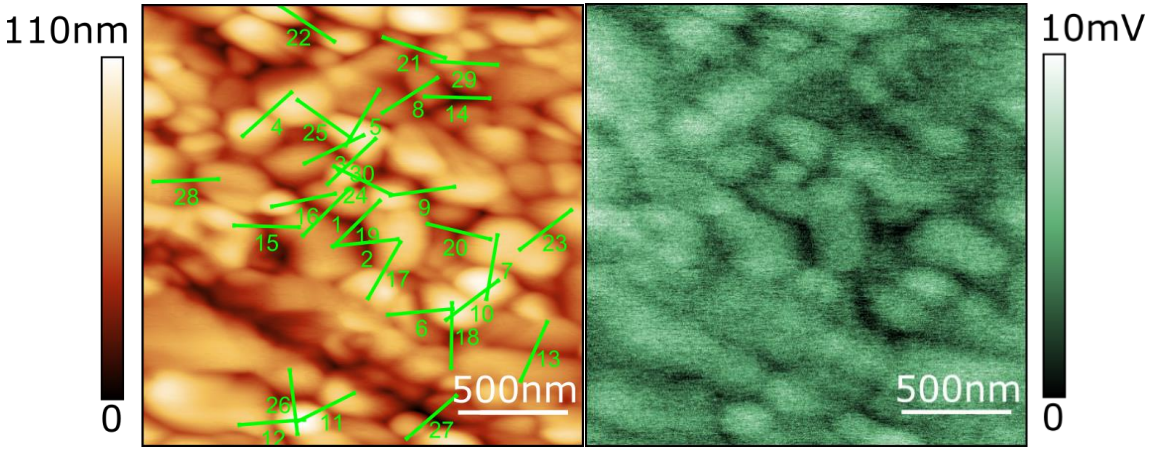
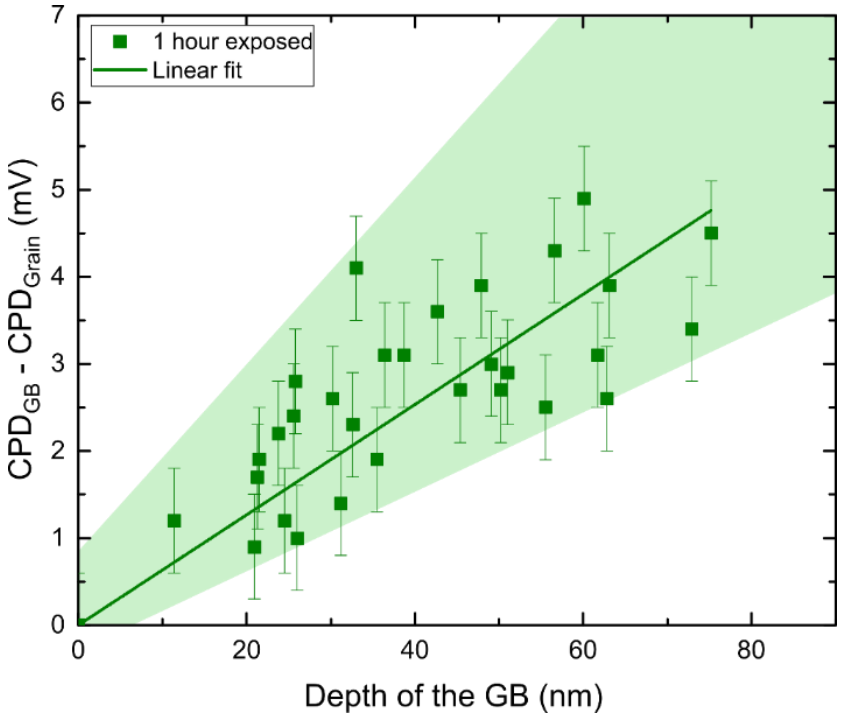


