Polymer microparticles could help verify goods

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Portable authentication of currency. The covert, encoded particles become visible when illuminated with a near-infrared light source. (Inset) Encoded particles imaged under near-infrared illumination. Credit: Jiseok Lee

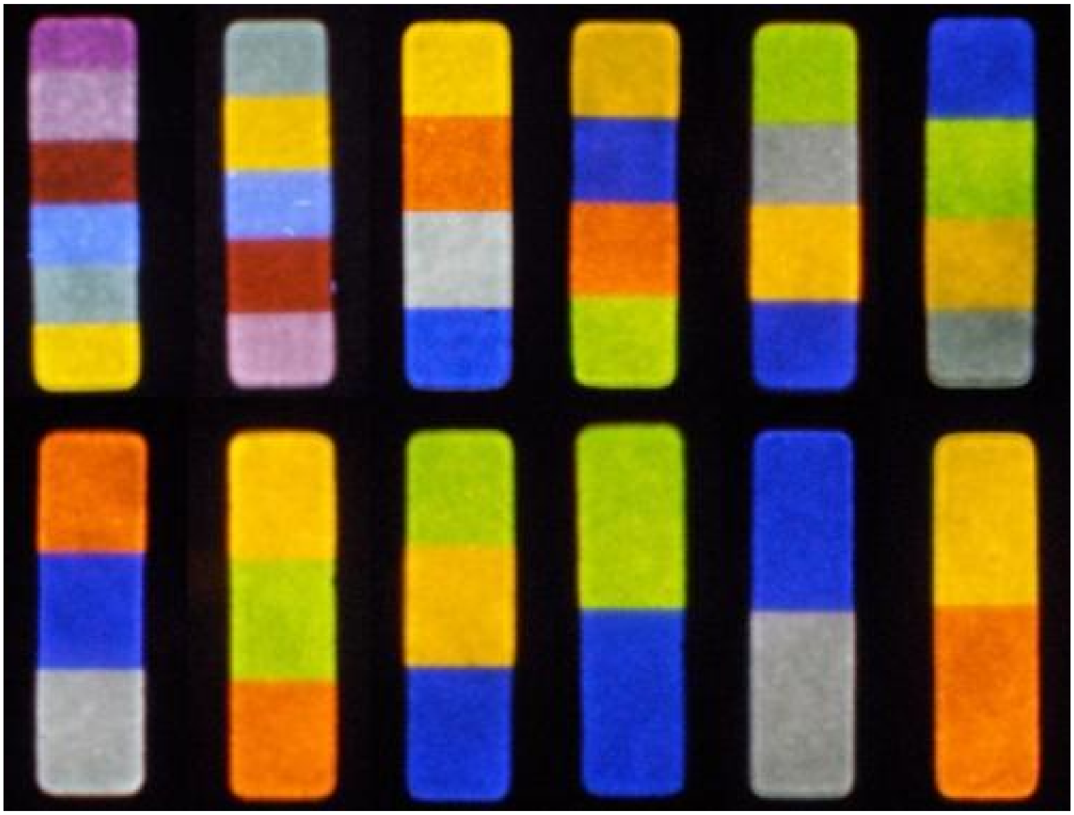
Some 2 to 5 percent of all international trade involves counterfeit goods, according to a 2013 United Nations report. These illicit products—which include electronics, automotive and aircraft parts, pharmaceuticals, and food—can pose safety risks and cost governments and private companies hundreds of billions of dollars annually.

Many strategies have been developed to try to label legitimate products and prevent illegal trade—but these tags are often too easy to fake, are unreliable, or cost too much to implement, according to MIT researchers who have developed a new alternative.

Led by MIT chemical engineering professor Patrick Doyle and Lincoln Laboratory technical staff member Albert Swiston, the researchers have invented a new type of tiny, smartphone-readable particle that they believe could be deployed to help authenticate currency, electronic parts, and luxury goods, among other products. The particles, which are invisible to the naked eye, contain colored stripes of nanocrystals that glow brightly when lit up with near-infrared light.

