

Analysing ligand–receptor binding by QD-FRET can be done by conjugating the QDs with receptor proteins and monitoring the FRET efficiency as a function of ligand concentration. The ligand can either function itself as a FRET acceptor, or it can be labelled with an acceptor dye. In either case, binding of the ligand brings the acceptor into close proximity with the QD donor, allowing energy transfer to occur. The problem with devising such assays in the past has been the inability to control the number and orientation of the receptor proteins, and hence the position of the acceptor dyes relative to the QDs⁶. As a result, it has not been clear whether the energy transfer was due mainly to FRET or to some other process, such as electron transfer, or surface deactivation.

By using the QDs as resonance energy-transfer donors, Mauro and colleagues devised two FRET-based maltose-binding assays based on the interaction between maltose-binding proteins conjugated to the QDs, and the cyclodextrin ligand, which is conjugated to an acceptor dye (Fig. 1). The critical aspect of these FRET experiments is the unique surface attachment chemistry used to form the QD–protein conjugates. In previous papers, these authors reported novel polypeptide ‘zipper’ tails appended to the receptor proteins. These ‘zippers’ interact electrostatically with the functional groups on the QD surface, and cause the receptor proteins to self-assemble onto the QD in a well-defined orientation⁷. The present work uses a simplified pentahistidine tail with equally successful results. This has allowed the creation of FRET assays in which the arrangement of the donors and acceptors is relatively well known.

The good news is that QD-FRET assays can now be designed in such a way that FRET is confirmed to be the dominant energy-transfer process. The bad news is that the FRET efficiency is inherently low compared to that of conventional dyes. This is because the large size of the QDs makes it nearly impossible to bring the acceptor into close-enough proximity to the donor for FRET to occur efficiently. Although multiple acceptor sites can be incorporated to boost the efficiency, the assay sensitivity is limited because higher acceptor concentrations are needed to produce a detectable signal. Still, the self-assembly of these energy-transfer complexes is noteworthy, and should lead to improved FRET assay constructions in the future. Perhaps more importantly, these studies may serve as the basis for novel fluorescence imaging techniques that exploit the QDs enhanced stability, as well as nanoscale optoelectronic devices that incorporate QDs as synthetic light harvesters.

References

1. Chan, W. C. W. & Nie, S. *Science* **281**, 2016–2018 (1998).
2. Bruchez, M. Jr, Moronne, M., Gin, P., Weiss, S. & Alivisatos, A. P. *Science* **281**, 2013–2016 (1998).
3. Goldman, E. R. *et al. Anal. Chem.* **74**, 841–847 (2002).
4. Medintz, I. L. *et al. Nature Mater.* **2**, 630–638 (2003).
5. Van Der Meer, B. W. *Resonance Energy Transfer: Theory and Data* (VCH, New York, 1994).
6. Willard, D. M., Carillo, L. L., Jung, J. & van Orden, A. *Nano Lett.* **1**, 469–474 (2001).
7. Mattoussi, H. *et al. J. Am. Chem. Soc.* **122**, 12142–12150 (2000).

MATERIAL WITNESS

Space myths

Thank goodness for space exploration, which has given us that vital ingredient of modern life: the perfect fried egg.

Or has it? Never mind the bathos, what about the facts? The idea that DuPont’s Teflon was a spin-off from research on space technology is one of the most pervasive myths about today’s materials. But it was nothing of the sort.

Polytetrafluoroethylene was in fact the serendipitous offshoot of research on refrigerators. When Roy Plunkett and his co-workers stumbled across it in 1938, they were attempting to make a new CFC refrigerant. This white plastic that resisted water, acids, organic solvents and fungus clearly had something going for it, and DuPont patented it in 1941.

The real boost for applications of PTFE came from the Second World War, when it was used under the code-name K416 as a protective coating against corrosive uranium hexafluoride in isotope separation for the Manhattan Project, as well as in aircraft engines and explosives manufacture. Seeing its commercial potential, DuPont registered the Teflon trademark in 1944 and developed mass-production methods. By 1950 the company’s Teflon plant in Virginia was producing a million pounds in weight of the material a year, used largely as an insulator and sealant. Non-stick cooking equipment followed soon after, although DuPont was cautious about introducing it for domestic use until its safety had been established. Teflon-coated pans were all the rage by the time Yuri Gagarin flew in space in 1961.

So although PTFE featured in the space suits, blankets, heat shields and insulation of the lunar module in which Neil Armstrong and colleagues landed on the moon in 1969, such space applications were a minor sideline in the burgeoning Teflon market.

And yet the myth continues. US senator Kay Bailey Hutchison claimed only last February in the *Dallas Morning News* that not only Teflon but also Velcro “were developed through our space programme”.

Why does this notion persist? One can’t blame an over-zealous NASA press agency; indeed, it gives the impression that it would be relieved not to have to keep denying the tale. “There was a guy last week who was assuring me that Teflon was a NASA product”, said a NASA spokesman earlier this year, “and I kept saying to him ‘Show me the documentation’.” The same is true of several other putative spin-offs, such as the instant fruit-drink Tang. “We didn’t develop it”, says the man from NASA, “we just bought it off the shelf like everyone else.”

Partly this stems from a refusal to believe that wonderful modern materials can have such prosaic origins. But some banging of the spin-off drum is for propaganda purposes, as a way to revitalize the moribund and obsolete vision of manned spaceflight. Setting foot on Mars, claims Robert Zubrin of the Mars Society, would produce an even greater spin-off benefit than Teflon. If, in 30 years’ time and after astronomical expenditure, that were to happen, I wonder what products we will be asked to thank it for — carbon nanotubes, perhaps?



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