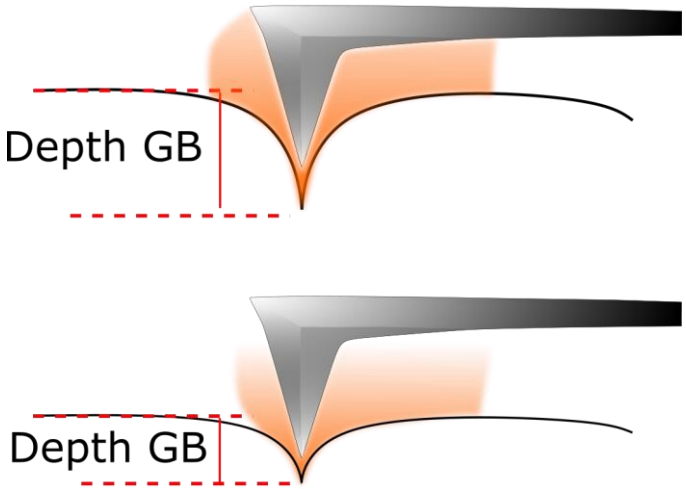
Work function changing with GB depth



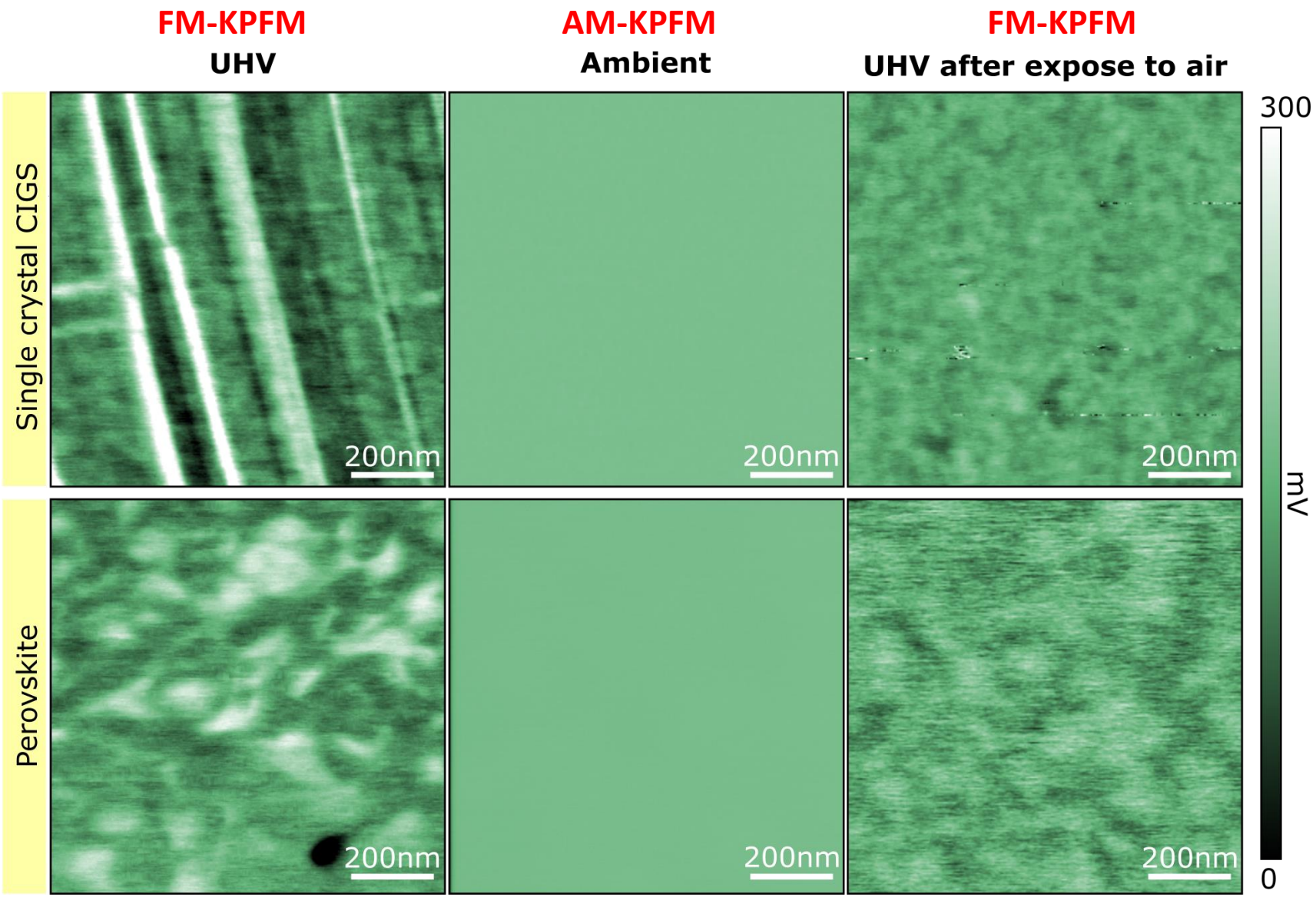


Work-function can not change according to the depth of the GB.

AM-KPFM



Environment



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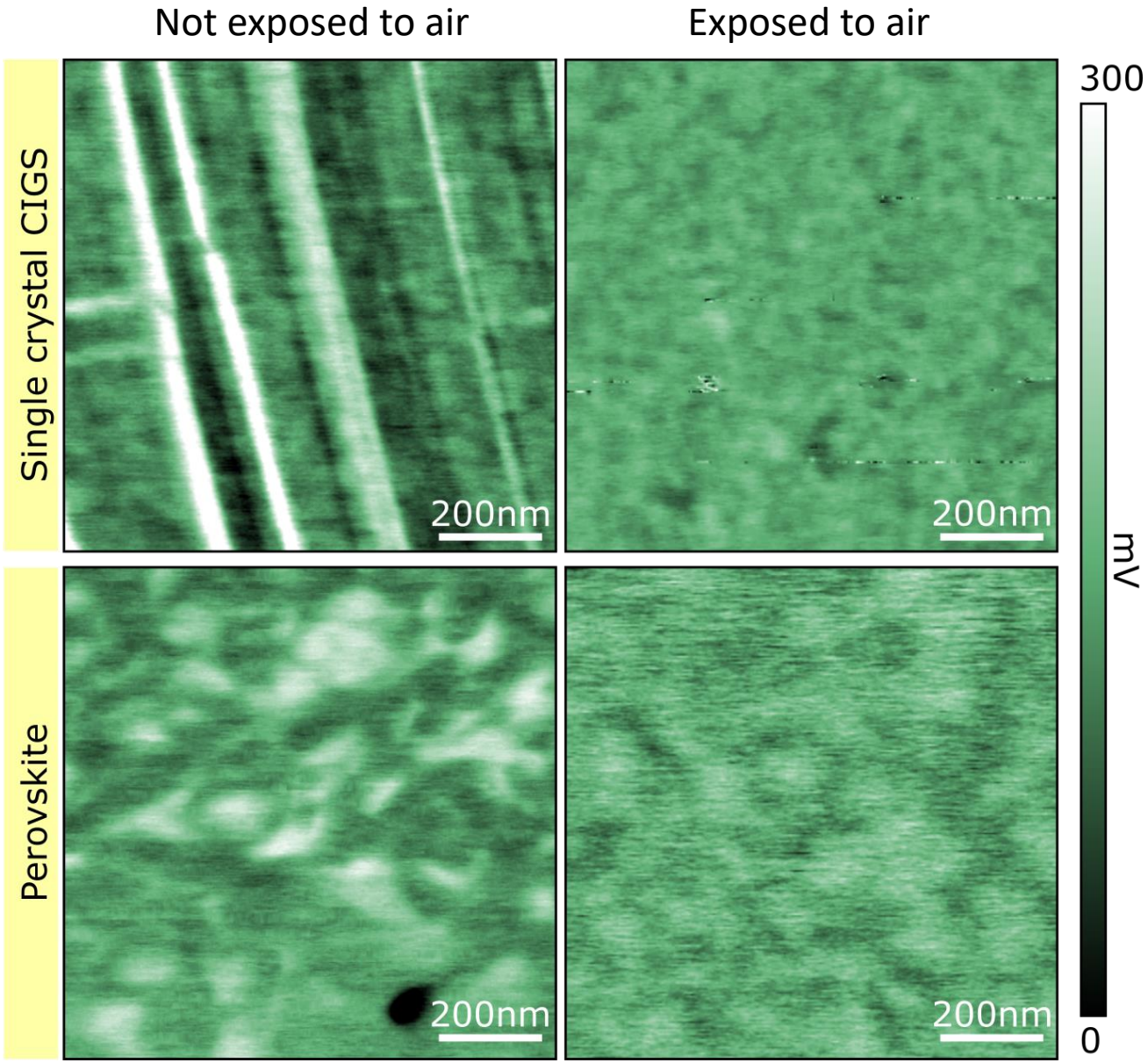


