Dissertation reader`s review of RNDr. Lukáš Ondič doctoral thesis „Silicon nanocrystals, photonic structures and optical gain“.

The subject of this thesis is investigation of a possibility of enhancing the optical gain of light emitting silicon nanocrystals by combining them with a two-dimensional photonic crystal. This is a top topic in terms of both physical and application. To achieve the aim of the thesis, L. Ondič studied the recombination and relaxation processes of photo-excited carriers in silicon nanocrystals; he evaluated the optical gain coefficient of his silicon nanocrystal structures. Two types of two-dimensional photonic crystals were used to increase the extraction efficiency and optical gain of embedded silicon nanocrystals. The photonic structures were designed so that an overlap between the emission spectrum of silicon nanocrystals and the leaky modes of the photonic crystal was achieved. The optical properties of prepared two-dimensional photonic crystals were determined. The possibility of enhancing optical gain of silicon nanocrystals combined with a photonic crystal was studied both experimentally and theoretically. Chosen theoretical and experimental approaches used in doctoral thesis very well correspond with the goal of the thesis.

The text of this thesis is organized into seven chapters and the thesis is supplemented very illustrative videos of the SES & VSL methods. The fundamental chapters (3-6) including original author results of this work are build on the articles authored or co-authored by L. Ondič. In these chapters, always short introduction of the studied problems, experimental and summary of the main results are given, which is then followed by the enclosed publications. Thesis is clearly written and very well arranged graphical. The contribution of the author is given in the thesis conclusions.

Chapter 1 of this thesis summarizes results from the literature concerning the optical properties of silicon nanocrystals which are relevant in the following parts. There is also a list of the properties of an ideal sample that should possess high optical gain.

Chapter 2 presents the mechanism of light propagation in photonic crystals, the concept of a photonic band diagram, the principle of light extraction from photonic crystal slabs and the principle of the optical gain enhancement phenomenon together with its experimental realization.

Chapter 3 is focused on the fundamental optical properties of oxide-passivated silicon nanocrystals with conclusion that the F-band origin in oxidized SiNCs prepared by etching of Si after lies predominantly in the core-related quasi-direct radiative recombination between the states in the vicinity of the Γ-point. Experimental methods employed for the characterization of recombination processes are also discussed.

Chapter 4 describes the principle of methods used for the evaluation of an optical gain coefficient and the results of the gain measurements of different types of samples based on silicon nanocrystals.

Chapter 5 explains theoretical and experimental approaches employed to design and characterize the two-dimensional photonic crystals. It also comprises the results of enhanced light extraction efficiency from nanocrystalline diamond photonic crystals.

Chapter 6 summarizes experimental results, which evidence the influence of photonic crystals (fabricated on the top of two different materials) on the emission properties of silicon nanocrystals.

Chapter 7 concludes the experimental and theoretical findings of this work.

This thesis presents lot of very interesting new findings from which I select the next:

1. The determination of the physical origin of the fast blue-green emission band in oxide-passivated freestanding SiNCs. It was shown that the quasi-direct recombination of electron-

hole pairs between the states in the close vicinity of the Si band structure Γ-point is the main radiative channel responsible for the blue band.

2. Manifestation of the optical gain of the order of tens of cm^{-1} for SiNCs in a SiO_2-solgel matrix.

3. Computation of the effect of periodic patterning of an active material on the intensity of light propagating through it. Finite-difference time-domain simulations showed that the propagating light intensity may be amplified in the case of a 2D photonic crystal and a photonic crystal slab.

4. Enhancement of the intensity of vertically-extracted light by a factor of 7 from a 2D photonic crystal prepared on the top of a silica layer with embedded SiNCs.

I have a few comments which have to be discussed by L. Ondič during the PhD thesis defence.

1. Please, discuss in detail the thermalization process of the excited electron towards the Δ1-valley which is mentioned in the discussion paragraph b in paper "Complex study of the fast blue luminescence of oxidized silicon nanocrystals: The role of the core"L. Ondič, et al.

2. Can you discuss the influence of sample properties (homogeneity, shape and etc.) on the results of the gain measurement?

3. Can you more specify a future direction of the development of the devices based on SiNCs combined with a photonic crystal that would allow manifesting the enhancement of optical gain?

4. Can you discuss the possibility of electroluminescence in such structures?

RNDr. Lukáš Ondič doctoral thesis „Silicon nanocrystals, photonic structures and optical gain" meets the requirements for a doctoral dissertation and the author demonstrates assumptions for independent scientific work. I recommend doctoral thesis for defence.

Disertační práce RNDr. Lukáše Ondiče „Silicon nanocrystals, photonic structures and optical gain" splňuje požadavky kladené na disertační práci a prokazuje předpoklady autora k samostatné vědecké práci. Disertační práci doporučuji k obhajobě.

Prague 13.1. 2014 *Ing. Jiří Oswald CSc.*

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