

University of Groningen

Self-assembled structures and applications of DNA hybrid materials

Kwak, Min Seok

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version

Publisher's PDF, also known as Version of record

Publication date:

2011

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Kwak, M. S. (2011). *Self-assembled structures and applications of DNA hybrid materials*. s.n.

Copyright

Other than for strictly personal use, 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), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

Bibliography

- [1] T. E. Patten and K. Matyjaszewski. Atom transfer radical polymerization and the synthesis of polymeric materials. *Adv. Mater.*, 10(12):901–915, 1998.
- [2] N. Hadjichristidis, S. Pispas, and G. Floudas. *Block Copolymers: Synthetic Strategies, Physical Properties, and Applications*. John Wiley and Sons, New York, 2002.
- [3] G. R. Newkome, C. N. Moorefield, and F. Vögtle. *Dendrimers and Dendrons - Concepts, Syntheses, Applications*. Wiley-VCH, Weinheim, 2001.
- [4] U. M. Wiesler, T. Weil, and K. Müllen. Nanosized polyphenylene dendrimers. In *Dendrimers III: Design, Dimension, Function*, volume 212 of *Topics in Current Chemistry*, pages 1–40. Springer, 2001.
- [5] A. Herrmann, T. Weil, V. Sinigersky, U. M. Wiesler, T. Vosch, J. Hofkens, F. C. De Schryver, and K. Müllen. Polyphenylene dendrimers with perylene diimide as a luminescent core. *Chem. Eur. J.*, 7(22):4844–4853, 2001.
- [6] T. Weil, U. M. Wiesler, A. Herrmann, R. Bauer, J. Hofkens, F. C. De Schryver, and K. Müllen. Polyphenylene dendrimers with different fluorescent chromophores asymmetrically distributed at the periphery. *J. Am. Chem. Soc.*, 123(33):8101–8108, 2001.
- [7] T. Weil, E. Reuther, and K. Müllen. Shape-persistent, fluorescent polyphenylene dyads and a triad for efficient vectorial transduction of excitation energy. *Angew. Chem., Int. Ed.*, 41(11):1900–1904, 2002.
- [8] R. B. Merrifield. Solid phase peptide synthesis. I. Synthesis of a tetrapeptide. *J. Am. Chem. Soc.*, 85(14):2149–2154, 1963.
- [9] W. C. Chan and P. D. White. *Fmoc Solid Phase Peptide Synthesis - A Practical Approach*. Oxford University Press, Oxford, 2000.
- [10] P. E. Dawson and S. B. H. Kent. Synthesis of native proteins by chemical ligation. *Ann. Rev. Biochem.*, 69:923–960, 2000.
- [11] M. Kohn and R. Breinbauer. The Staudinger ligation – A gift to chemical biology. *Angew. Chem., Int. Ed.*, 43(24):3106–3116, 2004.
- [12] G. Casi and D. Hilvert. Convergent protein synthesis. *Curr. Opin. Struct. Biol.*, 13(5):589–594, 2003.
- [13] R. Serwa, I. Wilkening, G. Del Signore, M. Muhlberg, I. Claussnitzer, C. Weise, M. Gerrits, and C. P. R. Hackenberger. Chemoselective Staudinger-phosphite reaction of azides for the phosphorylation of proteins. *Angew. Chem., Int. Ed.*, 48(44):8234–8239, 2009.

- [14] M. H. Caruthers, G. Beaton, J. V. Wu, and W. Wiesler. Chemical synthesis of deoxyoligonucleotides and deoxyoligonucleotide analogs. *Method. Enzymol.*, 211:3–20, 1992.
- [15] M. H. Caruthers. Chemical synthesis of DNA and DNA analogs. *Acc. Chem. Res.*, 24(9):278–284, 1991.
- [16] M. H. Caruthers, A. D. Barone, S. L. Beaucage, D. R. Dodds, E. F. Fisher, L. J. McBride, M. Matteucci, Z. Stabinsky, and J. Y. Tang. Chemical synthesis of deoxyoligonucleotides by the phosphoramidite method. *Method. Enzymol.*, 154:287–313, 1987.
- [17] O. J. Plante, E. R. Palmacci, and P. H. Seeberger. Automated synthesis of polysaccharides. In *Combinatorial Chemistry, Part B*, volume 369 of *Methods Enzymol.*, pages 235–248. Academic Press, 2003.
- [18] P. H. Seeberger and D. B. Werz. Automated synthesis of oligosaccharides as a basis for drug discovery. *Nat. Rev. Drug Discov.*, 4(9):751–763, 2005.
- [19] P. H. Seeberger and D. B. Werz. Synthesis and medical applications of oligosaccharides. *Nature*, 446(7139):1046–1051, 2007.
- [20] N. M. Bell and J. Micklefield. Chemical modification of oligonucleotides for therapeutic, bioanalytical and other applications. *ChemBioChem*, 10(17):2691–2703, 2009.
- [21] K. E. Lundin, L. Good, R. Stromberg, A. Graslund, and C. I. E. Smith. Biological activity and biotechnological aspects of peptide nucleic acid. *Adv. Genet.*, 56:1–51, 2006.
- [22] P. E. Nielsen and G. Haaima. Peptide nucleic acid (PNA). A DNA mimic with a pseudopeptide backbone. *Chem. Soc. Rev.*, 26(2):73–78, 1997.
- [23] E. Uhlmann, A. Peyman, G. Breipohl, and D. W. Will. PNA: Synthetic polyamide nucleic acids with unusual binding properties. *Angew. Chem., Int. Ed.*, 37(20):2797–2823, 1998.
- [24] J. S. Jepsen, M. D. Sorensen, and J. Wengel. Locked nucleic acid: A potent nucleic acid analog in therapeutics and biotechnology. *Oligonucleotides*, 14(2):130–146, 2004.
- [25] M. Petersen and J. Wengel. LNA: A versatile tool for therapeutics and genomics. *Trends Biotechnol.*, 21(2):74–81, 2003.
- [26] H. M. König, R. Abbel, D. Schollmeyer, and A. F. M. Kilbinger. Solid-phase synthesis of oligo(p-benzamide) foldamers. *Org. Lett.*, 8(9):1819–1822, 2006.
- [27] L. Hartmann, E. Krause, M. Antonietti, and H. G. Börner. Solid-phase supported polymer synthesis of sequence-defined, multifunctional poly(amidoamines). *Biomacromolecules*, 7(4):1239–1244, 2006.
- [28] J. Sambrook and D. W. Russel. *Molecular Cloning*. Cold Spring Harbour Laboratory Press, New York, 2001.
- [29] L. Wang and P. G. Schultz. Expanding the genetic code. *Angew. Chem., Int. Ed.*, 44(1):34–66, 2005.

-
- [30] T. Hohsaka and M. Sisido. Incorporation of non-natural amino acids into proteins. *Curr. Opin. Chem. Biol.*, 6(6):809–815, 2002.
- [31] R. E. Connor and D. A. Tirrell. Non-canonical amino acids in protein polymer design. *Polym. Rev.*, 47(1):9–28, 2007.
- [32] S. Jager and M. Famulok. Generation and enzymatic amplification of high-density functionalized DNA double strands. *Angew. Chem., Int. Ed.*, 43(25):3337–3340, 2004.
- [33] H. O. Smith, C. A. Hutchison, C. Pfannkoch, and J. C. Venter. Generating a synthetic genome by whole genome assembly: ϕ X174 bacteriophage from synthetic oligonucleotides. *Proc. Natl. Acad. Sci. U. S. A.*, 100(26):15440–15445, 2003.
- [34] S. I. van Kasteren, H. B. Kramer, H. H. Jensen, S. J. Campbell, J. Kirkpatrick, N. J. Oldham, D. C. Anthony, and B. G. Davis. Expanding the diversity of chemical protein modification allows post-translational mimicry. *Nature*, 446(7139):1105–1109, 2007.
- [35] B. G. Davis. Synthesis of glycoproteins. *Chem. Rev.*, 102(2):579–601, 2002.
- [36] O. Seitz. *Organic Synthesis Highlights V*. Organic Synthesis Highlights. Wiley-VCH Verlag GmbH, Weinheim, Germany, 2003.
- [37] N. Venkatesan and B. H. Kim. Peptide conjugates of oligonucleotides: Synthesis and applications. *Chem. Rev.*, 106(9):3712–3761, 2006.
- [38] T. S. Zatsepin, J. J. Turner, T. S. Oretskaya, and M. J. Gait. Conjugates of oligonucleotides and analogues with cell penetrating peptides as gene silencing agents. *Curr. Pharm. Des.*, 11(28):3639–3654, 2005.
- [39] C. H. Tung and S. Stein. Preparation and applications of peptide-oligonucleotide conjugates. *Bioconjugate Chem.*, 11(5):605–618, 2000.
- [40] T. J. Kelly, M. S. Wold, and J. Li. Initiation of viral DNA replication. *Adv. Virus. Res.*, 34:1–42, 1988.
- [41] N. Soh, D. Umeno, Z. L. Tang, M. Murata, and M. Maeda. Affinity precipitation separation of DNA binding protein using block conjugate composed of poly(N-isopropylacrylamide) grafted double-stranded DNA and double-stranded DNA containing a target sequence. *Anal. Sci.*, 18(12):1295–1299, 2002.
- [42] B. Perly, A. Douy, and B. Gallot. Synthesis of polybutadiene-benzylpoly-L-glutamate sequential copolymers and structural study of mesophases. *CR Acad. Sci. Paris*, 279C:1109, 1974.
- [43] Y. Yamashita, Y. Iwaya, and K. Ito. Polymerization of the NCA of methyl D-glutamate by telechelic polystyrene having glycol groups as active chain ends. *Makromol. Chem.*, 176:1207, 1975.
- [44] T. J. Deming. Methodologies for preparation of synthetic block copolypeptides: Materials with future promise in drug delivery. *Adv. Drug Delivery Res.*, 54(8):1145–1155, 2002.

