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Quantum film threatens to replace CMOS image chips

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PORTLAND, Ore. — Just as photographic film was mostly replaced by silicon image chips, now quantum film threats to replace the conventional CMOS image sensors in digital cameras. Made from materials similar to conventional film—a polymer with embedded particles—instead of silver grains like photographic film the embedded particles are quantum dots. Quantum films can image scenes with more pixel resolution, according to their inventors, InVisage Inc., offering four-times better sensitivity for ultra-high resolution sensors that are cheaper to manufacture.

"Many innovations are said to be revolutionary, but are really incremental changes. InVisage's quantum film, on the other hand, really is revolutionary," said Tom Hausken, director of photonics and compound semiconductors at Strategies Unlimited (Mountain View, Calif.) "Quantum dots have been a solution looking for a problem for several years, and InVisage has found a very significant problem they can solve."

According to Morry Marshall, vice president of strategic technologies at Semico Research Corp. (Phoenix), InVisage could have the next generation image sensor. "It gathers more light so you can either make a smaller image sensor for a less expensive cell phone camera, or you make a higher resolution sensor for high-end digital cameras," Marshall said. "It's a huge step forward and the market is also huge, so they will also need to overcome the problems facing any small company when trying to penetrate a large market."

The new semiconducting material was invented by Univeristy of Toronto professor Ted Sargent, who is now chief technology officer at InVisage. Sargent perfected a method of suspending lead-sulfide nanoparticles in a polymer matrix to form a new class of semiconducting polymer that Invisage has spent the last three years integrating into a standard CMOS process. Now it can paint quantum film atop a low-cost wafer that has the electrode array for super-dense high-pixel-count images, but without any of the expensive CMOS photodetectors that make up the bulk of conventional digital camera sensors.

"Our quantum film replaces the silicon used for image capture, but what we have really created here is a new semiconductor material," said Jess Lee, InVisage president and CEO. "Our quantum film even looks like photographic film—an opaque black material that we deposit right on the top layer of our image chip."

Unlike tradition semiconductors, which have a fixed bandgap, the bandgap of Invisage's quantum film can be adjusted by changing the size of the embedded quantum dots. The film can also be painted-on at room temperature, obviating the need for expensive high-temperature fabrication techniques required by conventional sensors.

"We can paint our quantum-dot film onto any surface," said Lee. "Right now we are painting them on silicon wafers for our first product—an ultra low cost image sensor that obsoletes CMOS sensors."

Traditional CMOS sensors require that light filter down past several microns of metallization to reach the photodetectors on a silicon wafer, but InVisage's quantum film is on the top layer for 100 percent exposure to incident light.

"Traditional CMOS sensors require light to travel down through four or five microns of metal before reaching the photodetector, whereas our quantum film captures all the incident light in a layer just 500 nanometers thick," said Michael Hepp, director of marketing at InVisage (Santa Clara, Calif.).

This process that was improved upon by OmniVision (where Lee was formerly the vice president of the mainstream business unit) with back-side illumination (BSI). According to Lee, BSI only converts about 80 percent of incident light because trenches are required between pixels to prevent cross talk in conventional sensors. Quantum film, on the other hand, exposes the entire top layer of the chip to light, allowing 100 percent pixel coverage and without the need for BSI.

"Just by virtue of having our detector on the top surface, we get a 2X increase in sensitivity—the holy grail of the industry," said Lee. "Beyond that we have changed the materials too—our quantum film is twice as efficient at absorbing incident light for another 2X improvement, for a 4X improvement overall."

Physically, what happens is photons hit the quantum dots, but because of their small size quantum confinement converts the energy into an exciton—a bound electron-hole pair. The metal electrode then conducts the electron away thereby sensing the incident light.

"We draw down those electrons and store them on a capacitor in a very standard-looking CMOS pixel—except we don't have to build a photodetector too so we can use much larger and less expensive geometries, since the quantum film has already done all the light capturing steps on the first layer," said Lee.

As a consequence, InVisage claims to be able to create image sensors that are four-times as sensitive (or four times smaller for the same sensitivity) using a low-cost 8-inch, 1.1-micron CMOS line at TSMC, compared to the CMOS image vendors today who have to use an expensive 12-inch, 65 nanometer process to achieve inferior results.

For the future, the company also plans to target other specialized applications, such as pitch-black night vision goggles, cheaper solar cells and even spray-on displays.

"Because we have better quantum efficiency, we can also apply our quantum film technology to more efficiently collect light for solar cells, or for paintable displays on textiles, clothing and other novel uses such as glowing street signs and other night-time illumination needs," said Hepp.

InVisage has had two rounds of funding since its founding in 2006, including about $30 million so far from RockPort Capital, Charles River Ventures, InterWest Partners and OnPoint Technologies.