These particles can easily be manufactured and integrated into a variety of materials, and can withstand extreme temperatures, sun exposure, and heavy wear, says Doyle, the senior author of a paper describing the particles in the April 13 issue of *Nature Materials*. They could also be equipped with sensors that can "record" their environments—noting, for example, if a refrigerated vaccine has ever been exposed to temperatures too high or low.

The paper's lead authors are MIT postdoc Jiseok Lee and graduate student Paul Bisso. MIT graduate students Rathi Srinivas and Jae Jung Kim also contributed to the research.



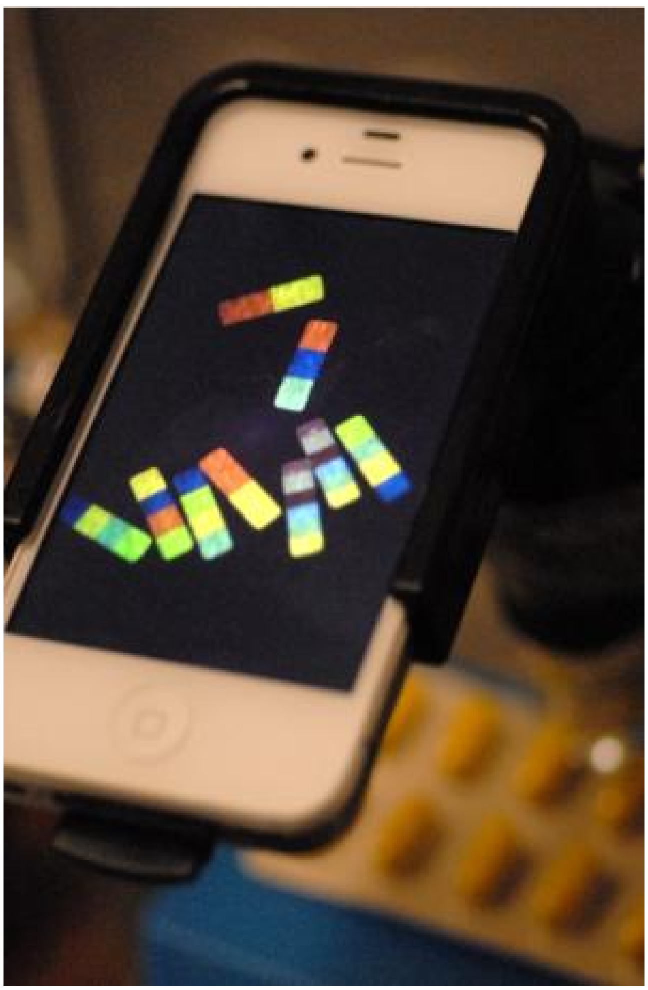
A small portfolio of encoded particles. The sequence of colors gives each particle an identity and over 1 million different particles are possible. Credit: Jiseok Lee

"A massive encoding capacity"

The new particles are about 200 microns long and include several stripes of different colored nanocrystals, known as "rare earth upconverting nanocrystals." These crystals are doped with elements such as ytterbium, gadolinium, erbium, and thulium, which emit visible colors when exposed to near-infrared light. By altering the ratios of these elements, the researchers can tune the crystals to emit any color in the visible spectrum.

To manufacture the particles, the researchers used stop-flow lithography, a technique developed previously by Doyle. This approach allows shapes to be imprinted onto parallel flowing streams of liquid monomers—chemical building blocks that can form longer chains called polymers. Wherever pulses of ultraviolet light strike the streams, a reaction is set off that forms a solid polymeric particle.

In this case, each polymer stream contains nanocrystals that emit different colors, allowing the researchers to form striped particles. So far, the researchers have created nanocrystals in nine different colors, but it should be possible to create many more, Doyle says.



