
Optical spectroscopy of individual nanoobjects

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Optical spectroscopy of individual nanoobjects (e.g. semiconductor nanocrystals, nanowires, luminescent defects, dopants centers etc.) enables to overcome inhomogeneity in ensembles of such objects that is omnipresent due to impossibility of production of identical objects by the up-to-date nanotechnology.

Common measurements on ensembles suffer from the so called inhomogeneous broadening, which obscure detailed information on energy levels and transitions in individual nanoobjects. Therefore, starting from 1970s, researchers developed various spectroscopic techniques that can indirectly reveal some information hidden by the inhomogeneous broadening, e.g. spectral hole-burning techniques.

Recent progress of detection devices enabled detecting luminescence spectra directly from single nanoobjects. Such techniques are being developed in our laboratory for more than 15 years. Between the possible approaches we prefer the luminescence microspectroscopy in a broad optical far-field, which is much less explored than confocal approaches. The reason for such choice is our focus on studies of silicon nanostructures, whose luminescence flux is extremely low due to the indirect band gap energy structure and related long excited-state lifetimes. Thus, our experimental techniques must achieve the maximal sensitivity and position stability in order to allow for long acquisition times (typically 10–60 min). Our main competitive advantage was gained by successful incorporation of a cryostat in the microspectroscopy set-up – this unique cryo-microspectroscopy device is exceptionally stable, giving the typical sample drift below 1 μm per one hour acquisition at 10 K. Using this set-up we performed several foreground studies, e.g. showing coexistence of quasi-1D and 0D excitons in silicon nanowires, revealing narrow zero-phonon lines and phonon-replicas in Si nanocrystals at low T or energy levels of single dopants in Si nanocrystals. Recently we extended our microspectroscopy technique into the near-infrared (NIR) spectral region, setting up two parallel detection branches covering a broad range from 350 to 1650 nm. The latest development consist of incorporation of a time-resolved luminescence detection for both VIS and NIR regions (the sensitivity is not on the single nanoobject level yet). We apply our microspectroscopy device also to study other inorganic (Au-nanoclusters and nanorods, SiC, ZnO, MoS₂ etc.) and organic materials (e.g. organic complexes with lanthanides) and also to measurements in living cell cultures.

Selected outputs

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- I. Sychugov, J. Valenta, and J. Linnros: Optical and electrical properties of silicon nanocrystals as revealed by single-dot studies (topical review), *Nanotechnology* 28, 072002 (2017), [dx.doi.org/10.1088/1361-6528/aa542b](https://doi.org/10.1088/1361-6528/aa542b).
- M. Greben, P. Khoroshyy, I. Sychugov, J. Valenta: Non-exponential decay kinetics: Correct assessment and description illustrated by slow luminescence of Si nanostructure, *Appl. Spectr. Reviews* 54, 1-44 (2019), DOI 10.1080/05704928.2018.1517263