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1. Outline of research results in 2010

In our research we use single-molecule spectroscopy to study nanoscale structure and optical/electrical properties of organic and polymeric materials.

1) Mapping of emitting sites in single conjugated polymer chains

Using high-resolution single-molecule imaging we carried out mapping of the emitting sites of the conjugated polymer MEH-PPV with a wide range of molecular weights and in different polymer matrices. From the fact that the average spatial jumps of the emitting site do not depend on time we concluded that the exciton is migrating over the whole chain rather than being confined in isolated domains.

2) Photophysics of single conjugated polymer chains in solution

All single-molecule studies on conjugated polymers have so far been done in a solid state. To examine the photophysical properties of a single chain of MEH-PPV in its thermodynamically relaxed state we carried out experiments in a concentrated solution of polystyrene as a good solvent for MEH-PPV. Unlike in the solid state, single MEH-PPV chains in solution show no blinking, reduced photobleaching and long-range exciton migration. The significantly reduced energy loss in the chain in a relaxed state is a potentially important result from the applications point of view.

3) Structure and optical properties of light-harvesting antennae of green photosynthetic bacteria

Chlorosomes, the antennae of green photosynthetic bacteria, absorb light and transfer the absorbed energy with very high efficiency, and together with conjugated polymers they continue to attract attention as models of high efficiency optoelectronic devices. We investigated the chlorosomal antennae on single particle level with the aim to study the relationship between their inner structure and optical properties. We used wild-type and mutant chlorosomes from the green photosynthetic bacterium *Chl. tepidum* to obtain information on the extent of inner structural disorder and orientation of the exciton transition dipole moment, and based on the results we proposed a structural model for the pigment organization inside the chlorosomes.

2. List of publications

Refereed papers

- 1) S. Furumaki, F. Vacha, S. Habuchi, Y. Tsukatani, D.A. Bryant and M. Vacha: Absorption linear dichroism measured directly on a single light-harvesting system: the role of disorder in chlorosomes of green photosynthetic bacteria. *J. Am. Chem. Soc.* (2011), published online 10.1021/ja111475z
- 2) S. Habuchi, T. Oba and M. Vacha: Multi-beam single-molecule defocused imaging reveals anisotropic chain orientation in a polymer thin film. *Phys. Chem. Chem. Phys.* 13 (2011) 6970-6976
- 3) K. Suzuki, S. Habuchi and M. Vacha: Blinking of single dye molecules in a polymer matrix is correlated with free volume in polymers. *Chem. Phys. Lett.* 505 (2011) 157-160
- 4) S. Habuchi, S. Onda and M. Vacha: Molecular weight dependence of emission intensity and emitting sites distribution within single conjugated polymer molecules. *Phys. Chem. Chem. Phys.* 13 (2011) 1743 – 1753
- 5) M. Vacha, S. Habuchi: Conformation and physics of polymer chains: a single-molecule perspective. *NPG Asia Mater.* 2 (2010) 134-142
- 6) S. Hirata, M. Vacha, and T. Watanabe: Investigation of Quenching Mechanism in Thermoreversible Fluorescent Recording Materials of Fluorescence Using Thermochromic Fluorescence Resonance Energy Transfer. *Jpn. J. Appl. Phys.* 49 (2010) 052501 (10 pages)
- 7) S. Furumaki, S. Habuchi and M. Vacha: Fluorescence-detected three-dimensional linear dichroism: A method to determine absorption anisotropy in single sub-wavelength size nanoparticles. *Chem. Phys. Lett.* 487 (2010) 312-314
- 8) S. Habuchi, N. Sato, T. Yamamoto, Y. Tezuka and M. Vacha: Multimode Diffusion of Ring Polymer Molecules Revealed by a Single-Molecule Study. *Angew. Chem. Int. Ed.* 49 (2010) 1418-1421

3. Conferences

International

- 1) M. Vacha, S. Furumaki, F. Vacha, J. Psencik, S. Habuchi: Absorption linear dichroism directly measured on a single light-harvesting complex of photosynthetic bacteria (Oral). 17th International Conference on Dynamical Processes in Excited states of Solids, Argonne, USA, June 20-25, 2010

