NANOSTRUCTURED MATERIALS WITH APPLICATIONS IN BIOSENSING AND BIOCOMPATIBILITY

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Advanced materials in the sub-100 nm regime have been shown to have novel and improved physical, chemical, and biological properties compared to traditional materials [1]. In this presentation, we will explore two diverse examples of nanostructured materials with applications in biology. First, we will focus on luminescent nanoparticles doped with lanthanide ions that have the capability to (up)convert infrared light to visible and/or ultraviolet. The small size of these materials (sub-20 nm) allow for the development of a "sandwich-type" bioassay where the analyte of interest is wedged between donor and acceptor labels and operates on the principle of fluorescence resonance energy transfer (FRET). Secondly, we will discuss biocompatible materials whose surfaces have been modified to create a nanotopography, which has yielded promising results.

(i) Conventional fluorescent sandwich assays use blue light to excite the donor label and have already been commercialized (Fig. 1a). However, the blue (high-energy) light absorbs readily by proteins (often damaging them) and also excites all fluorescent contaminants in the sample, resulting in poor sensitivity. By replacing the donor label with an Ln-doped upconverting nanoparticle, it becomes feasible to use an NIR light source, which selectively excites that label (Fig. 1b). However, before the biomedical studies of such assays are performed, it is essential to fully understand the mechanism(s) that lead to upconversion in nanosystems.

We developed for the first time erbium (Er^{3+}) doped nanomaterials that are capable of upconverting NIR light to green and red (Fig. 2). This ion is ideal for use in FRET assays since it has no emission in the region where the acceptor label would emit. Initially, we prepared Er^{3+}-doped binary nanocrystalline oxides (e.g. Y_2O_3:Er^{3+}) and studied various parameters that may influence the upconversion of the Er^{3+} ion [2, 3]. We found that after excitation with NIR radiation (980 nm) the nanocrystals emitted green and red light. However, when compared to an identically doped bulk sample, the intensity of the upconversion was several orders of magnitude lower. This was due to the presence of surface species bound to the outside of the nanoparticle that quenched the luminescence. We also proved that as a result of these species, the fundamental mechanism of upconversion was significantly altered and led to drastically different upconversion spectra. Subsequently, we investigated more complex ternary nanocrystalline oxides ($Gd_3Ga_5O_{12}$:Er^{3+}) and showed that these materials are much more promising. They do not suffer from surface contamination and as a result, their upconversion intensity was much stronger and ideal for use in assays. Upconversion emission was observed when pumping with low energy (5 mW) from inexpensive solid state NIR sources.

(ii) Titanium and its alloys are widely used in implants due to their excellent biocompatibility. To improve implants, it is essential to engineer biomaterials in ways that promote tissue integration and improve biological function. The key to the design of novel biomaterials is to properly manage the interaction of the surface and the interface between the material and the host tissue since in the human body, most reactions occur at surface and interfaces. Using a simple chemical treatment, we produced a unique nanostructured topography (Fig. 3) [4]. These surfaces selectively inhibit fibroblastic cell growth while promoting osteogenic cell activity. Such intelligent surfaces may be used for various applications, including implantable biomaterials as well as drug delivery and biosensors, with broad implications and a significant impact in nanomedicine.

References:

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Figures:

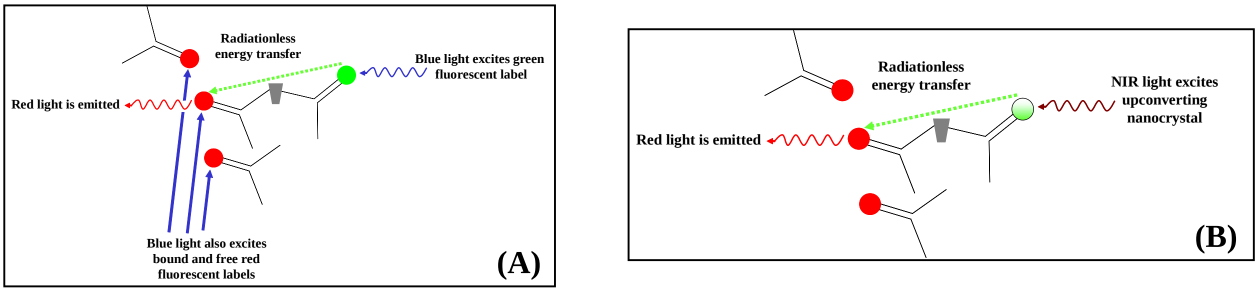

Figure 1: (A) Schematic representation of a conventional FRET assay. (B) Schematic representation of an upconversion FRET assay.

Figure 2: Upconversion luminescence of Y_2O_3:Er^{3+}, Yb^{3+} nanocrystals

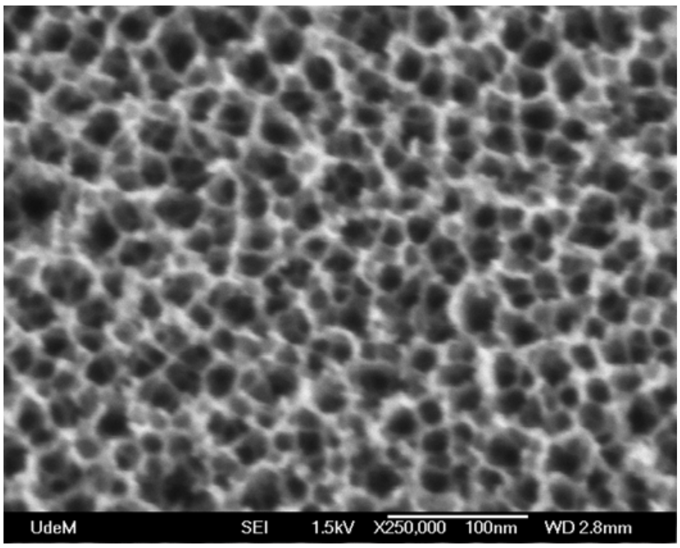

Figure 3: SEM image of nanostructured titanium alloy surface