Self-Assembly of Fluorescent Silica (glass) Beads

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ABSTRACT

We present self-assembly of fluorescent silica (glass) particles, beads. The beads are a few microns glass nanoporous particles which contain florescent dyes imbedded in the pores. The pores are self-closed, so the dye does not leak out being sealed inside the pores. The fluorescent activity of the beads is so high that there is no need in special fluorescent microscopy. Even ordinary dark-field microscopy mode is enough to detect the beads. The beads are stable for many hours (>8) of direct (blue) continuous laser excitation. It can survive direct open sun light showing from virtually none to ~50% (depending on the dye) intensity decrease after 6 hours of continuous irradiation (N44^o latitude, middle of July, 10am-4pm.). Having silica outside, the beads are biocompatible and can be used for labeling in-vivo. Amount of possible colors/spectra is almost unlimited and restricted by the detector only.

Keywords: fluorescent beads, glass beads, flow cytometry, cell assays, detection

Fluorescent silica particles have a huge potential to be used for labelling. Because the chemistry of silica is well known, it can easy be functionalized, covered with desired sensing molecules. Currently existing silica particles have open pores that allow fluorescent

One step self-assembly of the nanoporous glass particles with embedded multiple organic dyes can provide a high yield of glass particles with rather complicated colors, spectra. Such process can combine tremendous variability of organic dyes with the stability of solid glasses. For example, a simple combinatorial calculation shows that mixing 5 different dyes chosen out of 1000 available now gives ~10^{13} (10,000 billion) tags with different spectra. If we take into account possibility to mix the dyes in different concentrations and possible non-linear effects, while mixing the dyes, the total number of different spectra is practically unlimited. Because the majority of organic dyes are fluorescent, the particles can be traced even in very low concentrations.

Creation of stable complex color glass particles can also be used in creation of dye lasers, because almost all mentioned dyes have lasing activity.

While the need in such particles is clear, there three major problems associated with it:

1. Stability of the dyed glasses. Generally, the stability of dyes inside porous glass is higher than that of pure dyes. However, what needed is really very long-lived taggants with well-quantified stability documented.
2. Hard to optimize one-step process. The majority of processes of synthesis of dyed porous glasses are two- or more-step processes. Only a few cost effective one-step processes are known.
3. Mixing and interaction of multiple dyes inside the nanosized pores is virtually not studied in the literature.

Dyed particles are widely manufactured, but the processes used for their production are often tightly held trade secrets. Incorporation of dyes into glass particles seems to be one of most promising because of excellent sealing ability of the glass and wide compatibility of glass with other materials. Adding organic dyes to porous glasses is a well known and established area. Self-assembly of nanoporous glass is more than 10 years old. Sol-gel chemistry was used to create porous fluorescent particles for at least 10 years. Encapsulation of organic dyes inside nanoporous glasses is a cost-effective process and is under investigation.

We found one-step sol-gel self-assembling synthesis of nanoporous silica shapes, in which lasing organic dyes are incorporated inside the pores that are self-closed [US PATENT PENDING, 2004]. We used the process of self-organization of meso(nano)porous silica via cationic surfactant templating.

The assembled product contains specific shapes (mostly "discoids", "gyroids") and size of an order of a few microns. The pore size is about 4 nm, and can be varied by changing the length of the templating molecule. The most important property of the assembled particles is that the pores are closed. Therefore, the dye is sealed inside with no leakage out. Moreover, the amount of oxygen is rather limited inside the pores, preventing oxidation of the dye. This creates rather stable dyed particles.