- 2) S. Habuchi, S. Onda, T. Sugimoto, M. Vacha: Relationship between conformation and optical properties of single conjugated polymer molecules (Oral). 17th International Conference on Dynamical Processes in Excited states of Solids, Argonne, USA, June 20-25, 2010
- 3) M. Vacha, S. Furumaki, F. Vacha, J. Psencik, S. Habuchi: Absorption linear dichroism measured directly on a single chlorosome of green photosynthetic bacteria: the role of inner structural disorder (Oral). 15th International Congress on Photosynthesis, Beijing, China, August 22-27, 2010
- 4) S. Furumaki, F. Vacha, J. Psencik, S. Habuchi, M. Vacha: Development of new microscopic methods using absorption anisotropy for the study of the properties of antenna complexes of photosynthetic bacteria (Poster). 15th International Congress on Photosynthesis, Beijing, China, August 22-27, 2010
- 5) M. Vacha: Single-molecule approach to nanoscale structure and dynamics of molecular complexes: from conjugated polymers to photosynthetic light-harvesting (Invited). 5th International Symposium on Integrated Molecular materials Engineering, Changzhou, China, September 20-22, 2010
- 6) S. Habuchi, T. Yamamoto, Y. Tezuka, M. Vacha: Multimode diffusion of ring polymer molecules revealed by a single-molecule study (Oral). 5th International Symposium on Integrated Molecular materials Engineering, Changzhou, China, September 20-22, 2010

Domestic

- 1) M. Vacha, S. Furumaki, S. Habuchi: Structure of chlorosomal antennae of photosynthetic bacteria studied by single-molecule absorption spectroscopy (Oral). Annual Meeting on Photochemistry, September 8-10, 2010, Chiba University
- 2) S. Habuchi, T. Yamamoto, Y. Tezuka, M. Vacha: Multimode diffusion of ring polymer molecules revealed by a single-molecule study (Oral). Annual Meeting on Photochemistry, September 8-10, 2010, Chiba University
- 3) T. Oba, S. Habuchi, M. Vacha: Full three-dimensional distribution of single molecules determined by simultaneous multiple beam illumination (Poster). Annual Meeting on Photochemistry, September 8-10, 2010, Chiba University
- 4) T. Hatano, S. Habuchi, M. Vacha: Nanoscale characterization of conjugated polymer light emitting diodes by fluorescence micro-spectroscopy (Poster). Annual Meeting on Photochemistry, September 8-10, 2010, Chiba University

- 5) Y. Osawa, M. Vacha, S. Habuchi, T. Iyoda, H. Komiyama: Development of efficient optoelectronic materials using nanocylinders of a block copolymer as a template (Poster). Annual Meeting on Photochemistry, September 8-10, 2010, Chiba University
- 6) S. Onda, S. Habuchi, M. Vacha: Dependence of spatial jump size of emitting sites within a single conjugated polymer chain on the polymer molecular weight (Poster). Annual Meeting on Photochemistry, September 8-10, 2010, Chiba University
- 7) S. Habuchi, T. Michinobu, M. Vacha: A single-molecule study on the donor-acceptor type conjugated polymer (Poster). Annual Meeting on Photochemistry, September 8-10, 2010, Chiba University
- 8) S. Nozue, S. Habuchi, M. Vacha: Development of simultaneous AFM and fluorescence confocal microscopy with single molecule sensitivity for the study of nanoscale properties of organic materials (Poster). Annual Meeting on Photochemistry, September 8-10, 2010, Chiba University
- 9) S. Furumaki, S. Habuchi, M. Vacha: Development of new microscopic methods using absorption anisotropy for the study of the properties of antenna complexes of green sulfur bacteria (Poster). Annual Meeting on Photochemistry, September 8-10, 2010, Chiba University

4. International Collaboration

- 1) Prof. Donald A. Bryant
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