Conclusions

AM-KPFM

- Workfunction contrast depends on scan direction.
- Workfunction contrast is proportional to GB depth

FM-KPFM

- Reliable workfunction maps
- No detectable grain boundary contrast

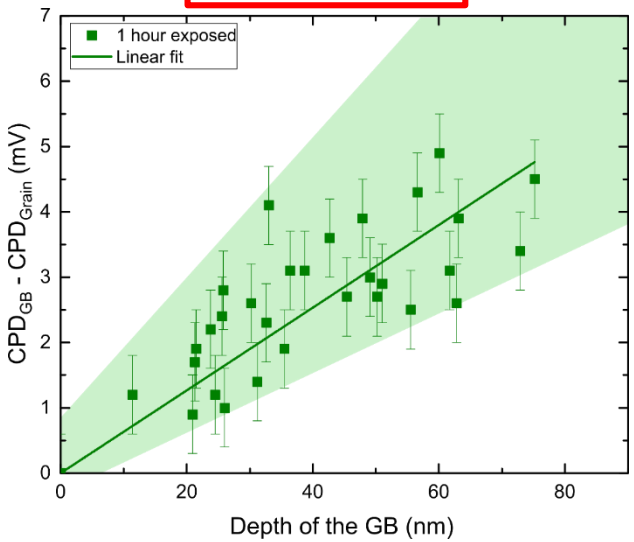
Environment

facet contrast vanishes when sample was air exposed.