- [45] H. A. Klok. Protein-inspired materials: Synthetic concepts and potential applications. *Angew. Chem., Int. Ed.*, 41(9):1509–1513, 2002.
- [46] D. W. P. M. Lowik, L. Ayres, J. M. Smeenk, and J. C. M. Van Hest. Synthesis of bio-inspired hybrid polymers using peptide synthesis and protein engineering. *Adv. Polym. Sci.*, 202:19–52, 2006.
- [47] T. J. Deming. Polypeptide and polypeptide hybrid copolymer synthesis via NCA polymerization. *Adv. Polym. Sci.*, 202:1–18, 2006.
- [48] J. C. M. van Hest. Biosynthetic-synthetic polymer conjugates. *Polym. Rev.*, 47(1):63–92, 2007.
- [49] H. G. Börner. Functional polymer-bioconjugates as molecular LEGO[®] bricks. *Macromol. Chem. Phys.*, 208(2):124–130, 2007.
- [50] H. G. Börner and H. Schlaad. Bioinspired functional block copolymers. *Soft Matter*, 3(4):394–408, 2007.
- [51] J. F. Lutz and H. G. Börner. Modern trends in polymer bioconjugates design. *Prog. Polym. Sci.*, 33(1):1–39, 2008.
- [52] M. A. Gauthier and H. A. Klok. Peptide/protein-polymer conjugates: Synthetic strategies and design concepts. *Chem. Commun.*, 23:2591–2611, 2008.
- [53] H. Schlaad. Solution properties of polypeptide-based copolymers. *Adv. Polym. Sci.*, 202:53–73, 2006.
- [54] H. A. Klok and S. Lecommandoux. Solid-state structure, organization and properties of peptide - synthetic hybrid block copolymers. *Adv. Polym. Sci.*, 202:75–111, 2006.
- [55] H. G. Börner. Strategies exploiting functions and self-assembly properties of bioconjugates for polymer and materials sciences. *Prog. Polym. Sci.*, 34(9):811–851, 2009.
- [56] C. M. Niemeyer. Semisynthetic DNA-protein conjugates for biosensing and nanofabrication. *Angew. Chem., Int. Ed.*, 49(7):1200–1216, 2010.
- [57] F. E. Alemdaroglu and A. Herrmann. DNA meets synthetic polymers – Highly versatile hybrid materials. *Org. Biomol. Chem.*, 5(9):1311–1320, 2007.
- [58] M. Lemaitre, B. Bayard, and B. Lebleu. Specific antiviral activity of a poly(L-lysine)-conjugated oligodeoxyribonucleotide sequence complementary to vesicular stomatitis-virus N-protein messenger-RNA initiation site. *Proc. Natl. Acad. Sci. U. S. A.*, 84(3):648–652, 1987.
- [59] J. P. Leonetti, G. Degols, P. Milhaud, C. Gagnor, M. Lemaitre, and B. Lebleu. Antiviral activity of antisense oligonucleotides linked to poly(L-lysine) - targets on genomic RNA and or messenger-RNA of vesicular stomatitis-virus. *Nucleos. Nucleot.*, 8(5-6):825–828, 1989.
- [60] J. P. Leonetti, B. Rayner, M. Lemaitre, C. Gagnor, P. G. Milhaud, J. L. Imbach, and B. Lebleu. Antiviral activity of conjugates between poly(L-lysine) and synthetic oligodeoxyribonucleotides. *Gene*, 72(1-2):323–332, 1988.

- [61] J. H. Jeong, S. H. Kim, S. W. Kim, and T. G. Park. Polyelectrolyte complex micelles composed of c-Raf antisense oligodeoxynucleotide-poly(ethylene glycol) conjugate and poly(ethylenimine): Effect of systemic administration on tumor growth. *Bioconjugate Chem.*, 16(4):1034–1037, 2005.
- [62] M. Oishi, Y. Nagasaki, K. Itaka, N. Nishiyama, and K. Kataoka. Lactosylated poly(ethylene glycol)-siRNA conjugate through acid-labile ss-thiopropionate linkage to construct pH-sensitive polyion complex micelles achieving enhanced gene silencing in hepatoma cells. *J. Am. Chem. Soc.*, 127(6):1624–1625, 2005.
- [63] Y. G. Takei, T. Aoki, K. Sanui, N. Ogata, T. Okano, and Y. Sakurai. Temperature-responsive bioconjugates. 1. Synthesis of temperature-responsive oligomers with reactive end groups and their coupling to biomolecules. *Bioconjugate Chem.*, 4(1):42–46, 1993.
- [64] R. B. Fong, Z. L. Ding, C. J. Long, A. S. Hoffman, and P. S. Stayton. Thermoprecipitation of streptavidin via oligonucleotide-mediated self-assembly with poly (N-isopropylacrylamide). *Bioconjugate Chem.*, 10(5):720–725, 1999.
- [65] J. H. Jeong and T. G. Park. Novel polymer-DNA hybrid polymeric micelles composed of hydrophobic poly(D,L-lactic-co-glycolic acid) and hydrophilic oligonucleotides. *Bioconjugate Chem.*, 12(6):917–923, 2001.
- [66] K. Lee, L. K. Povlich, and J. Kim. Label-free and self-signal amplifying molecular DNA sensors based on bioconjugated polyelectrolytes. *Adv. Func. Mat.*, 17:2580–2587, 2007.
- [67] M. Oishi, T. Hayama, Y. Akiyama, S. Takae, A. Harada, Y. Yarnasaki, F. Nagatsugi, S. Sasaki, Y. Nagasaki, and K. Kataoka. Supramolecular assemblies for the cytoplasmic delivery of antisense oligodeoxynucleotide: Polylon complex (PIC) micelles based on poly(ethylene glycol)-ss-oligodeoxynucleotide conjugate. *Biomacromolecules*, 6(5):2449–2454, 2005.
- [68] M. Oishi, F. Nagatsugi, S. Sasaki, Y. Nagasaki, and K. Kataoka. Smart polyion complex micelles for targeted intracellular delivery of pegylated antisense oligonucleotides containing acid-labile linkages. *ChemBioChem*, 6(4):718–725, 2005.
- [69] Z. Li, Y. Zhang, P. Fullhart, and C. A. Mirkin. Reversible and chemically programmable micelle assembly with DNA block-copolymer amphiphiles. *Nano Lett.*, 4(6):1055–1058, 2004.
- [70] F. E. Alemendaroglu, K. Ding, R. Berger, and A. Herrmann. DNA-templated synthesis in three dimensions: Introducing a micellar scaffold for organic reactions. *Angew. Chem., Int. Ed.*, 45(25):4206–4210, 2006.
- [71] F. E. Alemendaroglu, M. Safak, J. Wang, R. Berger, and A. Herrmann. DNA multiblock copolymers. *Chem. Commun.*, 13:1358–1359, 2007.
- [72] F. Teixeira, P. Rigler, and C. Veber-Nardin. Nucleo-copolymers: Oligonucleotide-based amphiphilic diblock copolymers. *Chem. Commun.*, 11:1130–1132, 2007.
- [73] C. Y. J. Yang, M. Pinto, K. Schanze, and W. H. Tan. Direct synthesis of an oligonucleotide-poly(phenylene ethynylene) conjugate with a precise one-to-one molecular ratio. *Angew. Chem., Int. Ed.*, 44(17):2572–2576, 2005.

