Large scale production, characterisation and functionalisation of nanoruby

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Fluorescence microscopy critically relies on properties of the probes, such as their photoluminescence, biocompatibility and cost. Herein, we report on a newly discovered photoluminescent probe known as nanoruby, which exhibits high quantum yield, extreme photostability, narrow emission spectra and long emission lifetime [1]. These properties make nanorubies suitable for long-term single molecule detection in a cell/tissue samples affected by crowded fluorescence background. This work focuses on the synthesis, detailed characterisation and functionalisation of nanoruby particles.

A high-energy ball milling method was used to produce large quantities of nanoparticles. At the beginning, $\alpha$-alumina was used as a prototype, since it is the host material of ruby, which contains the dopant Cr$^{3+}$ at $0.01 – 0.1\%$ atomic fraction. This method was able to produce biocompatible nanoaluminas as reported earlier [2]. Using a similar strategy, nanorubies were produced from bulk ruby. To this aim, synthetic bulk ruby crystals were crushed to micrometer sized particles, followed by the ball milling process. This yielded grams of nanorubies per batch, with the size ranging from 10 – 200 nm, with moderate control over the size distributions. Narrower size distributions were obtained by centrifugal fractionation. XRD analysis revealed $\alpha$-crystal structure of the milled sample, which was 98% pure after an acid-based purification procedure.

The ease of biofunctionalizing nanorubies was demonstrated using amino-propyltriethoxysilane to yield amine-functional surfaces. This is possible due to the presence of hydroxyl groups on the surface of the nanoruby surface. The amine groups were further modified to yield carboxyl groups. While as-synthesized nanorubies colloids were stable in water over months of testing, their stability in buffers was marginal. To counter this, nanorubies were functionalised with silane-terminated poly-ethyleneglycol reagents, resulting in stable colloids in buffers. The functionalisation was examined by the infrared spectroscopy and zeta potential measurements. Infrared absorption spectrum suggested the presence of N-H and C=O bonds, corresponding to amine and carboxyl functional group. This work shows the prospect of using ball milling method to produce photoluminescent nanomaterials in a large scale. In summary, straightforward production, easy functionalisation, unique optical properties and biocompatibility make the nanorubies an attractive photoluminescent probe for bioimaging applications.

References