Acknowledgment

Luxembourg National Research Fund

KPFM mode



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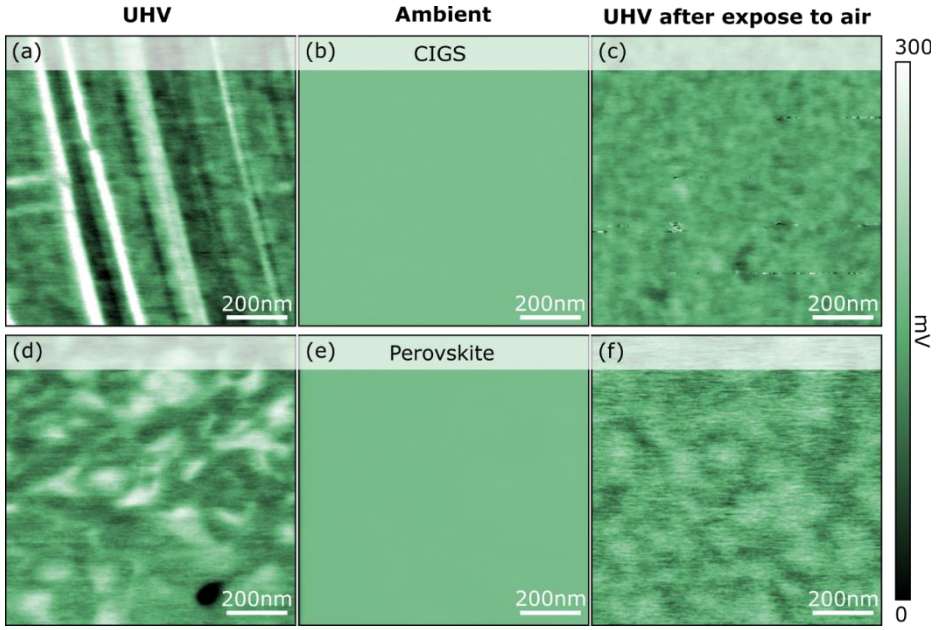
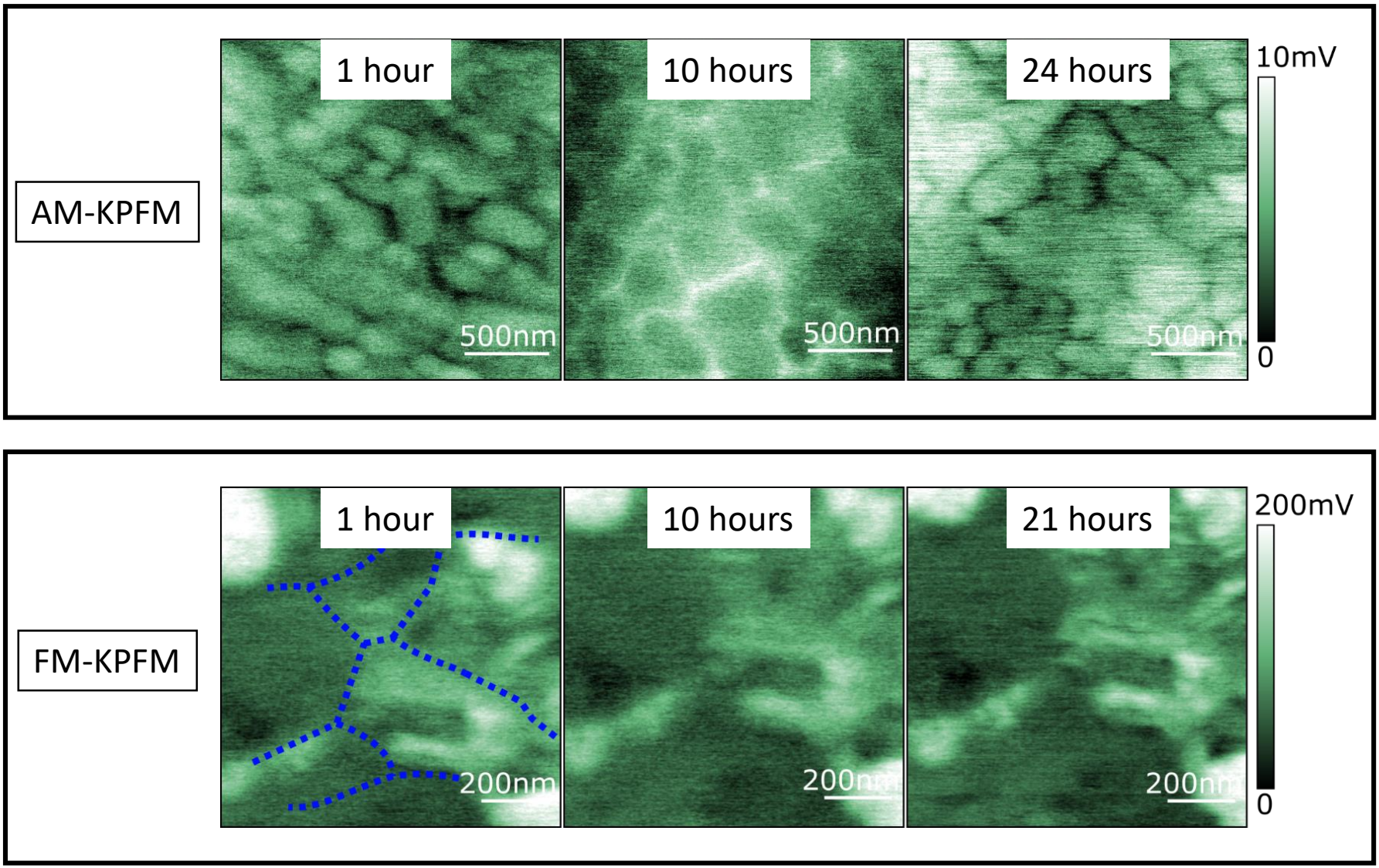
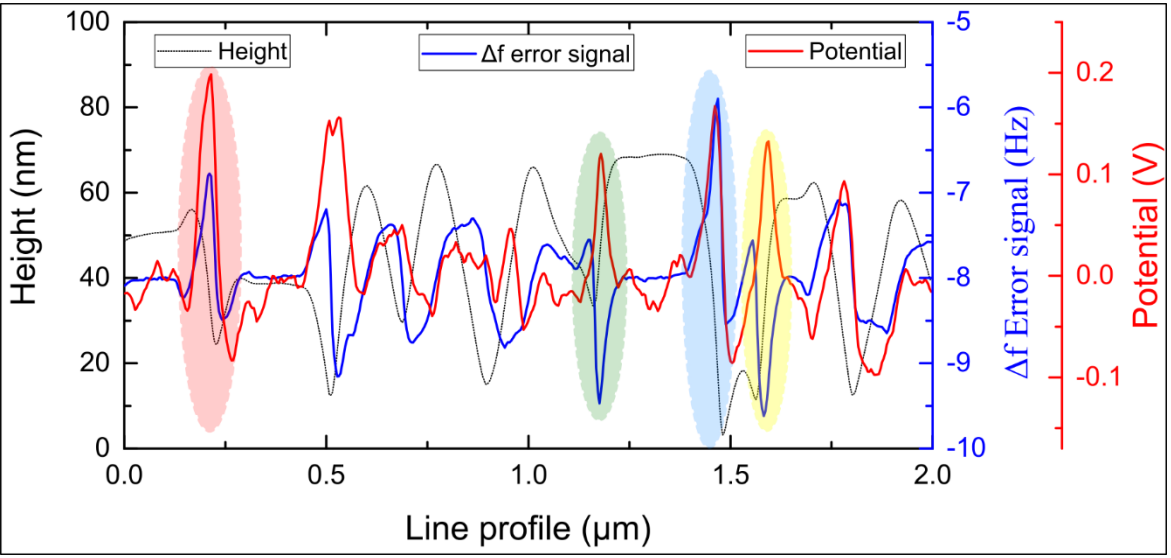