- [74] M. Safak, F. E. Alemдарoglu, Y. Li, E. Ergen, and A. Herrmann. Polymerase chain reaction as an efficient tool for the preparation of block copolymers. *Adv. Mater.*, 19:1499–1505, 2007.
- [75] F. E. Alemдарoglu, W. Zhuang, L. Zophel, J. Wang, R. Berger, J. P. Rabe, and A. Herrmann. Generation of multiblock copolymers by PCR: Synthesis, visualization and nanomechanical properties. *Nano Lett.*, 9(10):3658–3662, 2009.
- [76] N. C. Seeman. DNA in a material world. *Nature*, 421(6921):427–431, 2003.
- [77] P. W. K. Rothmund. Folding DNA to create nanoscale shapes and patterns. *Nature*, 440(7082):297–302, 2006.
- [78] U. Feldkamp and C. M. Niemeyer. Rational design of DNA nanoarchitectures. *Angew. Chem., Int. Ed.*, 45(12):1856–1876, 2006.
- [79] C. Lin, Y. Liu, and H. Yan. Designer DNA nanoarchitectures. *Biochemistry*, 48(8):1663–1674, 2009. Lin, Chenxiang Liu, Yan Yan, Hao.
- [80] T. F. A. Greef and E. W. Meijer. Materials science – supramolecular polymers. *Nature*, 453(7192):171–173, 2008.
- [81] E. A. Fogleman, W. C. Yount, J. Xu, and S. L. Craig. Modular, well-behaved reversible polymers from DNA-based monomers. *Angew. Chem., Int. Ed.*, 41(21):4026–4028, 2002.
- [82] Z. X. Deng, S. H. Lee, and C. D. Mao. DNA as nanoscale building blocks. *J. Nanosci. Nanotech.*, 5(12):1954–1963, 2005.
- [83] N. C. Seeman. An overview of structural DNA nanotechnology. *Mol. Biotechnol.*, 37:246–257, 2007.
- [84] K. Ding, F. E. Alemдарoglu, M. Börsch, R. Berger, and A. Herrmann. Engineering the structural properties of DNA block copolymer micelles by molecular recognition. *Angew. Chem., Int. Ed.*, 46(7):1172–1175, 2007.
- [85] F. E. Alemдарoglu, J. Wang, M. Börsch, R. Berger, and A. Herrmann. Enzymatic control of the size of DNA block copolymer nanoparticles. *Angew. Chem., Int. Ed.*, 47(5):974–976, 2008.
- [86] N. Cottenye, F. Teixeira, A. Ponche, G. Reiter, K. Anselme, W. Meier, L. Ploux, and C. Vebert-Nardin. Oligonucleotide nanostructured surfaces: Effect on escherichia coli curli expression. *Macromol. Biosci.*, 8(12):1161–1172, 2008.
- [87] X. Y. Li and D. R. Liu. DNA-templated organic synthesis: Nature’s strategy for controlling chemical reactivity applied to synthetic molecules. *Angew. Chem., Int. Ed.*, 43(37):4848–4870, 2004.
- [88] F. Cavalieri, A. Postma, L. Lee, and F. Caruso. Assembly and functionalization of DNA-polymer microcapsules. *ACS Nano*, 3(1):234–240, 2009.
- [89] C. H. Fan, S. Wang, J. W. Hong, G. C. Bazan, K. W. Plaxco, and A. J. Heeger. Beyond superquenching: Hyper-efficient energy transfer from conjugated polymers to gold nanoparticles. *Proc. Natl. Acad. Sci. U. S. A.*, 100(11):6297–6301, 2003.

-
- [90] A. Jaschke, J. P. Furste, D. Cech, and V. A. Erdmann. Automated incorporation of polyethylene-glycol into synthetic oligonucleotides. *Tetrahedron Lett.*, 34(2):301–304, 1993.
- [91] C. J. Langer. CT-2103: Emerging utility and therapy for solid tumours. *Expert. Opin. Inv. Drug.*, 13(11):1501–1508, 2004.
- [92] The EyeTech Study Group. Preclinical and phase 1A clinical evaluation of an anti-VEGF pegylated aptamer (EYE001) for the treatment of exudative age-related macular degeneration. *Retina*, 22:143–152, 2002.
- [93] J. H. Jeong, S. W. Kim, and T. G. Park. A new antisense oligonucleotide delivery system based on self-assembled ODN-PEG hybrid conjugate micelles. *J. Contr. Rel.*, pages 183–191, 2003.
- [94] S. H. Kim, J. H. Jeong, S. H. Lee, S. W. Kim, and T. G. Park. Local and systemic delivery of VEGF siRNA using polyelectrolyte complex micelles for effective treatment of cancer. *J. Contr. Rel.*, 129(2):107–116, 2008.
- [95] F. E. Alemdaroglu, C. N. Alemdaroglu, P. Langguth, and A. Herrmann. DNA block copolymer micelles – A combinatorial tool for cancer nanotechnology. *Adv. Mater.*, 20:899–902, 2008.
- [96] F. E. Alemdaroglu, C. N. Alemdaroglu, P. Langguth, and A. Herrmann. Shape dependent cellular uptake of DNA nanoparticles. *Macromol. Rapid Commun.*, 29:326–329, 2008.
- [97] K. Minagawa, Y. Matsuzawa, K. Yoshikawa, Y. Masubuchi, M. Matsumoto, M. Doi, C. Nishimura, and M. Maeda. Change of the higher-order structure of DNA induced by the complexation with intercalating synthetic-polymer, as is visualized by fluorescence microscopy. *Nucleic Acids Res.*, 21(1):37–40, 1993.
- [98] M. Maeda, C. Nishimura, A. Inenaga, and M. Takagi. Modification of DNA with poly(N-isopropylacrylamide) for thermally-induced affinity separation. *React. Polym.*, 21(1-2):27–35, 1993.
- [99] M. Maeda, C. Nishimura, D. Umeno, and M. Takagi. Psoralen-containing vinyl monomer for conjugation of double-helical DNA with vinyl-polymers. *Bioconjugate Chem.*, 5(6):527–531, 1994.
- [100] D. Umeno and M. Maeda. Poly(N-isopropylacrylamide) carrying double-stranded DNA for affinity separation of genotoxins. *Anal. Sci.*, 13(4):553–556, 1997.
- [101] D. Umeno, M. Kawasaki, and M. Maeda. Photolithographic coating of polymers on DNA as an approach for construction of nano-structures. *Supramol. Sci.*, 5(3-4):427–431, 1998.
- [102] S. Taira and K. Yokoyama. Self-assembly DNA-conjugated polymer for detection of single nucleotide polymorphism. *Biotechnol. and Bioeng.*, 88(1):35–41, 2004.
- [103] S. Nagahara and T. Matsuda. Hydrogel formation via hybridization of oligonucleotides derivatized in water-soluble vinyl polymers. *Polym. Gels Netw.*, 4(2):111–127, 1996.

