EMERGING RESEARCH FRONTS - 2009

April 2009

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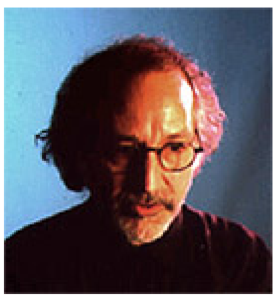
Geoffrey Alan Ozin talks with *ScienceWatch.com* and answers a few questions about this month's Emerging Research Front Paper in the field of Materials Science. The author has also sent along several images of his work.



Article: Colloidal crystal films: Advances in universality and perfection
Authors: Wong, S;Kitaev, V;Ozin, GA
Journal: J AM CHEM SOC, 125 (50): 15589-15598 DEC 17 2003
Addresses: Univ Toronto, Mat Chem Res Grp, Dept Chem, 80 St George St, Toronto, ON M5S 3H6, Canada.
Univ Toronto, Mat Chem Res Grp, Dept Chem, Toronto, ON M5S 3H6, Canada.

SW: Why do you think your paper is highly cited?

Our work paved the way for other researchers to reliably prepare high-quality colloidal crystal films for various applications in diverse research areas. We have demonstrated major advances in preparation of colloidal crystal films in two important directions: quality of microspheres, where monodispersity was improved to below 2%, and development of reliable universal procedure for preparation of high-quality films using arbitrary sizes of colloidal particles.

Importantly, the developed procedure is really facile and versatile, since it uses only simple laboratory equipment, so it can be readily implemented in different research laboratories. Furthermore, the developed procedure features all the necessary elements to be relatively easily-industrially-scaleable.

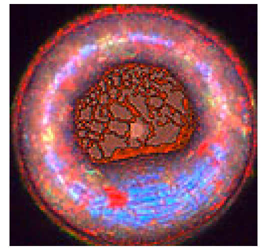
Finally, it was our decision to present the developed methodology in a form of clear well-detailed protocols for others to reproduce and build upon, rather than patenting the results. In this respect, it is pertinent to mention that one reviewer's critical comments on our manuscript was that the article feels and reads as a patent, which was actually the highest compliment given to us.

SW: Does it describe a new discovery, methodology, or synthesis of knowledge?

Compared to prior advances in the field (especially those made by Vicki L. Colvin of the Department of Chemistry, Rice University, Houston, TX, and David J. Norris of the NEC Research Institute in Princeton, NJ), we have developed a universal procedure to form colloidal crystal films out of arbitrary sizes of colloidal particles (from less than 100 nm to more than 1 micron).

We have clearly established the parameters necessary for reliable colloidal crystal film formation. These parameters included: i) most importantly, the quality of the microspheres, which happened to be extremely sensitive to the impurities within the largest sizes; ii) sufficient temperature and the geometry of the vessel to sustain required convection patterns; iii) the concentration of microspheres in dispersions which precisely control the thickness of the films.

The reported procedure has been demonstrated to be robust and reliable, so it can be repeated several times (e.g., Fig. 2), used for binary systems, scaled, etc., to produce virtually any type of colloidal crystal films to satisfy just about every requirement of the diverse fields of science that could benefit from the applications of advanced functional properties of colloidal crystal films.



Optical microphotographs of several attempts to deposit colloidal crystals on photonic fibers resulting in a donut and a bean, illustrating the beautiful colors of opals so formed. The diameter of the donut and the thickness of the bean are approximately 125 microns (300X magnification).

View/download accompanying four slides and descriptions.
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SW: Would you summarize the significance of your paper in layman's terms?

Similar to how oranges can be packed neatly in grocery stores, we mastered the packing of tiny spheres with the size of 1/100 of a human hair into perfectly ordered arrangements (Figs. 1,2). In addition, we have worked out how to make those spheres precisely the same—we did not want any bananas placed alongside our oranges.

The procedure for the sphere packing that we have developed is really straightforward. In a nutshell: the spheres are placed in a solvent, which is brought very close to its boiling point, so the liquid starts to evaporate quickly, and under the right conditions, these perfectly packed films grow upon evaporation.

While we—or other scientists doing similar work prior to us—would have liked to claim the credit for the novelty of these prepared materials, we certainly could not, as Nature had already prepared such materials long before. The opal, one of the earth's most lustrous gemstones, originated in Australia over 100 million years ago in silica-laden sediment deposited along the shoreline of the Artesian Basin. Opal is one of the few gemstones sedimentary in origin and contains 6 to 10% water from the ancient sea.

What we could take great pride in is that, with our control over sphere sizes and the way they pack, we could prepare opals of every possible color and shade! It may be curious to note that the best scientific samples had rather monotonous (if not to say relatively boring) colors (Fig. 3). At the same time, the scientific failures always had a silver lining of breathtaking colors (Fig. 4).

SW: How did you become involved in this research and were any particular problems encountered along the way?

The research was initiated in 2001 by a postdoctoral fellow and later research associate, Dr. Vladimir Kitaev, in a project on photonic crystal applications in optics. Vladimir started to work on the perfection of colloidal microspheres and their deposition under different conditions. The high-T setup was constructed and then an industrious undergraduate student, Sean Wong, came and put his energy to work along with Vladimir's on a project which later became a major part of the paper.

We are pleased to state that no specific problems were encountered along the way, but it is also instructive to note that we needed to take advantage of the extensive time needed to get everything just right and doubly checked before putting everything together to describe a reliable, highly reproducible procedure which others could easily adopt and utilize for their own diverse research activities.

SW: Where do you see your research leading in the future?

How we see it is, most importantly, that we have opened the way for other researchers to reliably prepare high-quality colloidal crystal films and to use them in their diverse areas of interest.

For us, this work served as a backbone for successful research on colloidal crystals, photonic crystals, sensors, and templating media, which resulted in a series of high-profile publications and the spin-off of a Toronto-based company, Opalux, whose mission is the development and commercialization of bottom-up active photonic crystal products that target electrically and mechanically tuneable full color coatings for applications exemplified by displays and battery state-of-charge monitors, along with banknote anti-counterfeit and product-authentification devices.

SW: Do you foresee any social or political implications for your research?

We evaluate this only in terms of the indirect scientific and technological impact of the proposed methodology, along with the reliable preparation of diverse high-quality colloidal films, which provide a versatile tool for further research within the diverse areas of chemistry, physics, materials science, engineering, biology, and medicine with direct applications in photonics and sensors, displays and security devices, membranes, and templating.

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KEYWORDS: BENARD-MARANGONI CONVECTION; PHOTONIC CRYSTAL; OPTICAL-PROPERTIES; THICKNESS; FABRICATION; OPALS; BAND; LITHOGRAPHY; CONTAINERS; PARTICLES.

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