Quantum Dot Tracers for Use in Engineered Geothermal Systems

May 19, 2010

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Track Name

Mandatory Overview Slide

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- Timeline
  - This project has not yet started
- Budget
  - Total project funding, DOE share, awardee share, funding received in FY09, funding for FY10
- EGS Barriers:
  - Barrier J: Tracers—Inadequate tracers and/or tracer methodology to accurately define the subsurface system of fractures and mapping of fluid flow.
  - limited fracture detection capability
  - lack of high-temperature monitoring tools and sensors
  - limited flow path identification capacity
  - a lack of suitable tracers

– AltaRock Energy, Inc.; Los Alamos National Laboratory

Objective

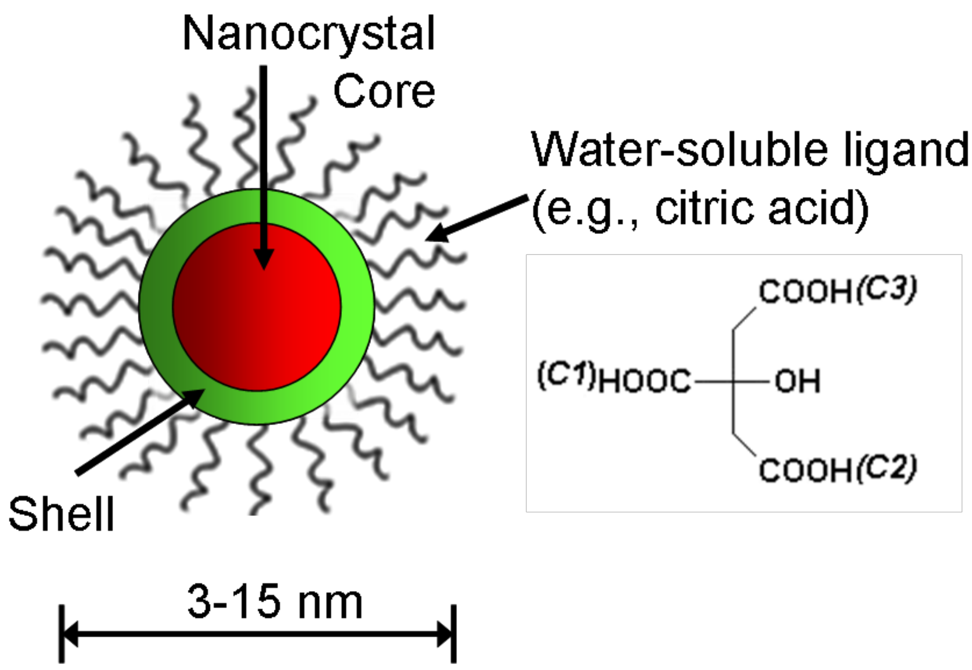
To develop and demonstrate a new class of tracers—semiconductor nanoparticles (quantum dots)—that offer great promise for use in characterizing fracture networks in EGS reservoirs. Due to their inherently excellent thermal stability and detectability, these structures can be designed to provide novel ways of interacting with fracture surfaces and vein pores in order to characterize the heat-exchange capacity of an EGS formation.

Summary of Scientific/Technical Approach

- *Synthesize laboratory quantities of nonsorptive quantum-dot tracers that fluoresce in the visible*
- *Test the quantum dot tracers for thermal stability and detectability*
- *Test the nonsorptive quantum dot tracers in benchtop reactors*
- *Modify the surface chemistry of the quantum dots to allow for interaction with fracture surfaces:*
  - *Reversible sorption on negatively charged rocks*
  - *Thermal decay*
  - *Contrasting diffusivity into vein pores*
- *Develop analytical/numerical models for the interaction of the quantum dot tracers with reservoir rock*
- *Synthesize kilogram quantities of quantum-dot tracers for use in field tests*
- *Field test the quantum dot tracers (nonsorptive, sorptive, diffusive and thermally decaying) in single-well injection/backflow applications*