- [104] G. Degols, J. P. Leonetti, C. Gagnor, M. Lemaitre, and B. Lebleu. Antiviral activity and possible mechanisms of action of oligonucleotides-poly(L-lysine) conjugates targeted to vesicular stomatitis-virus messenger-RNA and genomic RNA. *Nucleic Acids Res.*, 17(22):9341–9350, 1989.
- [105] K. J. Watson, S. J. Park, J. H. Im, S. T. Nguyen, and C. A. Mirkin. DNA-block copolymer conjugates. *J. Am. Chem. Soc.*, 123(23):5592–5593, 2001.
- [106] J. M. Gibbs, S. J. Park, D. R. Anderson, K. J. Watson, C. A. Mirkin, and S. T. Nguyen. Polymer-DNA hybrids as electrochemical probes for the detection of DNA. *J. Am. Chem. Soc.*, 127(4):1170–1178, 2005.
- [107] C. Chaix, C. Minard-Basquin, T. Delair, C. Pichot, and B. Mandrand. Oligonucleotide synthesis on maleic anhydride copolymers covalently bound to silica spherical support and characterization of the obtained conjugates. *J. Appl. Polym. Sci.*, 70(12):2487–2497, 1998.
- [108] C. Minard-Basquin, C. Chaix, and C. Pichot. The use of oligonucleotide-maleic anhydride copolymer conjugates in nucleic acid diagnostic assays: Effect of the number of oligonucleotides per polymer on test sensitivity improvement. *Nucleos. Nucleot. Nucl.*, 20(4-7):895–899, 2001.
- [109] T. Mori, D. Umeno, and M. Maeda. Sequence-specific affinity precipitation of oligonucleotide using poly(N-isopropylacrylamide)-oligonucleotide conjugate. *Biotechnol. and Bioeng.*, 72(3):261–268, 2001.
- [110] D. C. Lin, B. Yurke, and N. A. Langrana. Inducing reversible stiffness changes in DNA-crosslinked gels. *J. Mater. Res.*, 20(6):1456–1464, 2005.
- [111] D. C. Lin, B. Yurke, and N. A. Langrana. Mechanical properties of a reversible, DNA-crosslinked polyacrylamide hydrogel. *J. Biomech. Eng-T. Asme*, 126(1):104–110, 2004.
- [112] M. Murata, W. Kaku, T. Anada, Y. Sato, M. Maeda, and Y. Katayama. Temperature-dependent regulation of antisense activity using a DNA/poly(N-isopropylacrylamide) conjugate. *Chem. Lett.*, 32(11):986–987, 2003.
- [113] M. Murata, W. Kaku, T. Anada, N. Soh, Y. Katayama, and M. Maeda. Thermo responsive DNA/polymer conjugate for intelligent antisense strategy. *Chem. Lett.*, 32(3):266–267, 2003.
- [114] M. Murata, T. Yamasaki, M. Maeda, and Y. Katayama. An artificial regulation system for DNA-transcription: Learning from prokaryotic organisms. *Chem. Lett.*, 33(1):4–5, 2004.
- [115] D. J. Caruana and A. Heller. Enzyme-amplified amperometric detection of hybridization and of a single base pair mutation in an 18-base oligonucleotide on a 7 μm -diameter microelectrode. *J. Am. Chem. Soc.*, 121(4):769–774, 1999.
- [116] K. Lee, J.-M. Rouillard, T. Pham, E. Gulari, and J. Kim. Signal-amplifying conjugated polymer-DNA hybrid chips. *Angew. Chem., Int. Ed.*, 46:4667–4670, 2007.
- [117] H. KorriYousoufi, F. Garnier, P. Srivastava, P. Godillot, and A. Yassar. Toward bioelectronics: Specific DNA recognition based on an oligonucleotide-functionalized polypyrrole. *J. Am. Chem. Soc.*, 119(31):7388–7389, 1997.

-
- [118] T. Livache, A. Roget, E. Dejean, C. Barthet, G. Bidan, and R. Teoule. Preparation of a DNA matrix via an electrochemically directed copolymerization of pyrrole and oligonucleotides bearing a pyrrole group. *Nucleic Acids Res.*, 22(15):2915–2921, 1994.
- [119] T. Livache, B. Fouque, A. Roget, J. Marchand, G. Bidan, R. Teoule, and G. Mathis. Polypyrrole DNA chip on a silicon device: Example of hepatitis C virus genotyping. *Anal. Biochem.*, 255(2):188–194, 1998.
- [120] A. Kudlay, J. M. Gibbs, G. C. Schatz, S. T. Nguyen, and M. O. de la Cruz. Sharp melting of polymer-DNA hybrids: An associative phase separation approach. *J. Phys. Chem. B*, 111(7):1610–1619, 2007.
- [121] S. Y. Park, J. M. Gibbs-Davis, S. T. Nguyen, and G. C. Schatz. Sharp melting in DNA-linked nanostructure systems: Thermodynamic models of DNA-linked polymers. *J. Phys. Chem. B*, 111:8785–8791, 2007.
- [122] J. J. Storhoff, R. Elghanian, R. C. Mucic, C. A. Mirkin, and R. L. Letsinger. One-pot colorimetric differentiation of polynucleotides with single base imperfections using gold nanoparticle probes. *J. Am. Chem. Soc.*, 120(9):1959–1964, 1998.
- [123] R. C. Jin, G. S. Wu, Z. Li, C. A. Mirkin, and G. C. Schatz. What controls the melting properties of DNA-linked gold nanoparticle assemblies? *J. Am. Chem. Soc.*, 125(6):1643–1654, 2003.
- [124] N. L. Rosi and C. A. Mirkin. Nanostructures in biodiagnostics. *Chem. Rev.*, 105(4):1547–1562, 2005.
- [125] T. Mori and M. Maeda. Stability change of DNA-carrying colloidal particle induced by hybridization with target DNA. *Polym. J.*, 34(8):624–628, 2002.
- [126] C. Minard-Basquin, C. Chaix, C. Pichot, and B. Mandrand. Oligonucleotide-polymer conjugates: Effect of the method of synthesis on their structure and performance in diagnostic assays. *Bioconjugate Chem.*, 11(6):795–804, 2000.
- [127] C. Minard-Basquin, C. Chaix, F. D’Agosto, M. T. Charreyre, and C. Pichot. Oligonucleotide synthesis onto poly(N-acryloylmorpholine-co-N-acryloxysuccinimide): Assessment of the resulting conjugates in a DNA sandwich hybridization test. *J. Appl. Polym. Sci.*, 92(6):3784–3795, 2004.
- [128] B. Bordier, M. Peralaepe, G. Degols, B. Lebleu, S. Litvak, L. Sarihcottin, and C. Helene. Sequence-specific inhibition of human-immunodeficiency-virus (HIV) reverse transcription by antisense oligonucleotides – comparative-study in cell-free assays and in HIV-infected cells. *Proc. Natl. Acad. Sci. U. S. A.*, 92(20):9383–9387, 1995.
- [129] M. Murata, W. Kaku, T. Anada, Y. Sato, T. Kano, M. Maeda, and Y. Katayama. Novel DNA/polymer conjugate for intelligent antisense reagent with improved nuclease resistance. *Bioorg. Med. Chem. Lett.*, 13(22):3967–3970, 2003.
- [130] T. L. Schlick, Z. Ding, E. W. Kovacs, and M. B. Francis. Dual-surface modification of the tobacco mosaic virus. *J. Am. Chem. Soc.*, 127(11):3718–23, 2005.

- [131] I. W. Hamley. Nanotechnology with soft materials. *Angew. Chem., Int. Ed.*, 42(15):1692–1712, 2003.
- [132] P. Singh, M. J. Gonzalez, and M. Manchester. Viruses and their uses in nanotechnology. *Drug Develop Res.*, 67(1):23–41, 2006.
- [133] T. Douglas and M. Young. Viruses: Making friends with old foes. *Science*, 312(5775):873–875, 2006.
- [134] M. Young, D. Willits, M. Uchida, and T. Douglas. Plant viruses as biotemplates for materials and their use in nanotechnology. *Ann. Rev. Phytopathol.*, 46:361–384, 2008.
- [135] G. Destito, A. Schneemann, and M. Manchester. Biomedical nanotechnology using virus-based nanoparticles. In *Viruses and Nanotechnology*, volume 327 of *Current Topics in Microbiology and Immunology*, pages 95–122. Springer, 2009.
- [136] A. de la Escosura, R. J. M. Nolte, and J. J. L. M. Cornelissen. Viruses and protein cages as nanocontainers and nanoreactors. *J. Mater. Chem.*, 19(16):2274–2278, 2009.
- [137] E. Strable and M. G. Finn. Chemical modification of viruses and virus-like particles. *Viruses and Nanotechnology*, 327:1–21, 2009.
- [138] Y. F. Hu, R. Zandi, A. Anavitarte, C. M. Knobler, and W. M. Gelbart. Packaging of a polymer by a viral capsid: The interplay between polymer length and capsid size. *Biophys. J.*, 94(4):1428–1436, 2008.
- [139] L. O. Liepold, J. Revis, M. Allen, L. Oltrogge, M. Young, and T. Douglas. Structural transitions in Cowpea chlorotic mottle virus (CCMV). *Phys. Biol.*, 2(4):S166–S172, 2005.
- [140] F. D. Sikkema, M. Comellas-Aragones, R. G. Fokkink, B. J. M. Verduin, J. J. L. M. Cornelissen, and R. J. M. Nolte. Monodisperse polymer-virus hybrid nanoparticles. *Org. Biomol. Chem.*, 5(1):54–57, 2007.
- [141] I. J. Minten, Y. J. Ma, M. A. Hempenius, G. J. Vancso, R. J. M. Nolte, and J. J. L. M. Cornelissen. CCMV capsid formation induced by a functional negatively charged polymer. *Org. Biomol. Chem.*, 7(22):4685–4688, 2009.
- [142] M. Comellas-Aragones, H. Engelkamp, V. I. Claessen, N. A. J. M. Sommerdijk, A. E. Rowan, P. C. M. Christianen, J. C. Maan, B. J. M. Verduin, J. J. L. M. Cornelissen, and R. J. M. Nolte. A virus-based single-enzyme nanoreactor. *Nat. Nanotechnol.*, 2(10):635–639, 2007.
- [143] Y. Ren, S. M. Wong, and L. Y. Lim. Folic acid-conjugated protein cages of a plant virus: A novel delivery platform for doxorubicin. *Bioconjugate Chem.*, 18(3):836–843, 2007.
- [144] C. Xu, P. Taylor, M. Ersoz, P. D. I. Fletcher, and V. N. Paunov. Microcontact printing of DNA-surfactant arrays on solid substrates. *J. Mater. Chem.*, 13(12):3044–3048, 2003.
- [145] E. Strable, J. E. Johnson, and M. G. Finn. Natural nanochemical building blocks: Icosahedral virus particles organized by attached oligonucleotides. *Nano Lett.*, 4(8):1385–1389, 2004.