Backup slides

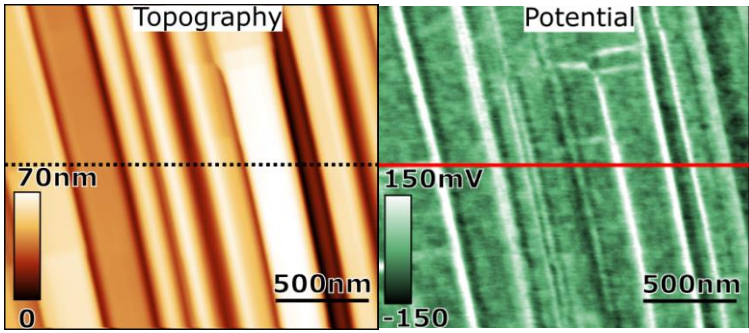
Perovskite sample over time

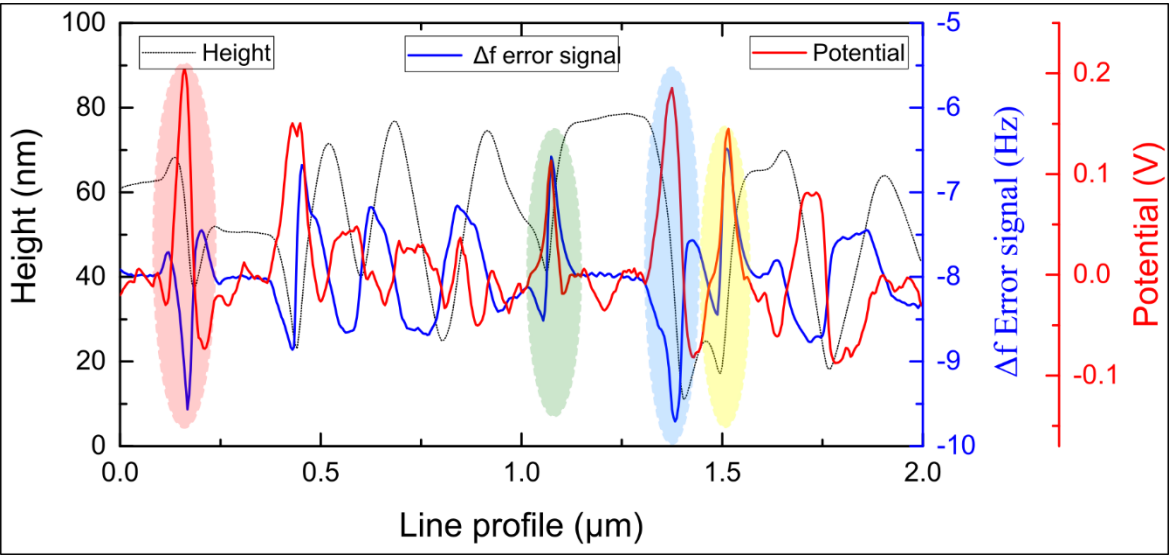


FM-KPFM UHV conditions CIGS

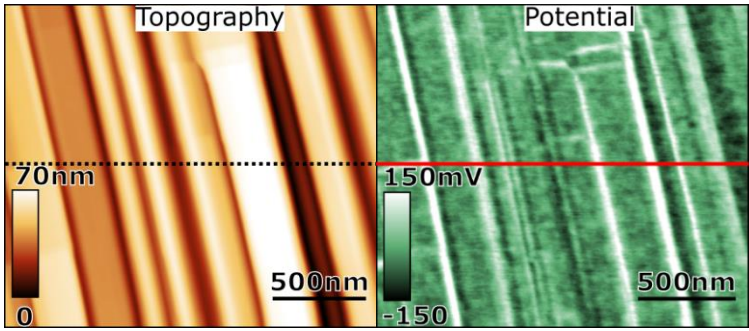


Trace images

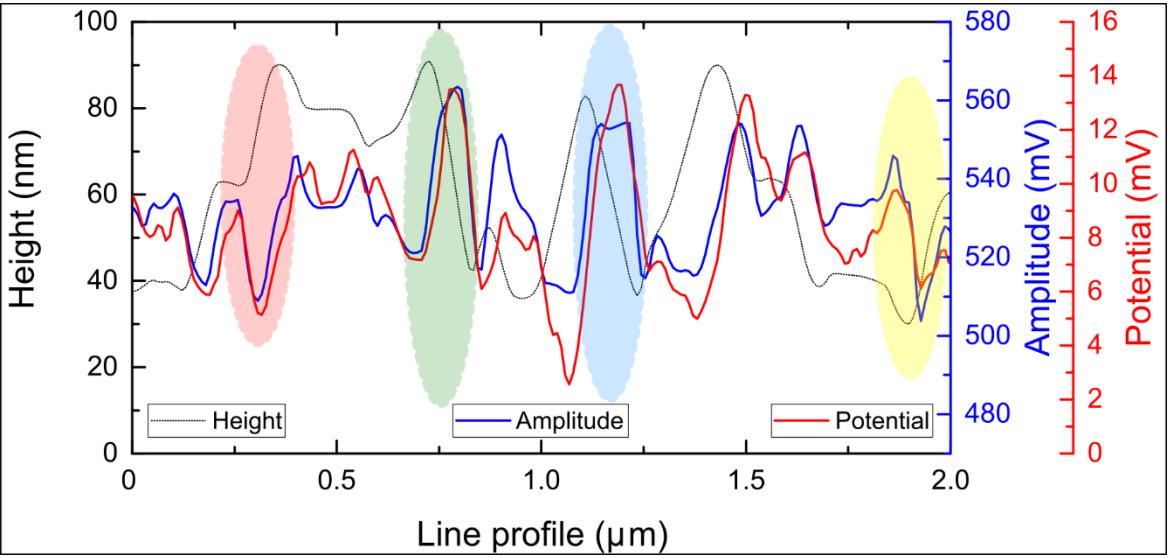




Retrace images



AM-KPFM ambient conditions CIGS



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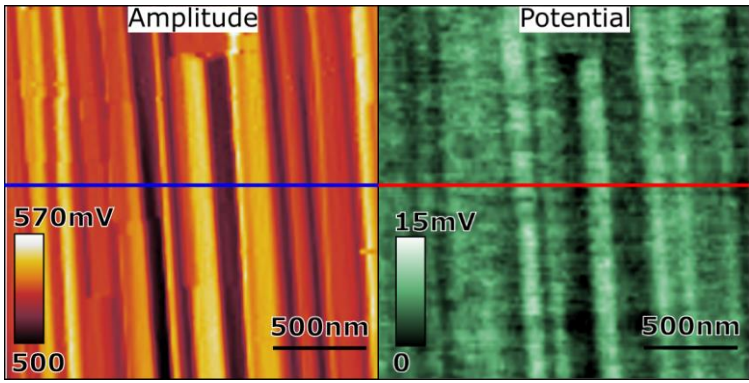