Summary of Scientific/Technical Approach

Task 1.2 Design and synthesize water-soluble quantum dot tracers using newly developed low-temperature methods:

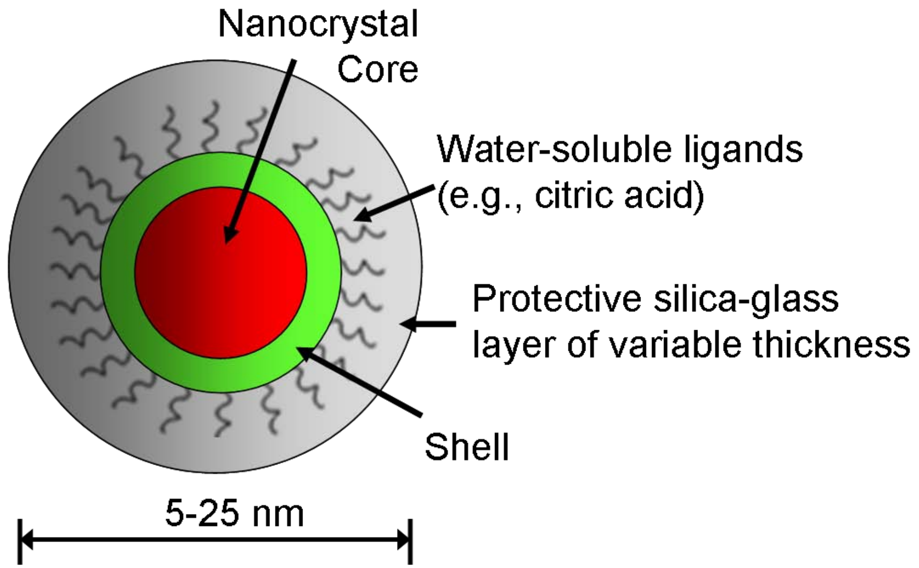


Option 1 – Conventional synthesis to create hydrophobic quantum dots, followed by a second step of surface-ligand exchange to render them hydrophilic

Option 2 – Modification of synthetic approach to allow for direct synthesis of hydrophilic nanocrystals

Summary of Scientific/Technical Approach

Task 1.4 Fabricate temperature and corrosion-stable nonsorbing quantum dot tracers:



Task 1.5 Test thermal stability of the nanocrystals in batch autoclave reactor experiments.

Task 1.6 Develop methods (direct spectroscopic and HPLC) for analyzing the nanocrystals.

Quantum Dot Tracers Can Be Used in the Determination of Fracture Surface Area

Modification of quantum dot surfaces allows for interaction with the fracture surfaces and pores that can then be used to infer the surface area for heat exchange:

- *Thermal decay*
- *Contrasting diffusivity*
- *Reversible sorption on negatively charged rocks*