-
- [146] S. Henke, A. Rohmann, W. M. Bertling, T. Dingermann, and A. Zimmer. Enhanced in vitro oligonucleotide and plasmid DNA transport by VP1 virus-like particles. *Pharm. Res.*, 17(9):1062–1070, 2000.
- [147] J. J. Bujarski. *Bromovirus isolation and RNA extraction*. Methods in Molecular Biology. Springer, 1998.
- [148] F. Delie, R. Gurny, and A. Zimmer. Fluorescence correlation spectroscopy for the characterisation of drug delivery systems. *Biol. Chem.*, 382(3):487–490, 2001.
- [149] C. Gosse, A. Boutorine, I. Aujard, M. Chami, A. Kononov, E. Cogne-Laage, J. F. Allemand, J. Li, and L. Jullien. Micelles of lipidoligonucleotide conjugates: Implications for membrane anchoring and base pairing. *J. Phys. Chem. B*, 108(20):6485–6497, 2004.
- [150] M. L. Adams, A. Lavasanifar, and G. S. Kwon. Amphiphilic block copolymers for drug delivery. *J. Pharm. Sci.*, 92(1):1343–1355, 2003.
- [151] V. P. Torchilin. Structure and design of polymeric surfactant-based drug delivery systems. *J. Control. Release*, 73(2–3):137–172, 2001.
- [152] P. Alexandridis, J. F. Holzwarth, and T. A. Hatton. Micellization of poly(ethylene oxide)-poly(propylene oxide)-poly(ethylene oxide) triblock copolymers in aqueous-solutions - thermodynamics of copolymer association. *Macromolecules*, 27(9):2414–2425, 1994.
- [153] A. V. Kabanov, E. V. Batrakova, and V. Y. Alakhov. Pluronic™ block copolymers as novel polymer therapeutics for drug and gene delivery. *J. Control. Release*, 82(2–3):189–212, 2002.
- [154] D. Cohn, H. Sagiv, Al. Benyamin, and G. Lando. Engineering thermoresponsive polymeric nanoshells. *Biomaterials*, 30(19):3289–3296, 2009.
- [155] P. Petrov, M. Bozukov, and C. B. Tsvetanov. Innovative approach for stabilizing poly(ethylene oxide)-*b*-poly(propylene oxide)-*b*-poly(ethylene oxide) micelles by forming nano-sized networks in the micelle. *J. Mater. Chem.*, 15(14):1481–1486, 2005.
- [156] Z. Yang, G. Sahay, S. Sriadibhatla, and A. V. V. Kabanov. Amphiphilic block copolymers enhance cellular uptake and nuclear entry of polyplex-delivered DNA. *Bioconjugate Chem.*, 19(10):1987–1994, 2008.
- [157] M. Kwak and A. Herrmann. Nucleic acid-organic polymer hybrid materials: Synthesis, superstructures and applications. *Angew. Chem., Int. Ed.*, 2010.
- [158] Y. Ding, Y. Wang, and R. Guo. Aggregation properties of amphiphilic poly(ethylene oxide)-poly(propylene oxide)-poly(ethylene oxide) block copolymer studied by cyclic voltammetry. *J. Surfactants Deterg.*, 7(4):379–385, 2004.
- [159] M. Y. Kozlov, N. S. Melik-Nubarov, E. V. Batrakova, and A. V. Kabanov. Relationship between Pluronic™ block copolymer structure, critical micellization concentration and partitioning coefficients of low molecular mass solutes. *Macromolecules*, 33(9):3305–3313, 2000.
- [160] P. Petrov, M. Bozukov, M. Burkhardt, S. Muthukrishnan, A. H. E. Müller, and C. B. B. Tsvetanov. Stabilization of polymeric micelles with a mixed poly(ethylene oxide)/poly(2-hydroxyethyl methacrylate) shell by formation of poly(pentaerythritol tetraacrylate) nanonetworks within the micelles. *J. Mater. Chem.*, 16(22):2192–2199, 2006.

- [161] S. A. Claridge, H. W. Liang, R. S. Basu, J. M. J. Frechet, and A. P. Alivisatos. Isolation of discrete nanoparticle – DNA conjugates for plasmonic applications. *Nano Lett.*, 8(4):1202–1206, 2008.
- [162] R. L. Wolin, H. Venkatesan, L. Tang, A. Santillán, T. Barclay, S. Wilson, D. H. Lee, and T. W. Lovenberg. Novel glycine transporter type-2 reuptake inhibitors. part 1: α -Amino acid derivatives. *Bioorgan. Med. Chem.*, 12(16):4477–4492, 2004.
- [163] Y. Su, J. Wang, and H. Liu. FT-IR spectroscopic investigation of effects of temperature and concentration on PEO-PPO-PEO block copolymer properties in aqueous solutions. *Macromolecules*, 35(16):6426–6431, 2002.
- [164] V. Kotzabasakis, E. Georgopoulou, M. Pitsikalis, N. Hadjichristidis, and G. Papadogianakis. Catalytic conversions in aqueous media: A novel and efficient hydrogenation of polybutadiene-1,4-block-poly(ethylene oxide) catalyzed by rh/tppts complexes in mixed micellar nanoreactors. *J. Mol. Catal. A-Chem.*, 231(1-2):93–101, 2005.
- [165] Paulo S. Kuhn, Yan Levin, and Marcia C. Barbosa. Charge inversion in DNA-amphiphile complexes: possible application to gene therapy. *Physica A*, 274:8–18, 1999.
- [166] J.A Wolff, J.E Hagstrom, S.D Monahan, V.Budker, D.B Rozema, and P.M Slattum. Compositions and methods for drug delivery using amphiphile binding molecules, 2004.
- [167] Y. Kakizawa and K. Kataoka. Block copolymer micelles for delivery of gene and related compounds. *Adv. Drug Delivery Rev.*, 54(2):203–222, 2002.
- [168] K. Kataoka, A. Harada, and Y. Nagasaki. Block copolymer micelles for drug delivery: Design, characterization and biological significance. *Adv. Drug Delivery Rev.*, 47(1):113–131, 2001.
- [169] R. Savic, L. B. Luo, A. Eisenberg, and D. Maysinger. Micellar nanocontainers distribute to defined cytoplasmic organelles. *Science*, 300(5619):615–618, 2003.
- [170] T. Gore, Y. Dori, Y. Talmon, M. Tirrell, and H. Bianco-Peled. Self-assembly of model collagen peptide amphiphiles. *Langmuir*, 17(17):5352–5360, 2001.
- [171] Y. C. Yu, P. Berndt, M. Tirrell, and G. B. Fields. Self-assembling amphiphiles for construction of protein molecular architecture. *J. Am. Chem. Soc.*, 118(50):12515–12520, 1996.
- [172] M. G. J. ten Cate and H. G. Börner. Synthesis of ABC-triblock peptide-polymer conjugates for the positioning of peptide segments within block copolymer aggregates. *Macromol. Chem. Phys.*, 208(13):1437–1446, 2007.
- [173] J. I. Sheu and E. Y. Sheu. Characterization of DNA degradation using direct current conductivity and dynamic dielectric relaxation techniques. *AAPS Pharmscitech.*, 7(2):E36, 2006.
- [174] M. Kwak, A. J. Musser, J. Lee, and A. Herrmann. DNA-functionalised blend micelles: mix and fix polymeric hybrid nanostructures. *Chem. Commun.*, 46:4935–4937, 2010.
- [175] H. Rosemeyer. Nucleolipids: Natural occurrence, synthesis, molecular recognition, and supramolecular assemblies as potential precursors of life and bioorganic materials. *Chem. Biodiversity*, 2(8):977–1062, 2005.