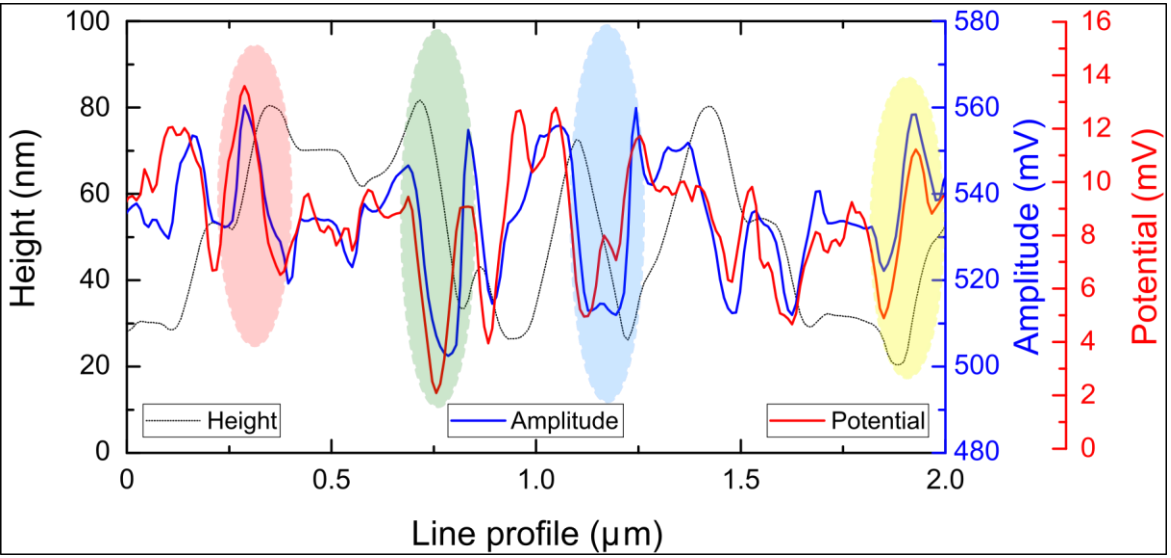

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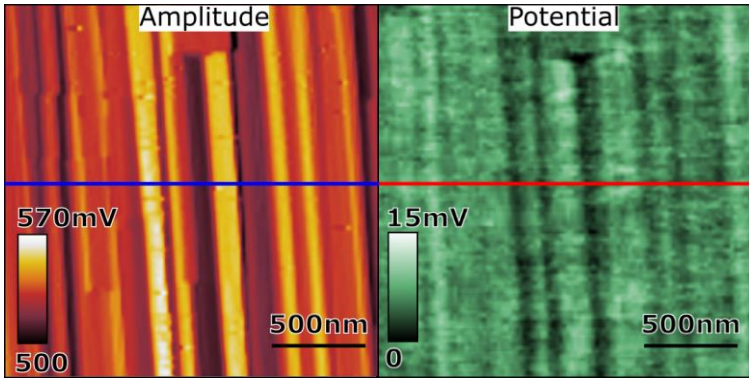
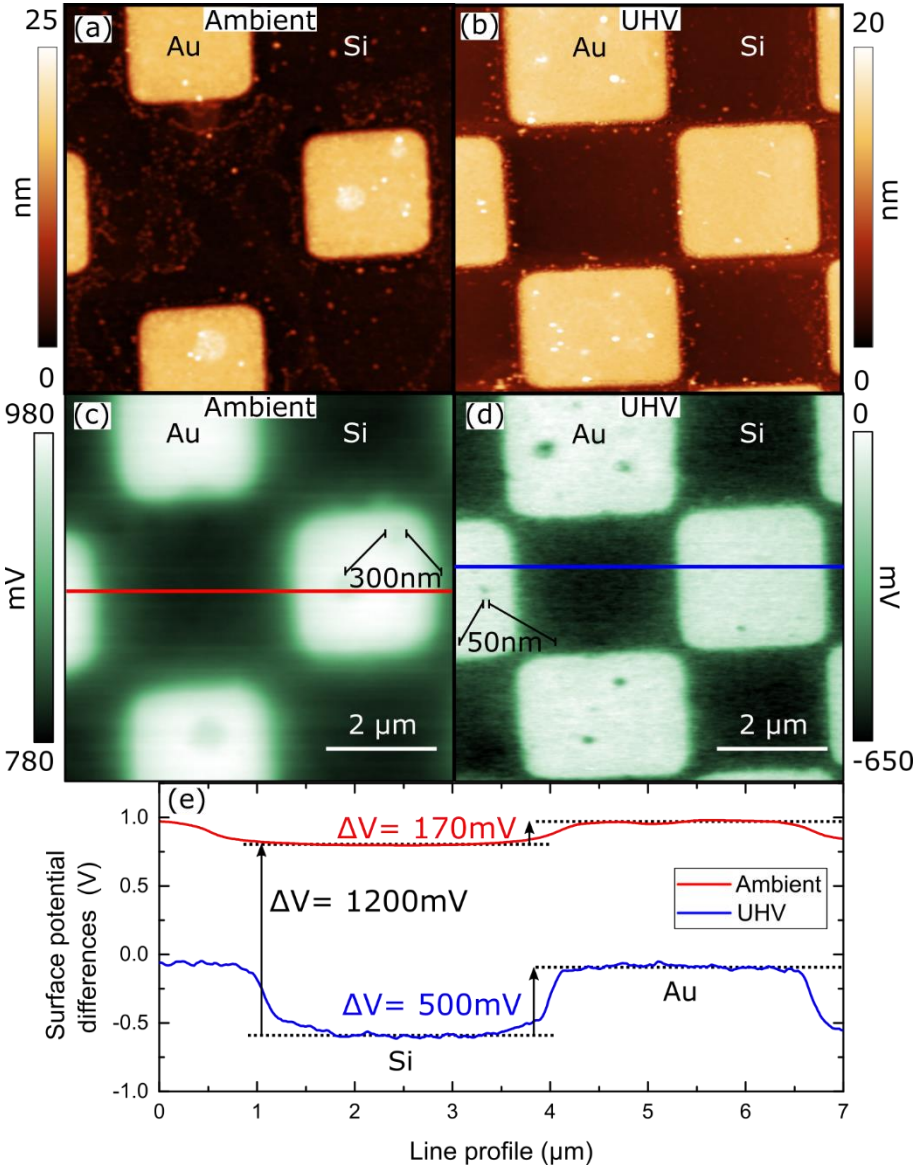
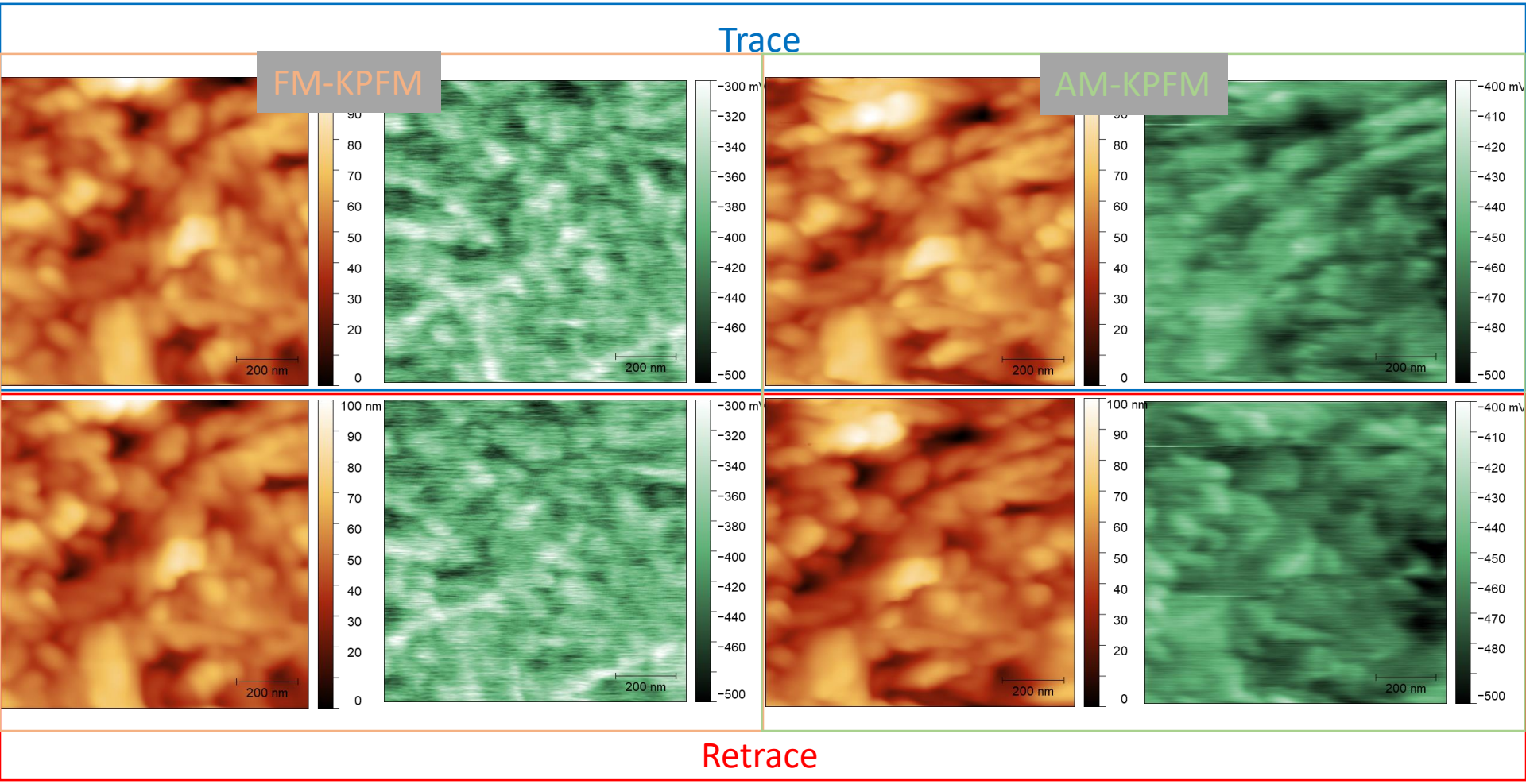


