



UvA-DARE (Digital Academic Repository)

Monocrystalline halide perovskite nanostructures for optoelectronic applications

Khoram, P.

Publication date

2018

Document Version

Other version

License

Other

[Link to publication](#)

Citation for published version (APA):

Khoram, P. (2018). *Monocrystalline halide perovskite nanostructures for optoelectronic applications*.

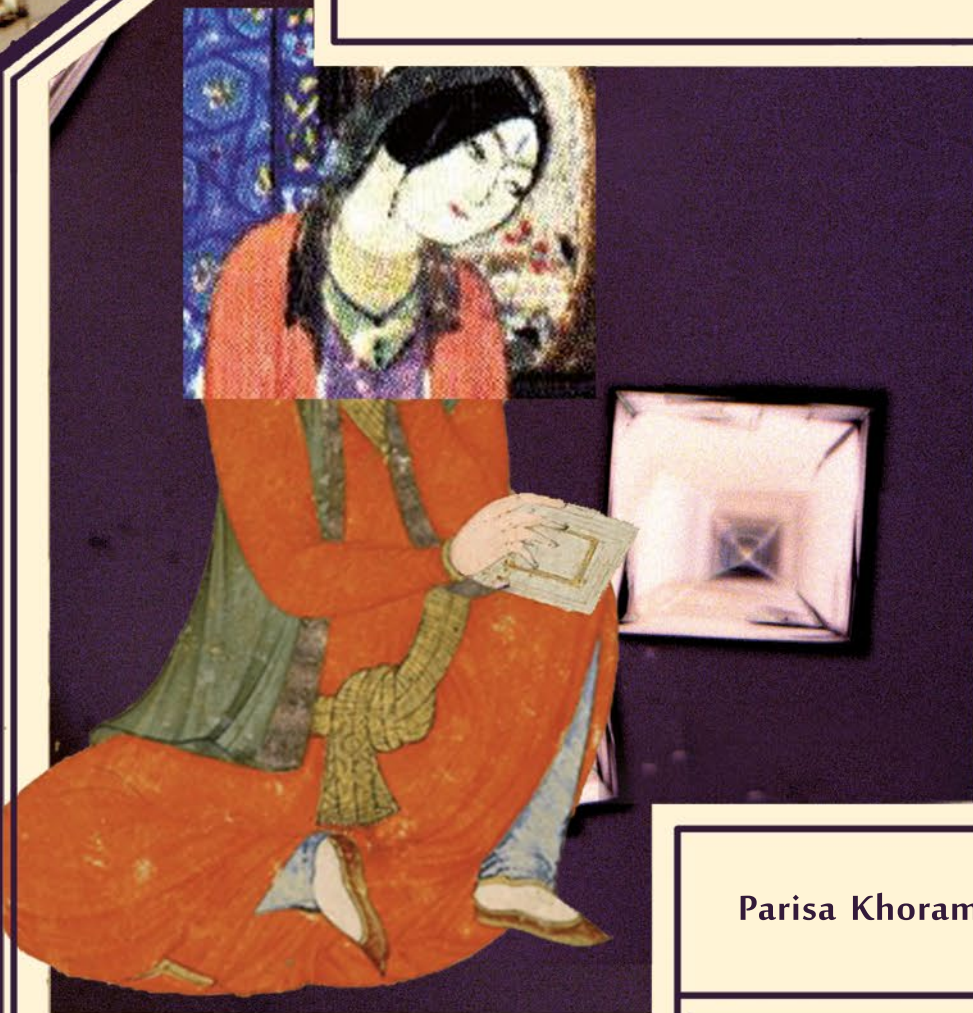
General rights

It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations

If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: <https://uba.uva.nl/en/contact>, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.

**Monocrystalline Halide
Perovskite Nanostructures**
for Optoelectronic Applications



Parisa Khoram

Monocrystalline Halide
Perovskite Nanostructures
for Optoelectronic Applications



Cover image: Collage of Persian miniature illustrations and optical image of $\text{CH}_3\text{NH}_3\text{PbBr}_3$ single crystals. Designed by Taraneh Khorram.