-
- [176] U. Rädler, C. Heiz, P. L. Luisi, and R. Tampe. Base-pair formation of self-organizing RNA amphiphiles within two dimensions. *Langmuir*, 14(23):6620–6624, 1998.
- [177] P. Baglioni and D. Berti. Self assembly in micelles combining stacking and H-bonding. *Curr. Opin. Colloid Interface Sci.*, 8(1):55–61, 2003.
- [178] D. Berti, P. Barbaro, I. Bucci, and P. Baglioni. Molecular recognition through H-bonding in micelles formed by dioctylphosphatidyl nucleosides. *J. Phys. Chem. B*, 103(23):4916–4922, 1999.
- [179] G. Zandomeneghi, P. L. Luisi, L. Mannina, and A. Segre. NMR study of micelles formed by monoalkylphosphoryl nucleosides. *Helvetica Chimica Acta*, 84(12):3710–3725, 2001.
- [180] L. Ötvös, J. Sági, G. Sági, and A. Szemző. Base modified oligodeoxynucleotides. II. Increase of stability to nucleases by 5-alkyl-, 5-(1-alkenyl)- and 5-(1-alkynyl)-pyrimidines. *Nucleos. Nucleot.*, 18(9):1929–1933, 1999.
- [181] F. Seela and M. Zulauf. Oligonucleotides containing 7-deazaadenines: The influence of the 7-substituent chain length and charge on the duplex stability. *Helvetica Chimica Acta*, 82(11):1878–1898, 1999.
- [182] I. Pfeiffer and F. Höök. Bivalent cholesterol-based coupling of oligonucleotides to lipid membrane assemblies. *J. Am. Chem. Soc.*, 126(33):10224–10225, 2004.
- [183] Y. H. M. Chan, B. van Lengerich, and S. G. Boxer. Effects of linker sequences on vesicle fusion mediated by lipid-anchored DNA oligonucleotides. *Proc. Natl. Acad. Sci. U. S. A.*, 106(4):979–984, 2009.
- [184] H. P. Liu, Z. Zhu, H. Z. Kang, Y. R. Wu, K. Sefan, and W. H. Tan. DNA-based micelles: Synthesis, micellar properties and size-dependent cell permeability. *Chem. Eur. J.*, 16(12):3791–3797, 2010.
- [185] U. Jakobsen, A. C. Simonsen, and S. Vogel. DNA-controlled assembly of soft nanoparticles. *J. Am. Chem. Soc.*, 130(32):10462–10463, 2008.
- [186] M. Kwak, I. J. Minten, D. M. Anaya, A. J. Musser, M. Brasch, R. J. M. Nolte, K. Müllen, J. J. L. M. Cornelissen, and A. Herrmann. Virus-like particles templated by DNA micelles: A general method for loading virus nanocarriers. *J. Am. Chem. Soc.*, 132(23):7834–7835, 2010.
- [187] X. M. Liang, G. Z. Mao, and K. Y. S. Ng. Probing small unilamellar EggPC vesicles on mica surface by atomic force microscopy. *Colloids Surf., B*, 34(1):41–51, 2004.
- [188] C. M. Hoo, N. Starostin, P. West, and M. L. Mecartney. A comparison of atomic force microscopy (AFM) and dynamic light scattering (DLS) methods to characterize nanoparticle size distributions. *J. Nanopart. Res.*, 10:89–96, 2008.
- [189] J.C Leroux and A.S Benahmed. Polymeric micelle compositions, US Patent 6,338,859, 2002.
- [190] C. Tanford. Theory of micelle formation in aqueous-solutions. *J. Phys. Chem.*, 78(24):2469–2479, 1974.

- [191] C. Tanford. Thermodynamics of micelle formation – Prediction of micelle size and size distribution. *Proc. Natl. Acad. Sci. U. S. A.*, 71(5):1811–1815, 1974.
- [192] Lo Chun-Liang, Lin Sheng-Jie, Tsai Hsieh-Chih, Chan Wei-Hsiang, Tsai Cheng-Hung, C. H. D. Cheng, and Hsiue Ging-Ho. Mixed micelle systems formed from critical micelle concentration and temperature-sensitive diblock copolymers for doxorubicin delivery. *Biomaterials*, 30(23-24):3961–3970, 2009.
- [193] P. Sehgal, O. Kosaka, H. Doe, and D. E. Otzen. Interaction and stability of mixed micelle and monolayer of nonionic and cationic surfactant mixtures. *J. Dispers. Sci. Technol.*, 30(7):1050–1058, 2009.
- [194] G. Kwon, M. Naito, M. Yokoyama, T. Okano, Y. Sakurai, and K. Kataoka. Micelles based on AB block copolymers of poly(ethylene oxide) and poly(beta-benzyl-L-aspartate). *Langmuir*, 9(4):945–949, 1993.
- [195] M. Wilhelm, C. L. Zhao, Y. C. Wang, R. L. Xu, M. A. Winnik, J. L. Mura, G. Riess, and M. D. Croucher. Polymer micelle formation. 3. Poly(styrene-ethylene oxide) block copolymer micelle formation in water – A fluorescence probe study. *Macromolecules*, 24(5):1033–1040, 1991.
- [196] K. Kalyanasundaram and J. K. Thomas. Solvent-dependent fluorescence of pyrene-3-carboxaldehyde and its applications in estimation of polarity at micelle-water interfaces. *J. Phys. Chem.*, 81(23):2176–2180, 1977.
- [197] T. Inoue, G. H. Chen, K. Nakamae, and A. S. Hoffman. An AB block copolymer of oligo(methyl methacrylate) and poly(acrylic acid) for micellar delivery of hydrophobic drugs. *J. Control. Release*, 51(2-3):221–229, 1998.
- [198] Y. Y. Li, X. Z. Zhang, J. L. Zhu, H. Cheng, S. X. Cheng, and R. X. Zhuo. Self-assembled, thermoresponsive micelles based on triblock PMMA-b-PNIPAAm-b-PMMA copolymer for drug delivery. *Nanotechnology*, 18(21):7, 2007.
- [199] X. Jin, S. Yue, K. S. Wells, and V. L. Singer. SYBR Green™ I – a new fluorescent dye optimized for detection of picogram amounts of DNA in gels. *Biophys. J.*, 66(2):A159–A159, 1994.
- [200] T. Maruyama, T. Takata, H. Ichinose, L. C. Park, N. Kamaiya, and M. Goto. Simple detection of point mutations in DNA oligonucleotides using SYBR Green™ I. *Biotechnol. Lett.*, 25(19):1637–1641, 2003.
- [201] R. S. Tuma, M. P. Beaudet, X. K. Jin, L. J. Jones, C. Y. Cheung, S. Yue, and V. L. Singer. Characterization of SYBR Gold nucleic acid gel stain: A dye optimized for use with 300-nm ultraviolet transilluminators. *Anal. Biochem.*, 268(2):278–288, 1999.
- [202] A. E. Kiltie and A. J. Ryan. Sybr green i staining of pulsed field agarose gels is a sensitive and inexpensive way of quantitating DNA double-strand breaks in mammalian cells. *Nucleic Acids Res.*, 25(14):2945–2946, 1997.
- [203] J. Skeidsvoll and P. M. Ueland. Analysis of double-stranded DNA by capillary electrophoresis with laser-induced fluorescence detection using the monomeric dye SYBR Green™ I. *Anal. Biochem.*, 231(2):359–365, 1995.