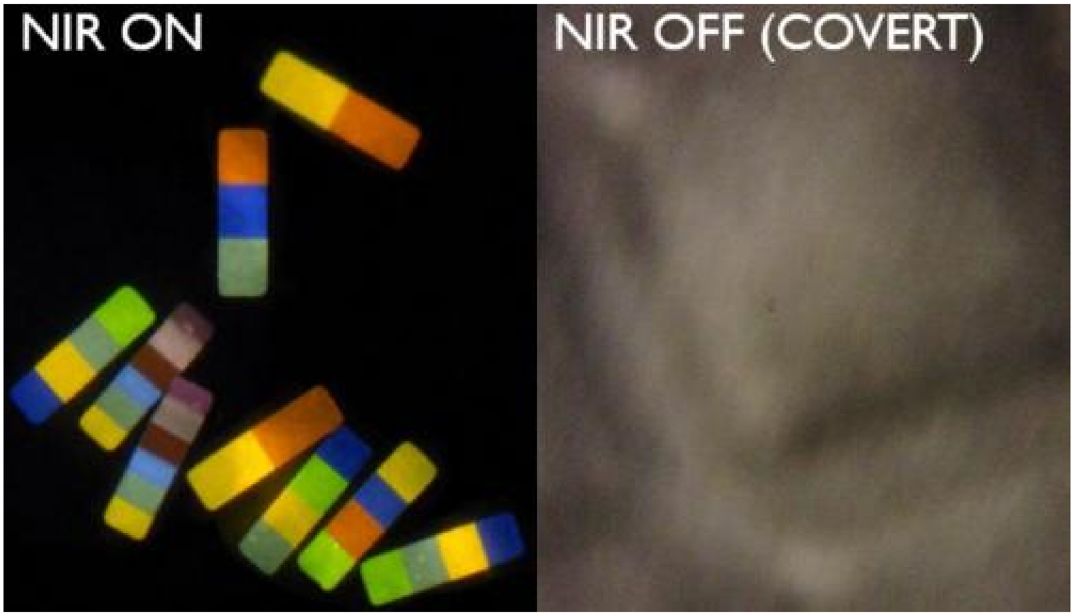
Use of a widely available portable device and versatile, secure tags has the potential to disrupt the anti-counterfeiting industry and make counterfeiting a fruitless, unprofitable venture. Credit: Jiseok Lee

Using this procedure, the researchers can generate vast quantities of unique tags. With particles that contain six stripes, there are 1 million different possible color combinations; this capacity can be exponentially enhanced by tagging products with more than one particle. For example, if the researchers created a set of 1,000 unique particles and then tagged products with any 10 of those particles, there would be 1030 possible combinations—far more than enough to tag every grain of sand on Earth.

"It's really a massive encoding capacity," says Bisso, who started this project while on the technical staff at Lincoln Lab. "You can apply different combinations of 10 particles to products from now until long past our time and you'll never get the same combination."

Versatile particles

The microparticles could be dispersed within electronic parts or drug packaging during the manufacturing process, incorporated directly into 3-D-printed objects, or printed onto currency, the researchers say. They could also be incorporated into ink that artists could use to authenticate their artwork.



Covert nature of tags. By matching the refractive index of the tag to the surrounding environment, the particles cannot be seen even under high magnification. Left: acquired image of tags on a pharmaceutical blister pack under near-infrared illumination. Right: acquired image of blister pack surface under a microscope without near-infrared illumination. Credit: Jiseok Lee

The researchers demonstrated the versatility of their approach by using two polymers with radically different material properties—one hydrophobic and one hydrophilic —to make their particles. The color readouts were the same with each, suggesting that the process could easily be adapted to many types of products that companies might want to tag with these particles, Bisso says.

"The ability to tailor the tag's material properties without impacting the coding strategy is really powerful," he says. "What separates our system from other anti-counterfeiting technologies is this ability to rapidly and inexpensively tailor material properties to meet the needs of very different and challenging requirements, without impacting smartphone readout or requiring a complete redesign of the system."

Another advantage to these particles is that they can be read without an expensive decoder like those required by most other anti-counterfeiting technologies. Using a smartphone camera equipped with a lens offering twentyfold magnification, anyone could image the particles after shining near-infrared light on them with a laser pointer. The researchers are also working on a smartphone app that would further process the images and reveal the exact composition of the particles.

More information: Universal process-inert encoding architecture for polymer microparticles, dx.doi.org/10.1038/nmat3938

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