**Brief Introduction to A Nanobionic Light-Emitting Plant**

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**The engineering of living plants for visible light emission and sustainable illumination is compelling because plants possess independent energy generation and storage mechanisms and autonomous self-repair. Professor Michael S. Strano’s research group of MIT demonstrates a plant nanobionic approach, as reported in their article “A Nanobionic Light-Emitting Plant”, that enables exceptional luminosity and lifetime utilizing four chemically interacting nanoparticles, including firefly luciferase conjugated silica (SNP-Luc), D-luciferin releasing poly(lactic-co-glycolic acid) (PLGA-LH2), coenzyme A functionalized chitosan (CS-CoA) and semiconductor nanocrystal phosphors for longer wave-length modulation. Here we gave a brief introduction to their method and achievements of of nanobionic plants as self-powered photonics, direct and indirect light sources.**

**Introduction**

Plants on our planet are independent energy source, which are adapted for persistence and self-repair in harsh environments . Therefore, plants are compelling platforms for engineering new functions. Prof. Strano developed a new method to generating light-emitting plant, which previously focused on genetic engineering using firefly luciferase or bacterial *lux* operon. Genetically modified plants requires tedious work but only emit weak light for very short period of time. While using Nano technology, Strano’s group successfully transport all the reagents and enzyme into plant leave cells with high efficiency and low toxity. Their group successfully colocalized reactive enzymes for chemiluminescence within substrate producing regions and high adenosine triphosphate (ATP) concentration,requiring external administration of 1 mM luciferin in the case of the former, despite its toxicity to plant cells above 400 μM. Combined with theoretical optimization, they showed for the first time the use of plants as self-powered light sources using exclusive nanotechnology approaches.

**Recent Progress**

Chemiluminescence within plants reported in this article is firefly luciferase-luciferin reaction pathway, which is a commonly employed system utilizing ATP to generate yellow-green photoemission. D-luciferin is oxidized by firefly luciferase in the presence of ATP, Mg2+, and O2, with ATP convert to AMP for energy supply.

They rationally designed and fabricated three chemically interacting nanoparticles with controlled size and surface charge, so that they could target specific compartments of the leaf. They immobilized firefly luciferase onto maleide-functionalized silica nanoparticles(SNP-Luc) to increase the stability of the enzyme.[2] Also, that can help the enzyme efficiently traverse the plant cell membrane. Due to the luciferin toxicity in plant cells, poly(lactic-co-glycolic acid) (PLGA) nanoparticle was synthesized to supply a high extracellular flux of luciferin while suppressing the local concentration. To release coenzyme A (CoA) , chitosan- tripolyphosphate (CS) carriers were used because CoA extends the light emission by regenerating firefly luciferase activity via a reaction with ehydroluciferyl-adenylate. SNP-Luc is designed to enter leaf mesophyll cells and stomata guard cells and localize near the organelles, chloroplasts, and mitochondria, where ATP generation is highest.15 The larger PLGA-LH2 and CS-CoA are intended to remain within the leaf mesophyll intercellular spaces as releasing the reagents to be subsequently transported through the cell walls and membranes.

To optimize the release kinetics and nanoparticle concentrations for light emission and duration, they studied the chemical interactions of chemiluminence (reaction 1) and regeneration of the enzyme(reaction 2) that result when PLGA-LH2, CS-CoA, and SNP-Luc are combined with 0.5 mM ATP. This optimization was accomplished by constructing a new chemical kinetic mathematical model by incorporating reaction 2, the reaction rate of dark reaction (k5) and regeneration of enzyme activity by CoA (k6), as well as accounting for reaction 1, the reaction rate of SNP-Luc and releasing kinetics of PLGA-LH2 and CS- CoA (Figure 2d, Table S2, Figure S6), showing excellent agreement with experimental data.

Their group developed the method termed pressurized bath infusion of nanoparticles (PBIN) to insert the nanoparticle mixture into the whole plant. Here, the entire plant is briefly submerged in a pressured aqueous chamber. The pressurization rate affects the efficiency of PBIN. Buy trial and error and with the help with kinetic modeling, the found that PBIN was successful at 0.04 bar/s applied without membrane damage.

PBIN is able to simultaneously infiltrate the nanoparticle mixture into wild-type spinach, arugula, and watercress but not kale without modification. They built a nanofluidic model , which predicted favorable PBIN infiltration if the plant leaf contact angle is less than approximately 113° , while kale has a contact angle over 120°. To overcome this unfavorable leaf contact angle, they used nonionic surfactant n-dodecyl-β-D-maltoside, resulting in a light-emitting kale plant.

**Discussion**

The rate of decay of the chemiluminescence is found to be strongly dependent on the incubation time of SNP-Luc within the living plants.The incubation time is apparently needed to allow for the diffusion of nanoparticles to leave the sub stomatal chamber, allow penetration of SNP-Luc into the mesophyll and the guard cells, chemically release from PLGA-LH2 or CS-CoA nanoparticles, and finally, the diffusion of the released chemicals across the cell membranes. Hence, they noted that control of nanoparticle localization is central to producing bright emission as extracellular ATP concentration is in the micromolar range compared with millimolar for the cytosol. They concluded that the incubation time is an additional key variable to control the localization of SNPs .

Strano’s group developed this novel Nano based method to modify the biological reactions in plant cells, making chemiluminence a stable and controllable. This proposed a potential new source for lighting in the city, which may save a lot of energy. Also, light emitting plant will be used for  artificial lighting indoor, in a fascinating way.

**References**

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