In the field of the functionalisation of surfaces for biological applications, we have developed Self-Assembly monolayers (SAMs) of isocyanates on oxidized silicon wafers (1,0,0) by reaction of isocyanatodecytrichlorosilane with the Si-OH groups of the surface. Excellent reactivity of the isocyanate monolayer with different nucleophiles was demonstrated. In particular, the semicarbazide group was obtained by reaction with Boc-hydrazine and deprotection of the tert-butyl carbamate. Alternatively, SAMs of semicarbazide groups were obtained by direct hydrosilylation of silicon wafers (1,1,1). The SAMs of semicarbazide group were very efficient for the grafting of functionalized peptides in mild conditions (figure 1). Biomolecular recognition with proteins or antibodies was then performed.

![Figure 1](image)

The functionalisation of Mesoporous Silica Nanoparticles (MSN) was also carried out. Covalent attachment of water-soluble photosensitizers (Figure 2) into (MSN) for photodynamic therapy (PDT) applications was realized. Those MSN were monodisperse with a diameter of 100 nm, a specific surface area of 860 m²/g and a pore diameter of 2.2 nm. These MSN were proved to be active on breast cancer cells after endocytosis. Moreover, MSN were functionalized on their surface by mannose using an original pathway with diethyl squarate as the linker. Those mannose-functionalized MSN dramatically improved the efficiency of PDT on breast cancer cells. In addition, the involvement of mannose receptors for the active endocytosis of mannose-functionalized MSN was demonstrated (Figure 3).
We have also designed MSN for two-photon PDT. A two-photon photosensitizer was synthesized (figure 3) and its properties analyzed in solution. This photosensitizer combines fluorescence (quantum yield 0.6), singlet oxygen production (quantum yield 0.2) and a high two-photon absorption cross-section (1200 GM) in the NIR range. This photosensitizer was encapsulated into MSN which were functionalized with mannose on the surface. Those MSN were incubated with colon (HCT-116), Retinoblastoma (Y-79), Breast (MCF-7, MDA-MB-231) cancer cells. Using two-photon excitation at 760 nm, Only 3 seconds of irradiation at low power (80 mW) were sufficient to kill 75% to 100 % of the cells. A preliminary study (proof of concept), carried out in vivo with athymic mice bearing HCT-116 colon xenografts, has shown the efficiency of the nanoparticles for the treatment of colorectal cancer in vivo. Thus MSN would present an important potential for small size tumors were surgery is not justified.