- [204] U. De Rossi, J. Moll, J. Kriwanek, and S. Daehne. Influence of the n-alkyl chain length on the J-aggregation behavior of a cyanine dye. *J. Fluoresc.*, 4:53–55, 1994.
- [205] D. A. Barawkar, K. G. Rajeev, V. A. Kumar, and K. N. Ganesh. Triplex formation at physiological pH by 5-Me-dC-N⁴-(spermine) [X] oligodeoxynucleotides: Non protonation of N3 in X of X*G:C triad and effect of base mismatch ionic strength on triplex stabilities. *Nucleic Acids Res.*, 24(7):1229–1237, 1996.
- [206] K. G. Rajeev, V. R. Jadhav, and K. N. Ganesh. Triplex formation at physiological pH: Comparative studies on DNA triplexes containing 5-Me-dC tethered at N⁴ with spermine and tetraethylethylenediamine. *Nucleic Acids Res.*, 25(21):4187–4193, 1997.
- [207] S. W. Kowalczyk, M. W. Tuijtel, S. P. Donkers, and C. Dekker. Unraveling single-stranded DNA in a solid-state nanopore. *Nano Lett.*, 10(4):1414–1420, 2010.
- [208] Y Lu, B Weers, and N.C. Stellwagen. DNA persistence length revisited. *Biopolymers*, 61:261–275, 2001.
- [209] B. Tinland, A. Pluen, J. Sturm, and G. Weill. Persistence length of single-stranded DNA. *Macromolecules*, 30(19):5763–5765, 1997.
- [210] L. C. Palmer and S. I. Stupp. Molecular self-assembly into one-dimensional nanostructures. *Acc. Chem. Res.*, 41(12):1674–1684, 2008.
- [211] T. Dwars, E. Paetzold, and G. Oehme. Reactions in micellar systems. *Angew. Chem., Int. Ed.*, 44(44):7174–7199, 2005.
- [212] T. Liu, J. Tang, M. M. Han, and L. Jiang. A novel microgravimetric DNA sensor with high sensitivity. *Biochem. Biophys. Res. Commun.*, 304(1):98–100, 2003.
- [213] W. Fritzsche. DNA-gold conjugates for the detection of specific molecular interactions. *J. Biotechnol.*, 82(1):37–46, 2001.
- [214] P. Hazarika, B. Ceyhan, and C. M. Niemeyer. Sensitive detection of proteins using difunctional DNA-gold nanoparticles. *Small*, 1(8-9):844–848, 2005.
- [215] N. K. Navani and Y. F. Li. Nucleic acid aptamers and enzymes as sensors. *Current Opinion in Chemical Biology*, 10(3):272–281, 2006.
- [216] J. W. Liu and Y. Lu. Colorimetric biosensors based on DNAzyme-assembled gold nanoparticles. *J. Fluoresc.*, 14(4):343–354, 2004.
- [217] J. Wang, F. E. Alemдарoglu, D. K. Prusty, A. Herrmann, and R. Berger. In-situ visualization of the enzymatic growth of surface-immobilized DNA block copolymer micelles by scanning force microscopy. *Macromolecules*, 41(8):2914–2919, 2008.
- [218] S. Forster, V. Abetz, and A. H. E. Muller. Polyelectrolyte block copolymer micelles. *Polyelectrolytes with Defined Molecular Architecture II*, 166:173–210, 2004.
- [219] O. Krichevsky and G. Bonnet. Fluorescence correlation spectroscopy: The technique and its applications. *Rep. Prog. Phys.*, 65(2):251–297, 2002.

- [220] A. Cao. Light scattering. Recent applications. *Anal. Lett.*, 36(15):3185–3225, 2003.
- [221] H. Cohen, T. Sapir, N. Borovok, T. Molotsky, R. Di Felice, A. B. Kotlyar, and D. Porath. Polarizability of G4-DNA observed by electrostatic force microscopy measurements. *Nano Lett.*, 7(4):981–986, 2007.
- [222] T. S. Jespersen and J. Nygard. Probing induced defects in individual carbon nanotubes using electrostatic force microscopy. *Appl. Phys. A-Mater.*, 88(2):309–313, 2007.
- [223] I. Medalsy, O. Dgany, M. Sowwan, H. Cohen, A. Yukashevskaya, S. G. Wolf, A. Wolf, A. Koster, O. Almog, I. Marton, Y. Pouny, A. Altman, O. S. Hoseyov, and D. Porath. SP1 protein-based nanostructures and arrays. *Nano Lett.*, 8(2):473–477, 2008.
- [224] C. Staii, A. T. Johnson, and N. J. Pinto. Quantitative analysis of scanning conductance microscopy. *Nano Lett.*, 4(5):859–862, 2004.
- [225] H. Cohen, C. Nogues, R. Naaman, and D. Porath. Direct measurement of electrical transport through single DNA molecules of complex sequence. *Proc. Natl. Acad. Sci. U. S. A.*, 102(33):11589–11593, 2005.
- [226] C. Nogues, S. R. Cohen, S. Daube, N. Apter, and R. Naaman. Sequence dependence of charge transport properties of DNA. *J. Phys. Chem. B*, 110(18):8910–8913, 2006.
- [227] X. T. Shuai, H. Ai, N. Nasongkla, S. Kim, and J. M. Gao. Micellar carriers based on block copolymers of poly(ϵ -caprolactone) and poly(ethylene glycol) for doxorubicin delivery. *J. Control. Release*, 98(3):415–426, 2004.
- [228] I. Horcas, R. Fernandez, J. M. Gomez-Rodriguez, J. Colchero, J. Gomez-Herrero, and A. M. Baro. Wsxn: A software for scanning probe microscopy and a tool for nanotechnology. *Rev. Sci. Instrum.*, 78(1), 2007.
- [229] M. Hersam. Progress towards monodisperse single-walled carbon nanotubes. *Nat. Nanotechnol.*, 3(7):387–394, 2008.
- [230] D. Tasis, N. Tagmatarchis, A. Bianco, and M. Prato. Chemistry of carbon nanotubes. *Chem. Rev.*, 106(3):1105–1136, 2006.
- [231] M. Tchoul, W. Ford, G. Lolli, D. Resasco, and S. Arepalli. Effect of mild nitric acid oxidation on dispersability, size, and structure of single-walled carbon nanotubes. *Chem. Mater.*, 19(23):5765–5772, 2007.
- [232] J. Amiran, V. Nicolosi, S. Bergin, U. Khan, P. Lyons, and J. Coleman. High quality dispersions of functionalized single walled nanotubes at high concentration. *J. Phys. Chem. C*, 112(10):3519–3524, 2008.
- [233] C. Ehli, C. Oelsner, D. Guldi, A. Mateo-Alonso, M. Prato, C. Schmidt, C. Backes, F. Hauke, and A. Hirsch. Manipulating single-wall carbon nanotubes by chemical doping and charge transfer with perylene dyes. *Nat. Chem.*, 1(3):243–249, 2009.
- [234] V. Moore, M. Strano, E. Haroz, R. Hauge, R. Smalley, J. Schmidt, and Y. Talmon. Individually suspended single-walled carbon nanotubes in various surfactants. *Nano Lett.*, 3(10):1379–1382, 2003.