Scientific/Technical Approach

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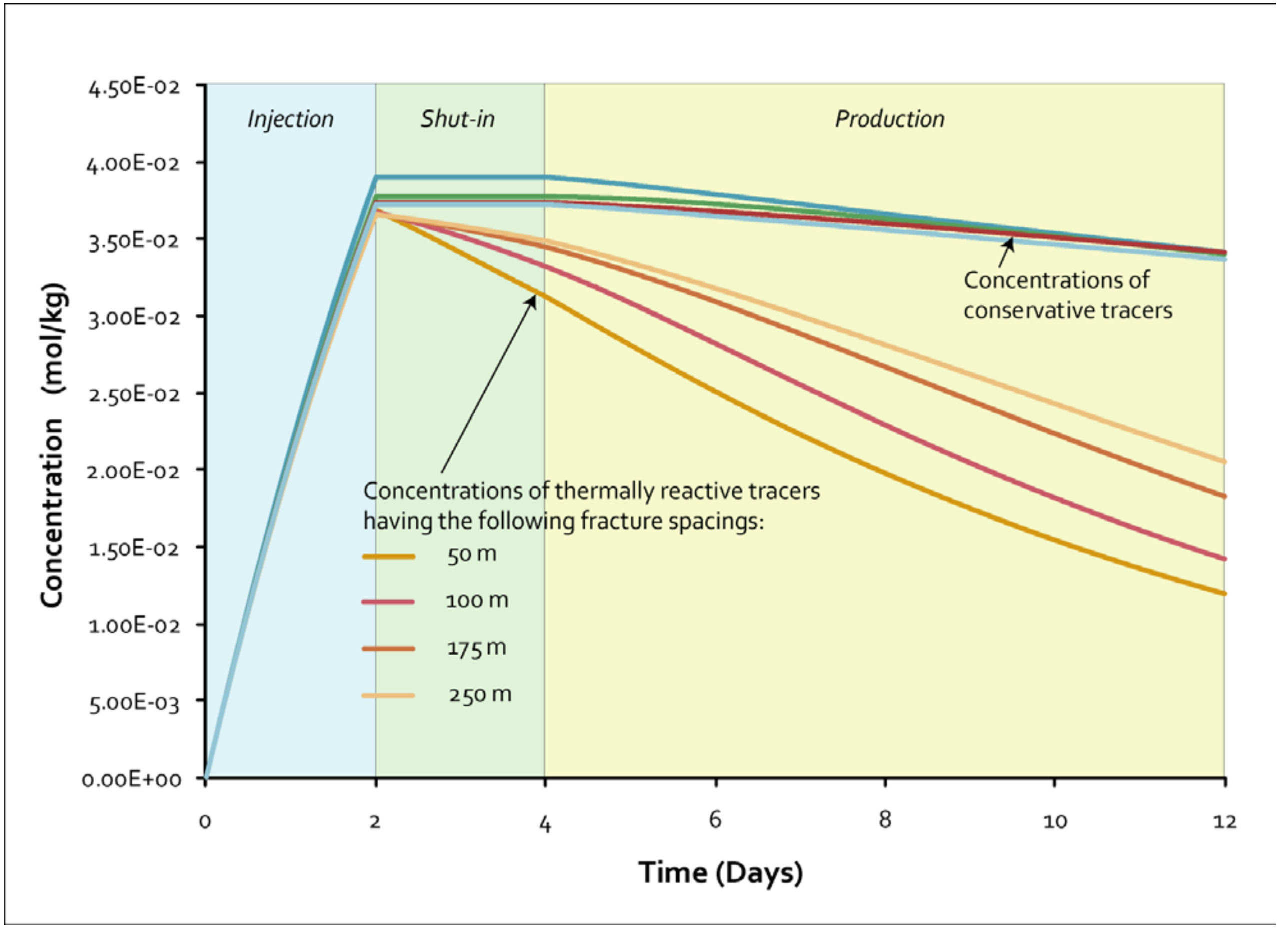
Summary of Scientific/Technical Approach:

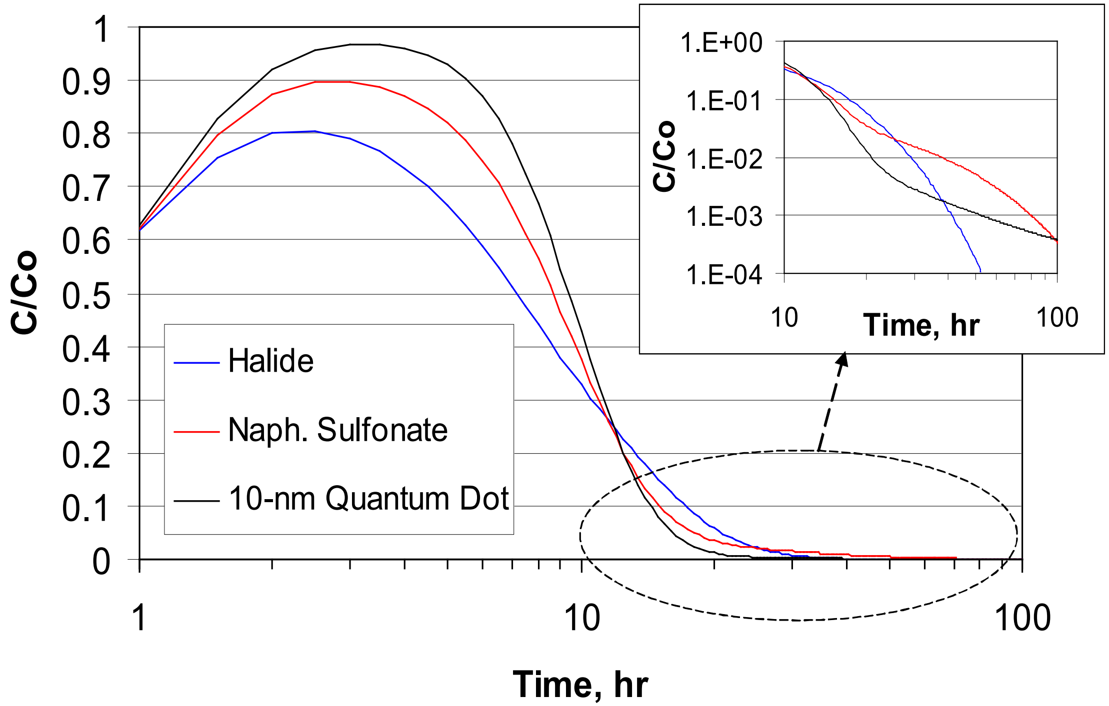
Thermal Decomposition of Surface Ligands Can Be Used To Turn the Quantum Dots into Reactive Tracers for Quantifying Near-Wellbore Fracture Surface Area

Plots of tracer concentration as a function of time during an injection/backflow numerical experiment. The curves show that the extent of thermal decomposition is a function of fracture spacing.



Summary of Scientific/Technical Approach:

Contrasts in Diffusivity Affects Tracer Response in an Injection/Backflow Test



Simulated breakthrough curves of a halide, a naphthalene sufonate, and a 10-nm-radius quantum dot tracer in a single-well tracer test. The differences between the curves will increase for greater surface area and decrease for less surface area.

Accomplishments, Expected Outcomes and Progress

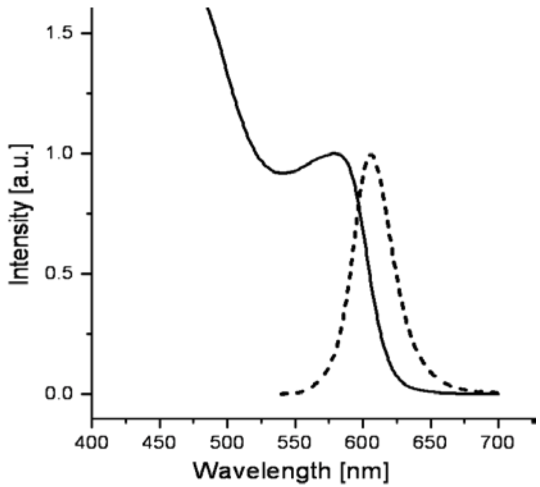
Describe the most important technical accomplishments or outcomes and their significance

- Full review projects: Describe accomplishments/outcomes from the past year to date
- Overview projects: Describe progress to date and/or planned accomplishments/outcomes.
- All Projects:
  - Include relevant data to support your accomplishments.
  - Highlight your team's qualifications, the quality of any special facilities or equipment, and any special recognition received.

Task 1.2: Design and synthesize highly-luminescent nonsorbing water-soluble quantum dot tracers

Two approaches to increasing laboratory production of the nanocrystals:

1. **Increasing the concentration of produced quantum dots in the reaction volume.**
2. **Increasing the reaction volume.**



Approach 1: A reaction at 130°C using the upscaling methods resulted in a 1,000-fold increase in yield, without sacrificing quantum dot quality.

Approach 2: Photograph of high-reaction-volume synthesis set-up for up-scaled quantum dot production.