Ph.D. Thesis, University of Amsterdam, April 2018

Monocrystalline Halide Perovskite Nanostructures for Optoelectronic Applications

Parisa Khoram

ISBN: 978-94-92323-18-7

A digital version of this thesis can be downloaded from <http://www.amolf.nl>

Monocrystalline Halide Perovskite Nanostructures for Optoelectronic Applications

ACADEMISCH PROEFSCHRIFT

ter verkrijging van de graad van doctor
aan de Universiteit van Amsterdam
op gezag van de Rector Magnificus
prof. dr. ir. K.I.J. Maex
ten overstaan van een door het College voor Promoties ingestelde commissie,
in het openbaar te verdedigen in de Agnietenkapel
op woensdag 25 april 2018, te 12.00 uur

door

Parisa Khoram

geboren te Mashhad, Iran

Promotiecommissie

Promotor: prof. dr. E. C. Garnett Universiteit van Amsterdam
Copromotor: prof. dr. A. Polman Universiteit van Amsterdam

Overige leden: prof. dr. D. Cahen Weizmann Institute of Science
prof. dr. M. A. Loi Rijksuniversiteit Groningen
prof. dr. J. N. H. Reek Universiteit van Amsterdam
prof. dr. W. C. Sinke Universiteit van Amsterdam
prof. dr. T. Gregorkiewicz Universiteit van Amsterdam

Faculteit der Natuurwetenschappen, Wiskunde en Informatica

The work described in this thesis was performed at
AMOLF, Science Park 104, 1098 XG Amsterdam, The Netherlands.

This work is part of the research programme of the Netherlands Organisation for Scientific Research (NWO). It is also funded by the European Research Council (ERC).

*There was the door to which I found no key
There was the veil through which I might not see:
Some little talk awhile of me and thee
There was - and then no more of thee and me*

Omar Khayyam (1048-1131),
Persian philosopher, mathematician and poet

Contents

1	Introduction	9
1.1	Brief history and crystal structure of perovskites	10
1.2	The ionic nature of halide perovskites	13
1.3	Charge carrier dynamics in halide perovskites	16
1.4	Halide perovskites in optoelectronic applications	20
1.5	Perovskites single crystals and nanostructures	24
1.6	Outline of this thesis	25
2	Growth and characterization of PDMS-stamped halide perovskite single microcrystals	29
2.1	Introduction	30
2.2	Fabrication of perovskite microcrystals using PDMS-stamping method	31
2.3	Crystallinity of PDMS-stamped $\text{CH}_3\text{NH}_3\text{PbBr}_3$ microcrystals	33
2.4	Optical and electrical characterization of $\text{CH}_3\text{NH}_3\text{PbBr}_3$ single crystals	34
2.5	Conclusion	41
2.6	Supplementary Information	42
2.6.1	Experimental methods	42
2.6.2	Scanning electron microscopy	44
2.6.3	Electron Backscatter Diffraction (EBSD)	44
2.6.4	Device Characterization	44
2.6.5	Scanning Photocurrent Mapping	44
2.6.6	Single-crystal X-ray diffraction of $\text{CH}_3\text{NH}_3\text{PbBr}_3$	45
2.6.7	Materials selection for the electrodes of the back-contacted platform	47

2.6.8	One-dimensional model to calculate relative changes in photocurrent based on changes of the thickness	49
3	Halide migration and its effect on the photoluminescence of single crystal perovskites	51
3.1	Introduction	52
3.2	Nanoprobe X-ray fluorescence mapping	54
3.3	Photoluminescence mapping	59
3.4	DFT calculations of ionic migration energy	61
3.5	Conclusion	63
3.6	Supplementary Information	63
3.6.1	Experimental details	63
3.6.2	Climbing-image nudged elastic band (CI-NEB) calculations	66
4	Perovskite nanowire extrusion	69
4.1	Introduction	70
4.2	Fabrication of nanowires via AAO templates	71
4.3	Single crystallinity of perovskite nanowire	74
4.4	Optical properties of nanowire	77
4.5	Conclusion and Outlook	80
4.6	Supplementary Information	81
4.6.1	Experimental details	81
4.6.2	Integrating sphere microscopy	83
4.6.3	Intensity-dependent PLQY	84
5	Charge carrier dynamics at the Perovskite/Alumina interface	87
5.1	Introduction	88
5.2	Fabrication of Perovskite/Alumina nanowires	91
5.3	Charge-carrier recombination dynamics at the perovskite/alumina nanowires	92
5.4	Surface recombination velocity at the perovskite/alumina interface	96
5.5	Radiative efficiency of Perovskite/Alumina nanowires	98
5.6	Conclusion and Outlook	101
5.7	Supplementary Information	102
5.7.1	Scanning electron microscopy	102
5.7.2	Time-correlated single photon counting	102
5.7.3	Calculation of SRV from continuity equation	104
5.7.4	PLQY measurement	105
5.7.5	Simulation of absorption and E-field distribution of nanowire array	108

References	111
Summary	133
Samenvatting	137
List of publications	141
Acknowledgements	143