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Geothermal Reservoir Characterization by Thermo-Reporting Nanoparticles

For a modular and comprehensive approach to characterization of reservoir properties such as temperature, pH or salinity, we present reporting nanoparticles with an architecture that forms a dual signal system in a core-shell structure. In this proof of concept example of thermo-reporting nanoparticles, the inner shell contains an inert signalling function, which enables the detection of the particles upon recovery at the exit point. The outer shell contains a reporting function, which undergoes an irreversible change that is triggered upon being exposed to a certain known and well-defined external stimulus that the particles experience while flowing inside the reservoir.

As a demonstration for our dual signal system, we synthesized core-shell silica nanoparticles, in which the core and the shell contain two different fluorescent dyes. The core encapsulates the dye in a tight and leak-proof manner, also protecting it for ambient conditions, in a way that ensures a stable and steady fluorescence-based signalling function even when the particles experience temperatures at least as high as 200 ℃. A second fluorescent dye is contained within the shell, where it is exposed to ambient conditions. Modification of the shell with different stimuli-responsive materials resulted in an irreversible change in the reporting fluorescence signal of the outer dye. Upon crossing the designated temperature threshold, the reporting signal either increased, decreased or shifted. In tests conducted in a closed system, this led to a distinguishable change in the ratio of reporting to signalling fluorescence emission signals and therefore to detection of an event of heating above the threshold temperature. The threshold could be detected at a resolution of 4 ℃ or less and was tried with 3 different materials for sensing of different temperatures.

The use of a dual signal system based on two different fluorescent dyes proved to have considerable advantages: The particles will be recovered in the geothermal fluids, which contain many different solutes, each with its own spectral features, making spectroscopic detection of tracers difficult. However, emissions from fluorescent dyes are only evoked by exciting the collected sample at specific wavelengths, giving the nanotracers a unique fingerprint. Fluorescent dyes also enable extremely sensitive detection, especially as many dye molecules are concentrated in a single particle. We were able to detect our particles in clean water with a sensitivity that translates to detection of 1.3 g of nanoparticles in 1,000,000 liters of water. Moreover, detection by fluorescence spectroscopy is fast, simple and cheap, and enables real time monitoring of geothermal fluids recovered at the exit point. The principle of an internal reference system makes the measurement direct and independent so that unambiguous data can be obtained without prior knowledge of reservoir parameters such as flow, without the need to conduct reservoir simulations or know reaction parameters to correctly analyse to results.

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