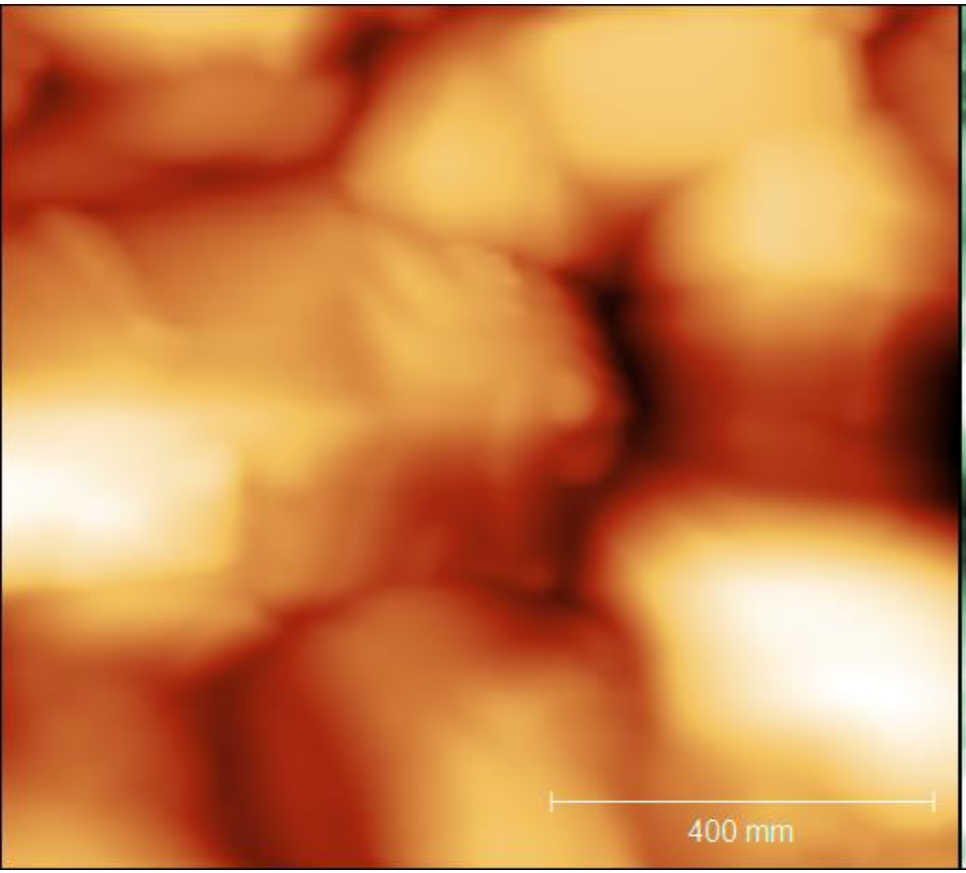

(a)
Ambient
Au
Si
(b)
UHV
Au
Si
25
0
nm
20
0
nm
(c)
Ambient
Au
Si
300nm
2 µm
(d)
UHV
Au
Si
50nm
2 µm
980
780
mV
0
-650
mV
(e)
ΔV= 170mV
ΔV= 1200mV
ΔV= 500mV
Ambient
UHV
Au
Si
Surface potential differences (V)
1.0
0.5
0.0
-0.5
-1.0
0
1
2
3
4
5
6
7
Line profile (µm)

Perovskite

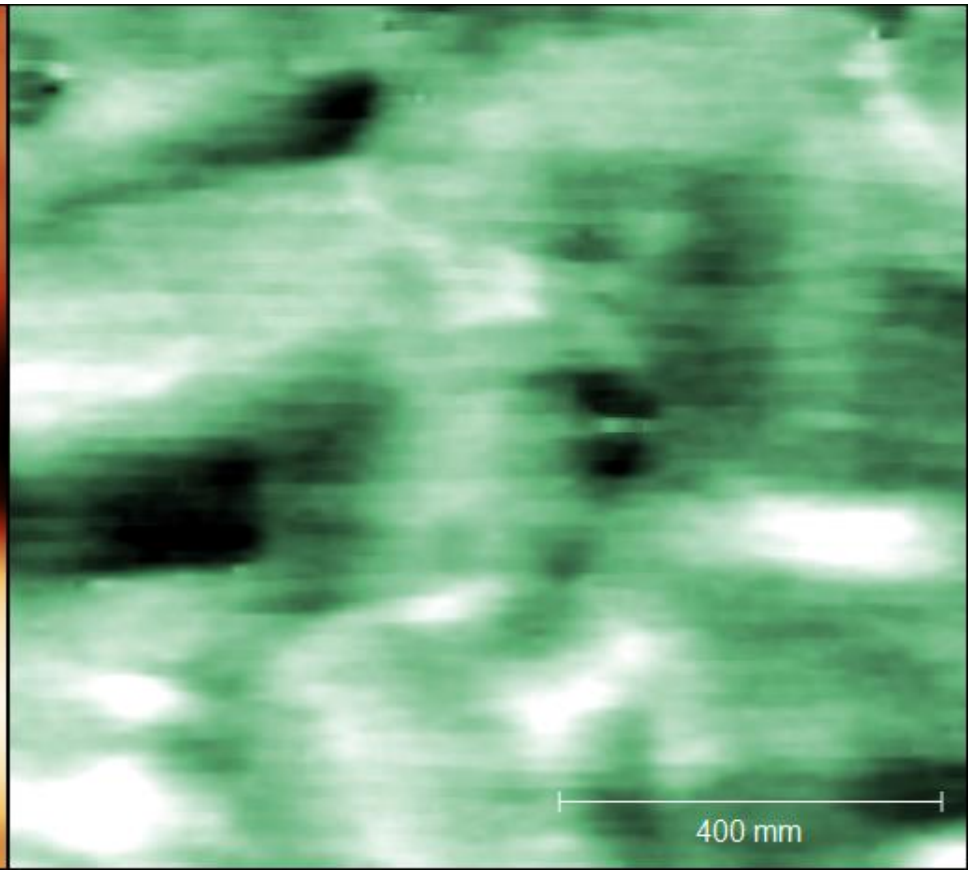

Trace
FM-KPFM
AM-KPFM
200 nm
100 nm
90
80
70
60
50
40
30
20
0
−300 mV
−320
−340
−360
−380
−400
−420
−440
−460
−500
−400 mV
−410
−420
−430
−440
−450
−460
−470
−480
−500
Retrace