Project Management/Coordination

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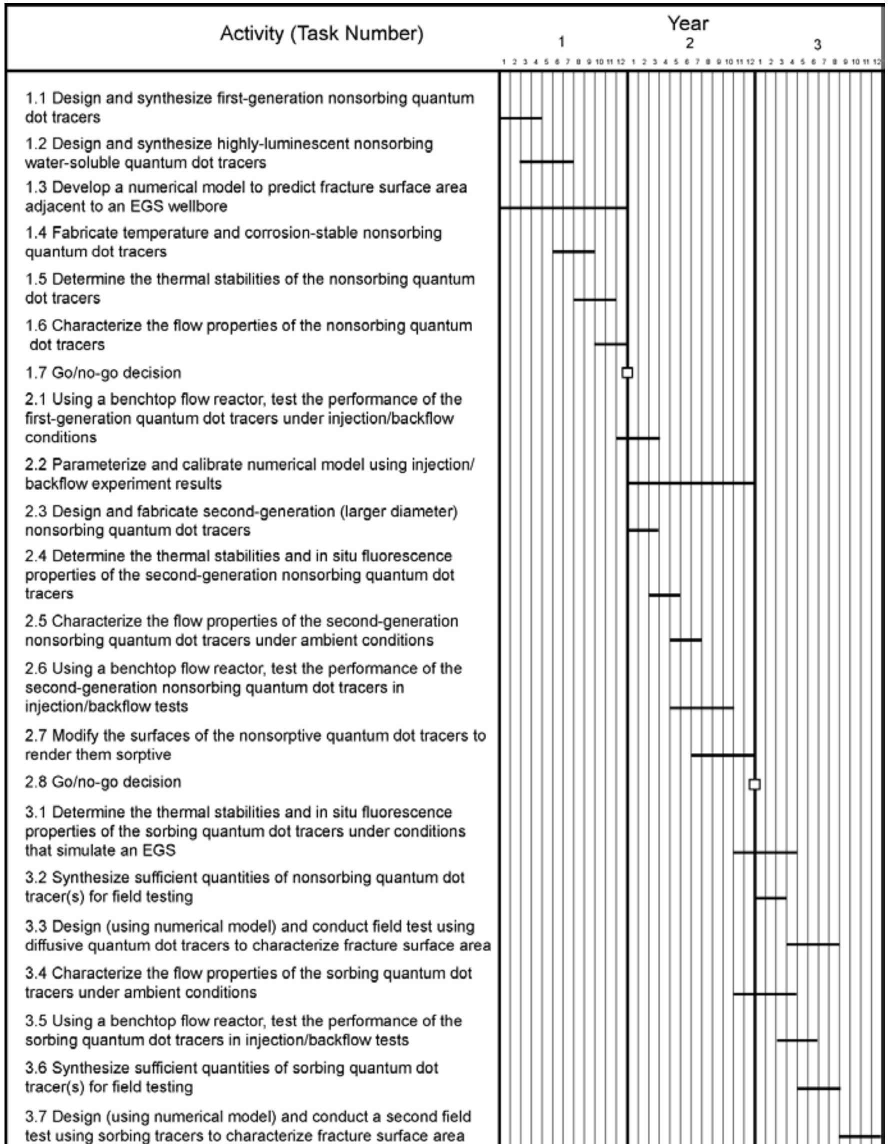

Summary and Conclusions

- Quantum dots are nanoparticle semiconductors that fluoresce according to their size. They show great promise for use as geothermal tracers since they can be synthesized through chemical approaches to have very distinct sizes and therefore very distinct colors.
- The surface chemistry of the quantum dots can and will be modified to allow for interaction with fracture surfaces:
  - Reversible sorption on negatively charged rocks
  - Thermal decay
  - Contrasting diffusivity into vein pores
- An array of quantum dots having a variety of colors can be excited by one common wavelength. This quality could be very useful in the design of field and wellbore tools, such as the borehole fluorimeter/flowmeter.