Luminescent solar concentrators based on nanoporous materials

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The concept of using luminescent solar concentrators (LSCs) to reduce the cost of photovoltaic power dates back to the late 1970s.[1] The optical efficiency of conventional LSCs, which typically consist of a fluorescent dye in a polymer matrix, is strongly limited by self-absorption. Energy transfer systems based on the organization of dye molecules in nanoporous hosts (zeolites and arrays of silica nanochannels, ASNCs, Figure 1) have the potential to solve the self-absorption problem and at the same time increase the photostability of the devices.[2]

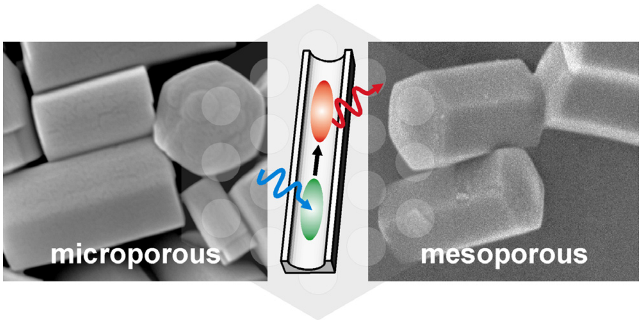

Figure 1. One-dimensional nanochannels in microporous and mesoporous (alumino)-silicates (zeolite L and ASNCs) can be used to obtain host-guest systems with efficient light harvesting and energy transfer.

In dye-zeolite/polymer based LSCs (Figures 2 and 3), absorption and emission spectra are separated by employing an absorbing species (or donor, **D)** and an emitting species (or acceptor, **A**). The concentration of **D** is high to ensure efficient light absorption. The electronic excitation energy is transferred along the zeolite channels by Förster resonance energy transfer (FRET) to **A**, which then emits light in a wavelength range where **D** does not absorb. As the concentration of **A** does not necessarily need to be high, self-absorption of light emitted by **A** should become negligible. Zeolites containing more than two dyes can be used to create an energy transfer cascade and to adjust the absorption properties of the LSC to the spectrum of the incident radiation (Figure 4). Based on this general concept, further optimization, such as the engineering of the electronic transition dipole moment orientation, is possible. Additional developments include the synthesis of materials with larger channel diameter to broaden the range of potential donor and acceptor dyes.

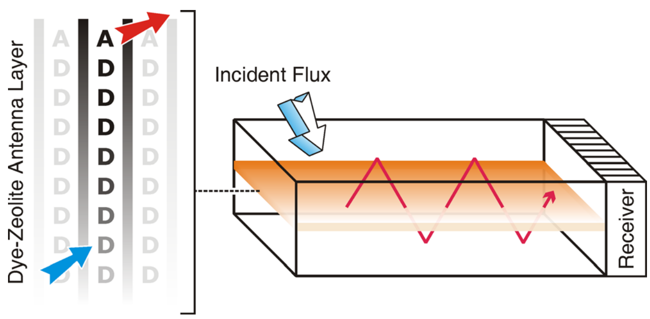

Figure 2. Advanced LSC based on a dye-zeolite/polymer film. The zeolite crystals are filled with donor (D) and acceptor (A) molecules to establish an energy transfer cascade. The dye-zeolite/polymer film can be sandwiched between two glass plates. In order to function as a concentrator, the face area needs to be larger than the edge area.

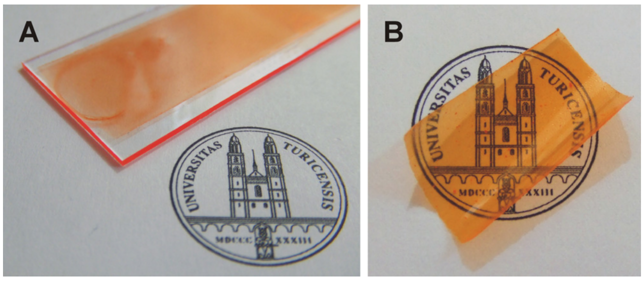

Figure 3. (A) LSC consisting of a dye-zeolite/polymer film on glass. The zeolite crystals contain two types of dyes, with the donor molecules being present in large excess. The image was taken under diffuse light (indoor, no artificial light source). An intense emission at the edges of the glass is visible. (B) Free standing dye-zeolite/polymer film. The diameter of the University seal is 2 cm.

Much of our recent work has been concerned with the synthesis of dye-zeolite systems featuring light absorption over a wide range of wavelengths coupled with efficient energy transfer to a comparatively small number of red-emitting dyes. Materials currently under investigation contain three types of dyes (two types of donor dyes, one type of acceptor dye, see Figure 4). In view of the potential application of these dye-zeolite materials in LSCs, we are also conducting stability studies and developing concepts to increase the long-term stability by sealing the zeolite channels.

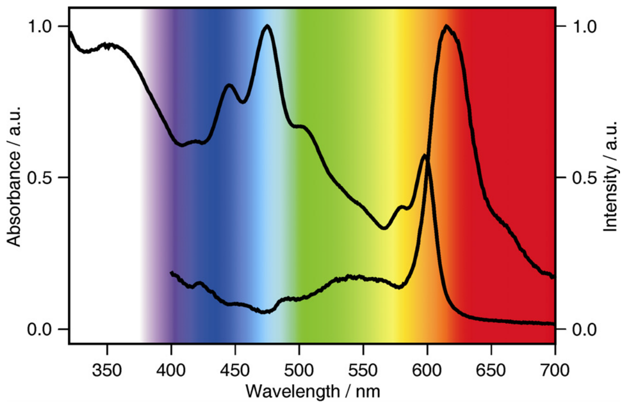

Figure 4. Absorption and emission spectrum of a 3-dye system. The emission spectrum was measured upon selective excitation of the short wavelength donor (375 nm). Even under these conditions, the emission of the acceptor molecules is dominant.

Recent key developments in the field of mesoporous materials are promising in terms of offering possibilities to extend the well-established concepts of supramolecular organization of dyes in zeolite L to guest species that cannot be included into microporous materials. These developments include the synthesis of mesoporous silica with narrow pore size distribution and defined morphology, as well as methods to selectively functionalize external and internal surfaces to provide a tailored environment for guests.[3] In the ideal case, it should become possible to adjust the properties of the host to a given guest in order to provide highly efficient light harvesting and energy transfer systems for use in advanced LSCs.

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