-
- [235] M. O'connell, S. Bachilo, C. Huffman, V. Moore, M. Strano, E. Haroz, K. Rialon, P. Boul, W. Noon, C. Kittrell, J. Ma, R. Hauge, R. Weisman, and R. Smalley. Band gap fluorescence from individual single-walled carbon nanotubes. *Science*, 297(5581):593–596, 2002.
- [236] M. S. Arnold, A. A. Green, J. F. Hulvat, S. I. Stupp, and M. C. Hersam. Sorting carbon nanotubes by electronic structure using density differentiation. *Nat. Nanotechnol.*, 1(1):60–65, 2006.
- [237] J. Gao and M. A. Loi. Photophysics of polymer-wrapped single-walled carbon nanotubes. *Eur. Phys. J. B*, 75(2):121–126, 2010.
- [238] A. Nish, J. Hwang, J. Doig, and R. Nicholas. Highly selective dispersion of single-walled carbon nanotubes using aromatic polymers. *Nat. Nanotechnol.*, 2(10):640–646, 2007.
- [239] S. J. Tans, A. R. M. Verschueren, and C. Dekker. Room-temperature transistor based on a single carbon nanotube. *Nature*, 393(6680):49–52, 1998.
- [240] P. Avouris, Z. Chen, and V. Perebeinos. Carbon-based electronics. *Nat. Nanotechnol.*, 2(10):605–615, 2007.
- [241] J. A. Misewich, R. Martel, P. Avouris, J. C. Tsang, S. Heinze, and J. Tersoff. Electrically induced optical emission from a carbon nanotube FET. *Science*, 300(5620):783–786, 2003.
- [242] Y. Yao, X. Dai, C. Feng, J. Zhang, X. Liang, L. Ding, W. Choi, J.-Y. Choi, J. M. Kim, and Z. Liu. Crinkling ultralong carbon nanotubes into serpentine by a controlled landing process. *Adv. Mater.*, 21(41):4158–4162, 2009.
- [243] ITRS. International technology roadmap for semiconductors. <http://www.itrs.net>, 2009.
- [244] J. Sharma, R. Chhabra, A. Cheng, J. Brownell, Y. Liu, and H. Yan. Control of self-assembly of DNA tubules through integration of gold nanoparticles. *Science*, 323(5910):112–116, 2009.
- [245] X. Tu, S. Manohar, A. Jagota, and M. Zheng. DNA sequence motifs for structure-specific recognition and separation of carbon nanotubes. *Nature*, 460:250–253, 2009.
- [246] M. Zheng, A. Jagota, E. D. Semke, B. A. Diner, R. S. Mclean, S. R. Lustig, R. E. Richardson, and N. G. Tassi. DNA-assisted dispersion and separation of carbon nanotubes. *Nat. Mater.*, 2(5):338–342, 2003.
- [247] S. Jung, M. Cha, J. Park, N. Jeong, G. Kim, C. Park, J. Ihm, and J. Lee. Dissociation of single-strand DNA: Single-walled carbon nanotube hybrids by Watson-Crick base-pairing. *J. Am. Chem. Soc.*, 132(32):10964–10966, 2010.
- [248] M. Hazani, D. Shvarts, D. Peled, V. Sidorov, and R. Naaman. Self-assembled electrical circuits and their electronic properties. *Faraday Discuss.*, 131:325–335, 2006.
- [249] K. Keren, R. Berman, E. Buchstab, U. Sivan, and E. Braun. DNA-templated carbon nanotube field-effect transistor. *Science*, 2003.
- [250] W. Yang, M. J. Moghaddam, S. Taylor, B. Bojarski, L. Wiczorek, J. Herrmann, and M. J. McCall. Single-walled carbon nanotubes with DNA recognition. *Chem. Phys. Lett.*, 443(4-6):169–172, 2007.

- [251] J. F. Campbell, I. Tessmer, H. H. Thorp, and D. A. Erie. Atomic force microscopy studies of DNA-wrapped carbon nanotube structure and binding to quantum dots. *J. Am. Chem. Soc.*, 130(32):10648–10655, 2008.
- [252] Z. Zhou, H. G. Kang, M. L. Clarke, S. H. De Paoli Lacerda, M. Zhao, J. A. Fagan, A. Shapiro, T. Nguyen, and J. Hwang. Water-soluble DNA-wrapped single-walled carbon-nanotube/quantum-dot complexes. *Small*, 5(19):2149–2155, 2009.
- [253] Y. Chen, H. Liu, T. Ye, J. Kim, and C. Mao. DNA-directed assembly of single-wall carbon nanotubes. *J. Am. Chem. Soc.*, 129(28):8696–8697, 2007.
- [254] H. T. Maune, S. Han, R. D. Barish, M. Bockrath, W. A. Goddard, P. W. K Rothemund, and E. Winfree. Self-assembly of carbon nanotubes into two-dimensional geometries using DNA origami templates. *Nat. Nanotechnol.*, 5(1):61–66, 2010.
- [255] K. Müller, S. Malik, and C. Richert. Sequence-specifically addressable hairpin DNA-single-walled carbon nanotube complexes for nanoconstruction. *ACS Nano*, 4(2):649–656, 2010.
- [256] D. Marsitzky, M. Klapper, and K. Müllen. End-functionalization of poly(2,7-fluorene): A key step toward novel luminescent rod-coil block copolymers. *Macromolecules*, 32(25):8685–8688, 1999.
- [257] Y. Tan and D. Resasco. Dispersion of single-walled carbon nanotubes of narrow diameter distribution. *J. Phys. Chem. B*, 109(30):14454–14460, 2005.
- [258] H. Kataura, Y. Kumazawa, Y. Maniwa, I. Umezū, S. Suzuki, Y. Ohtsuka, and Y. Achiba. Optical properties of single-wall carbon nanotubes. *Synthetic Met.*, 103(1-3):2555–2558, 1999.
- [259] Y. Ishibashi, T. Kobayashi, A. D. Prins, J. Nakahara, M. A. Lourenco, R. M. Gwilliam, and K. P. Homewood. Excitation and pressure effects on photoluminescence from dislocation engineered silicon material. *Phys. Status Solidi B*, 244(1):402–406, 2007.
- [260] J. Hwang, A. Nish, J. Doig, S. Douven, C. Chen, L. Chen, and R. Nicholas. Polymer structure and solvent effects on the selective dispersion of single-walled carbon nanotubes. *J. Am. Chem. Soc.*, 130(11):3543–3553, 2008.
- [261] T. M. Herne and M. J. Tarlov. Characterization of DNA probes immobilized on gold surfaces. *J. Am. Chem. Soc.*, 119(38):8916–8920, 1997.
- [262] A. Vijayaraghavan, S. Blatt, D. Weissenberger, M. Oron-Carl, F. Henrich, D. Gerthsen, H. Hahn, and R. Krupke. Ultra-large-scale directed assembly of single-walled carbon nanotube devices. *Nano Lett.*, 7(6):1556–1560, 2007.
- [263] M. Hazani, D. Shvarts, D. Peled, V. Sidorov, and R. Naaman. Self-assembled carbon-nanotube-based field-effect transistors. *Appl. Phys. Lett.*, 85(21):5025–5027, 2004.
- [264] P. Avouris and R. Martel. Progress in carbon nanotube electronics and photonics. *MRS Bull.*, 35(4):306–313, 2010.
- [265] P. G. Collins, K. Bradley, M. Ishigami, and A. Zettl. Extreme oxygen sensitivity of electronic properties of carbon nanotubes. *Science*, 287(5459):1801–1804, 2000.

-
- [266] X. D. Cui, M. Freitag, R. Martel, L. Brus, and P. Avouris. Controlling energy-level alignments at carbon nanotube/Au contacts. *Nano Lett.*, 3(6):783–787, 2003.
- [267] D. A. Giljohann, D. S. Seferos, W. L. Daniel, M. D. Massich, P. C. Patel, and C. A. Mirkin. Gold nanoparticles for biology and medicine. *Angew. Chem., Int. Ed.*, 49(19):3280–3294, 2010.
- [268] M. T. Martinez, Y. C. Tseng, N. Ormategui, I. Loinaz, R. Eritja, and J. Bokor. Label-free DNA biosensors based on functionalized carbon nanotube field effect transistors. *Nano Lett.*, 9(2):530–536, 2009.
- [269] K. Welsher, Z. Liu, S. P. Sherlock, J. T. Robinson, Z. Chen, D. Daranciang, and H. Dai. A route to brightly fluorescent carbon nanotubes for near-infrared imaging in mice. *Nat. Nanotechnol.*, 4(11):773–780, 2009.
- [270] W. A. Kibbe. Oligocalc: an online oligonucleotide properties calculator. *Nucleic Acids Res.*, 35:W43–W46, 2007.
- [271] D. van der Spoel, E. Lindahl, B. Hess, A. van Buuren, E. Apol, P. Meulenhoff, D. Tieleman, A. L. T. M. Sijbers, K. Feenstra, R. van Drunen, and H. Berendsen. *Gromacs User Manual*. University of Groningen, 2002.
- [272] E. Sorin and V. Pande. Exploring the helix-coil transition via all-atom equilibrium ensemble simulations. *Biophys. J.*, 88(4):2472–2493, 2005.
- [273] W. L. Jorgensen, D. Maxwell, and J. Tirado-Rives. Development and testing of the OPLS all-atom force field on conformational energetics and properties of organic liquids. *J. Am. Chem. Soc.*, 118(45):11225–11236, 1996.
- [274] W. L. Jorgensen, J. Chandrasekhar, J. Madura, R. Impey, J. Madura, R. Impey, and M. Klein. Comparison of simple potential functions for simulating liquid water. *J. Chem. Phys.*, 79:926–935, 1983.
- [275] J. Walther, R. Jaffe, T. Halicioglu, and P. Koumoutsakos. Carbon nanotubes in water: Structural characteristics and energetics. *J. Phys. Chem. B*, 105(41):9980–9987, 2001.

