Quantum dots in proteins embraces

You may already heard about quantum dots (QDs) when buying energy saving light source or choosing your new TV set. Quite the same structures are used in life sciences as tools to visualize and track other molecules. Some QDs may even help to power up enzymes. The feature of QDs, which is important in all their applications, is the ability to emit light. The second significant attribute is QDs composition of semiconductors - cadmium telluride, zinc sulfide and others, quite rock-like materials. So, QDs are basically very small pieces of semiconductor crystals. You may picture it as non-ideal spheres, usually with a diameter not exceeding 40-50 nm, and call them nanocrystals. QDs we are using are even smaller, below 10 nm. This very small size is a reason for their luminescence, not found for bulk of the same materials. In nanocrystals, due to the spatial constraints, the electrons get much higher energy after light absorption than they may get being in a bulk material. And in a consequence, the electrons falling back to their base energy levels are emitting photons, what we see as light emission. However, the nature of materials building QDs causes also their hydrophobicity – placed in water they tend to aggregate and lose their unique luminescence properties.

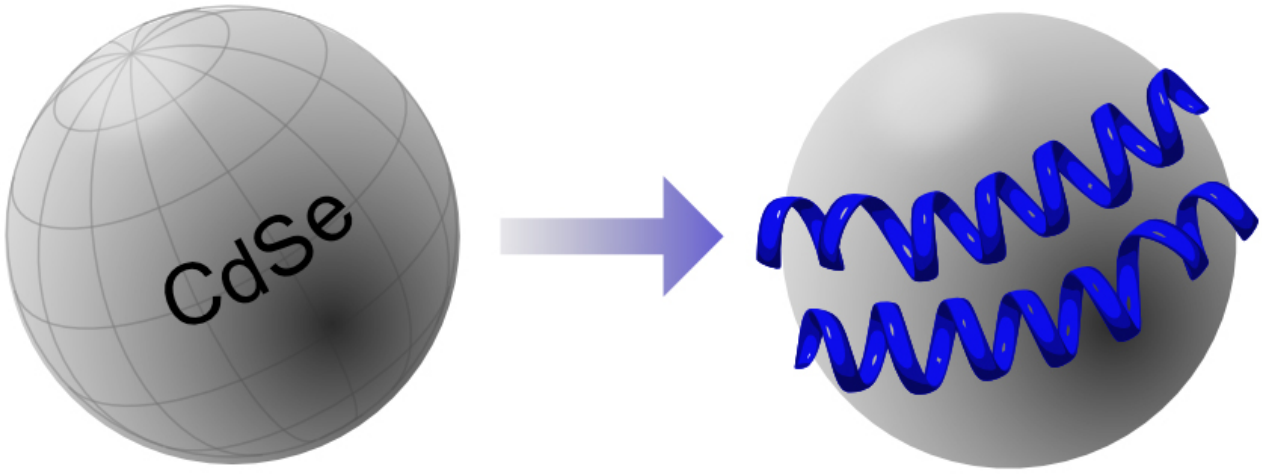

Fig. 1. Schematic representation of QD getting its protein coating.

Now, we are facing a challenge - how to use such nanocrystals in studies of living organisms, which are composed mostly of water? There is a way to add additional shell to the nanocrystal surface. Till now, such shells were built up from hundreds of small organic molecules, usually containing thiol (-SH) groups connecting to nanocrystal and hydrophilic groups (carboxy -COOH, hydroxyl -OH or amine -NH_3) exposed to water. With such a number of small molecules on the

surface, it is quite easy to start losing them, what again results in the aggregation - just after extended period of time. Nature herself comes to the aid here and offers one, long molecule, being able to cover most of QDs surface. There are proteins, which native function comprises formation of long embraces around hydrophobic tails of lipids. It may be pictured as a wide ribbon, wrapping flower stalks, leaving only their heads uncovered. An example is apolipoprotein A1, used by Stephen D. Sligar group to create membrane scaffold proteins (MSP) for laboratorial formation of nanodiscs (small lipid rafts, encircled by protein belt). It is possible because MSP has a strictly defined surface pattern: hydrophobic part facing lipids and hydrophilic, exposed to water. We found the way to adapt MSP as a cover for QDs. Basically, we use the same principles as in nanodiscs formation, with hydrophobic surface of protein interacting with nanocrystal surface. In the final step, we have protein tightly embracing nanocrystal. However, to make that junction possible, we have to use detergents: it creates a transitory complex with both a protein and QDs, and then is removed by dialysis. You may imagine this part of process as tightening of embraces. And finally, we have QD covered with one or just a few protein chains, much harder to be lost than it was in a case of several small organic molecules.

Having a protein as a coating of a nanocrystal will be very useful in the future, because genetic engineering enables creation of bigger constructions, composed of several domains. It just mean, that we may have a protein containing an MSP domain to cover a nanocrystal and second domain, which may be responsible for another function - e.g. a protein being recognized by a receptor on a surface of tissue, which we want to visualize with QD.

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Publication

Hydrophilic colloidal quantum dots with long peptide chain coats.
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