Trapping Energy from and Injecting Energy into Dye-Zeolite Nano Antennae

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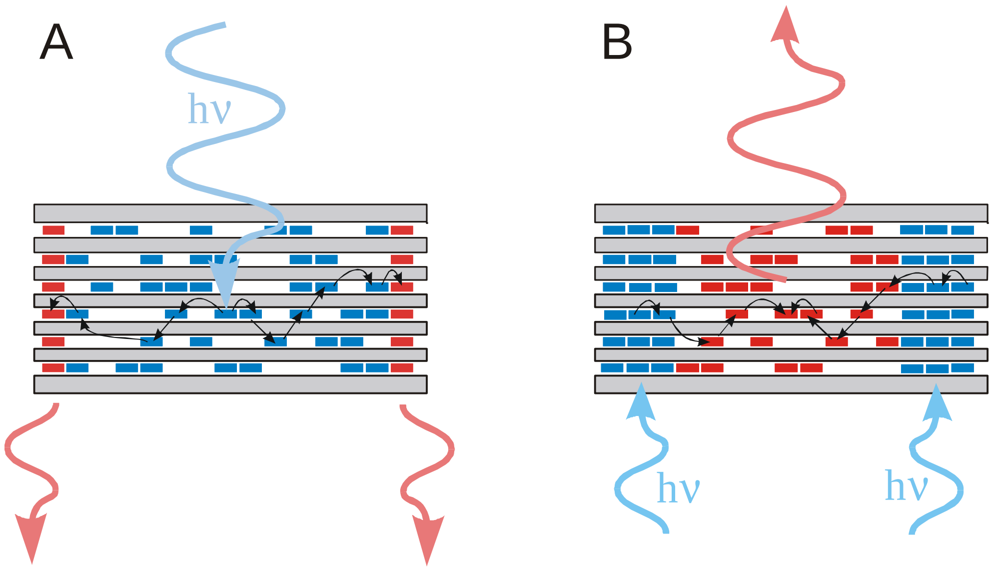
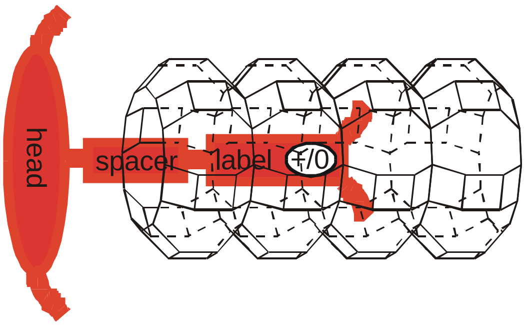
A photonic antenna is an organized multi-component arrangement in which several chromophores absorb the incident light and channel the excitation energy to a common acceptor component. Numerous attempts to make such systems have been presented in the literature. We have developed photonic antennae based on a host-guest system which shows exciting properties.[1-4] The host material is zeolite L, a hexagonal crystal with one-dimensional channels along the crystal axis. As guests we have used a wide range of highly fluorescent dye molecules which can enter the channels but do not interact electronically because of geometrical constraints. These systems are able to collect and transport excitation energy by radiationless energy transfer. Light shining on the cylinder is first absorbed and the energy is then transported by the dye molecules inside the tubes to a desired region. The principle of two types of photonic antenna materials is illustrated below:



The blue rectangles represent donor molecules while the red rectangles represent acceptor molecules. In A) de donor molecules are located in the middle of the cylindrical zeolite crystal and the acceptor molecules are located at the end, B) shows the inverse case. Both cases have been realized in our group.[5]

So far, these systems were only able to transport electronic excitation energy radiationless within the crystal structure. It would be challenging to lead the collected energy out of the crystals or, inversely, inject energy from the exterior into the dye-loaded zeolite L crystals. The approach we used to solve this problem is by adding ‘stopcock’ molecules.[4,6]

These molecules have a stopcock shape with a head that is too big to penetrate the free open diameter of the zeolite channels and a label that is smaller and can enter the channels. The head and the label are connected by a flexible spacer. The stopcock shape enables them to close the channels like a cork on a bottle of champagne:



The main function of the stopcocks is to connect the antenna function of the crystal to its surroundings. They act as bridges between the dye molecules inside the channels and the outside world by either trapping excitation energy coming from the inside, or injecting excitation energy into the dye-loaded zeolite crystals. We present first promising results on dye-loaded zeolite L antennae modified with such stopcocks.

The antenna effect, as it is found in natural photosynthetic systems, is an attractive tool to increase light absorption of solar cells. Sensitization of a semiconductor by electron injection however has the disadvantage that the electron donors need to be regenerated, usually by means of a redox couple. A different kind of dye sensitized solar cell was proposed by Dexter in 1979. He described sensitization of a semiconductor by energy transfer instead of electron injection, followed by the production of an electron-hole pair in the semiconductor. The dyes do not have to be regenerated in this case because they do not exchange electrons. Electron transfer can be prevented by introducing a thin insulating layer between antenna and semiconductor. It is very challenging to combine the exciting properties of the dye-loaded zeolite L antennae with the ideas of Dexter to make an antenna-sensitized solar cell.

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