Poly CIGS

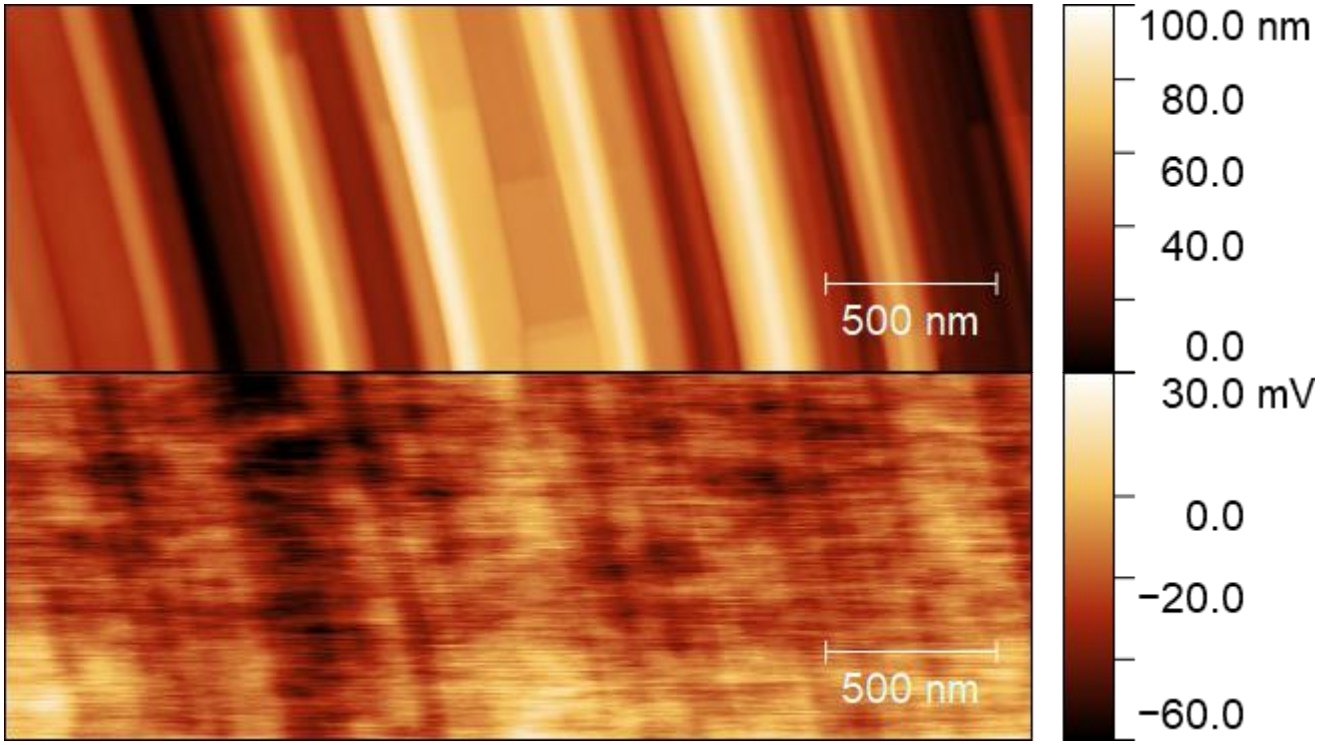
Topography



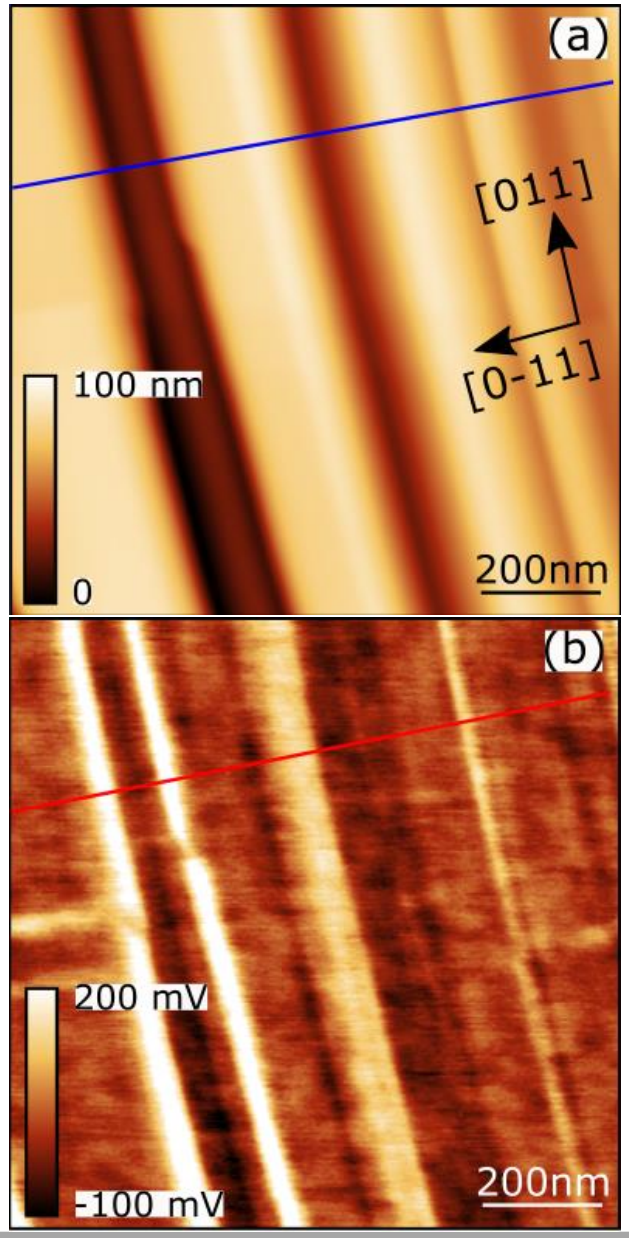
Potential



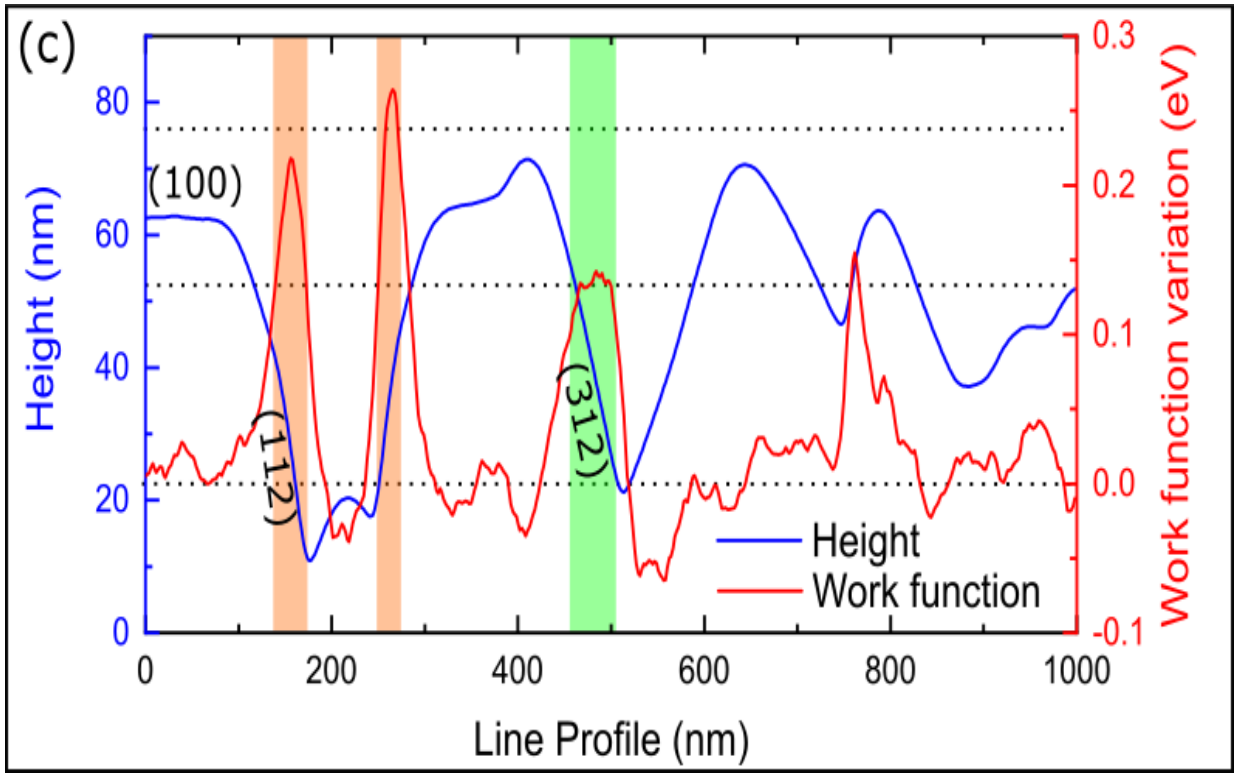
AM-KPFM UHV



UHV – KPFM Cu-rich CISe



KPFM signal is related to the facets of the crystal.



AM-KPFM ambient conditions CIGS

Cu-rich CISe grown on GaAs (100)

AM-KPFM in double pass mode and under ambient conditions