Abstract

Given the increasing demand for novel diagnostic and therapeutic agents that possess high cell specificity and long blood circulation times, enhanced efficiency in terms of cellular uptake and are capable of delivering functional molecules, research in the field of medicine is currently shifting toward the disciplines of engineering and technology. Especially the research area of nanomedicine has received increasing attention during the last decade as nano-sized carrier materials have shown to possess superior imaging and therapeutic properties attributed to their potential to interact with cells. During particle engineering, precise control over physicochemical properties of the carrier material plays a key role, allowing for a reproducible fabrication of optimized and highly efficient vectors. In this work, the employment of specific surface ligands as well as controlled variation of reaction parameters during thermal decompositions and solvothermal reactions enabled the synthesis of iron oxide nanoparticles (IONPs) with highly homogeneous particle morphology (spherical, cube-, ellipsoid-shaped), size (5-200 nm) and phase (Fe_3O_4, $Fe_{1-x}O$, α-Fe_2O_3). Subsequent magnetization and relaxivity measurements demonstrated that these particles were well-suited for bioimaging applications including magnetic resonance imaging (MRI) and magnetic particle imaging (MPI). The high MRI contrast obtained for IONPs prepared in this work was additionally exploited for the visualization of next generation electronic brain implants during *ex vivo* experiments. Moreover, specific absorption rate (SAR) measurements revealed that IONPs demonstrate a remarkable heating potential, possibly useful during hyperthermia applications. Additionally, a step-by-step approach towards the controlled surface modification and bioconjugation of IONPs was developed involving the covalent attachment of specific RNA strands that could be used for the first time for the intracellular capturing and purification of microRNAs and marker proteins. The interaction between biomolecules and nanostructures was further elucidated using silica particles, which were surface modified with cell penetrating peptides. Spectrometric analyses revealed that the secondary structure of the peptides is preserved after conjugation to the inorganic carrier, which is a crucial factor to retain their functionality. To further evaluate the potential health risk associated with nanomaterials, carbon-based nano-structures were evaluated toward their *in vitro* immunological response revealing remarkable shape-dependent differences. Overall, the results obtained in this thesis demonstrate the outstanding variability and promising potential of nanomaterials for medicinal purposes and allowed for a deeper insight into nanomaterial-cell interactions.