

## **In-product Anti-counterfeiting agrochemicals using phase change nanoparticles**

Miao Wang

Department of Chemical Engineering

Counterfeited agrochemicals are often made with low quality reactants, and contain high level of unknown or banned chemicals, which can pollute the environment, and cause health problem for famers, and damage crops. Barcodes are ubiquitously used to tag products including agrochemical products, but common barcodes attached on packing can be altered or duplicated, facing increasing challenge from counterfeiting and unlawful use. There is an unmet need to develop covert (invisible) barcodes that can be added into products for anti-counterfeiting purposes, but existing techniques are inappropriate for covert operation due to large size, visibility, low capacity, and possibility of losing code integrity.

Nanomaterials with at least one dimension in nanometer scale such as nanoparticles, nanowires/tubes can be produced at high yield in controlled manners. These nanomaterials are invisible to naked eyes, can be directly added into objects of interest without being noticed, and have shown great potentials as covert barcodes. The unique properties of nanoparticles including optical, magnetic, electric and electro-chemical ones can be used for readout without signal amplification. But the use of nanoparticles to tag each object in a large number of objects is seriously limited due to lack of particle-specific signature, and small coding space. There is no nanoparticle-specific magnetic or electrochemical property, suggesting that one type of nanoparticles cannot be distinguished from other according to magnetic or electrochemical property.

This paper describes a new nanoparticles-based in-product barcode system, in which a panel of phase change nanoparticles with discrete and sharp melting peaks is added as a barcode into in a variety of agrochemicals. Environmentally degradable organic solids are used to make nanoparticles. The barcode can be readout by detecting melting peaks of nanoparticles using differential scanning calorimetry. This method has high labeling capacity due to small sizes of nanoparticles, sharp melting peaks, and large scan range of thermal analysis. The in-product barcode can be effectively used to protect agrochemical products from being counterfeited due to its large coding capacity, technical readiness, covertness, and robustness.

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