

Cover Page



Universiteit Leiden



The handle <http://hdl.handle.net/1887/37043> holds various files of this Leiden University dissertation

**Author:** Markešević, Nemanja

**Title:** Optical properties of DNA-hosted silver clusters

**Issue Date:** 2015-12-16

# **Optical properties of DNA-hosted silver clusters**

---

**Nemanja Markešević**



# Optical properties of DNA-hosted silver clusters

---

PROEFSCHRIFT

ter verkrijging van  
de graad van Doctor aan de Universiteit Leiden,  
op gezag van Rector Magnificus prof. mr. C. J. J. M. Stolker,  
volgens besluit van het College voor Promoties  
te verdedigen op woensdag 16 december 2015  
klokke 12:30 uur

door

**Nemanja Markešević**

geboren te Čačak, Servië  
in 1985

Promotor: Prof. dr. D. Bouwmeester  
Co-promotor: Dr. D. Kraft  
Promotiecommissie: Dr. S. Bidault (Institut Langevin, Paris, France)  
Dr. P. Zijlstra (TU Eindhoven)  
Prof. dr. T. J. Aartsma  
Prof. dr. E. R. Eliel  
Prof. dr. T. Schmidt

The research reported in this thesis was conducted at the 'Leids Instituut voor Onderzoek in de Natuurkunde' (LION). This work is a part of the research program, which is financially supported by the Netherlands Organization for Scientific Research (NWO).

Casimir PhD series Delft-Leiden 2015-27  
ISBN 978-90-8593-233-8

*To the people I love*



---

# Contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
1.1	Metal clusters . . . . .	1
1.2	DNA-hosted silver clusters . . . . .	1
1.3	DNA scaffolds . . . . .	3
1.4	Experimental techniques . . . . .	4
1.5	Thesis outline . . . . .	6
<b>2</b>	<b>Spectral Properties of Individual DNA-Hosted Silver Nanoclusters at Low Temperatures</b>	<b>11</b>
2.1	Introduction . . . . .	12
2.2	Experimental methods . . . . .	13
2.3	Results . . . . .	15
2.4	Discussion . . . . .	26
2.5	Conclusion . . . . .	30
<b>3</b>	<b>Polarization resolved measurements of individual DNA-stabilized silver clusters</b>	<b>31</b>
3.1	Introduction . . . . .	32
3.2	Results and discussion . . . . .	34
3.3	Conclusion . . . . .	41
3.4	Experimental methods . . . . .	42
<b>4</b>	<b>Optical properties of the DNA-hosted silver clusters (Ag:DNAs) on DNA tiles and tubes</b>	<b>45</b>
4.1	Introduction . . . . .	46
4.2	Synthesis of Ag:DNAs, DNA tiles and tubes . . . . .	47



4.3	Temperature-dependent fluorescence and absorption spectroscopy . . . . .	49
4.4	Characterization of the free 9C Ag:DNA emitters . . . . .	52
4.5	Fluorescent properties of Ag:DNAs on DNA tubes . . . . .	54
4.6	Fluorescent properties of Ag:DNAs on DNA tiles . . . . .	56
4.7	Absorption properties of Ag:DNAs . . . . .	57
4.8	Conclusion . . . . .	60
<b>5</b>	<b>Lifetime measurements of the DNA-hosted (Ag:DNAs) silver clusters</b>	<b>63</b>
5.1	Introduction . . . . .	64
5.2	Synthesis procedure . . . . .	65
5.3	Experimental section . . . . .	68
5.4	Results for single emitters . . . . .	70
5.5	Results for multiple emitters . . . . .	72
5.6	Results for emitters on DNA tubes . . . . .	75
5.7	Conclusion . . . . .	80
<b>6</b>	<b>Strings of colloidal particles glued by DNA tubes</b>	<b>83</b>
6.1	Introduction . . . . .	84
6.2	Microscopy . . . . .	85
6.3	Functionalization of colloidal particles . . . . .	86
6.4	Tube synthesis . . . . .	87
6.5	Results . . . . .	88
6.6	Conclusion . . . . .	91
	<b>Summary</b>	<b>93</b>
	<b>Samenvatting</b>	<b>97</b>
	<b>Curriculum Vitae</b>	<b>111</b>
	<b>List of publications</b>	<b>113</b>
	<b>Acknowledgement</b>	<b>115</b>