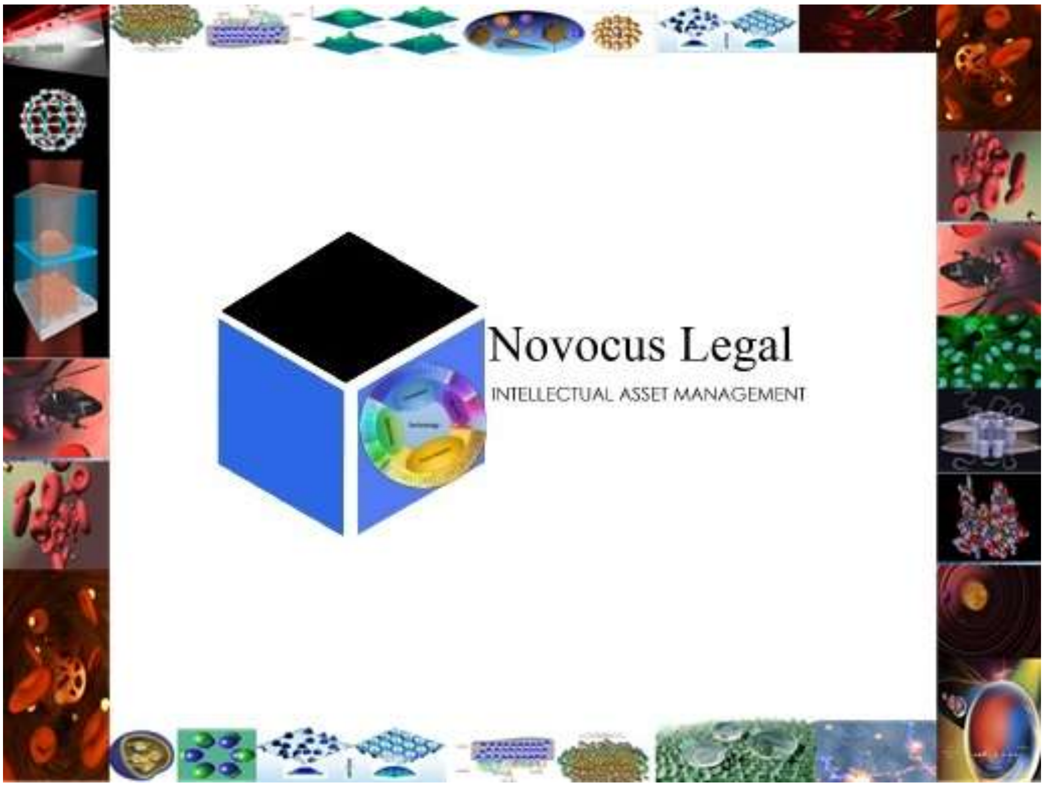


RARE NANOSTRUCTURES - I

ABSTRACT

This document is first in series of Rare Nanostructures or less known nanoparticles overviews, which we would present for our readers.

Ruchica Kumar

rkumar@novocuslegal.com

CONTENTS

INTRODUCTION

Purpose of this document is to provide readers with a glimpse of some rare nanostructures. We have compiled this document from reported facts and our sources are also given herein.

This document is first in series of Rare Nanostructures or less known nanoparticles overviews, which we would present for our readers.

All of us understand that nanotechnology is not a new product, but a potential enhancement to nearly all existing products. Numerous materials can be engineered into nanoparticles, using small clusters of atoms of gold, silver, iron, zinc, silica, titanium dioxide, etc. Carbon is another material used and can be made into hollow balls or tubes of atoms known as fullerenes. Breaking these materials down to the nanoparticle stages brings about new properties. For example, silver at this nanoparticle stage is very effective at killing microbes and keeping medical and food appliances hygienic; iron, on the other hand, has been found to be very effective at removing pollution from contaminated land. Scientists are discovering more and more uses for the technology around the world and are looking to bring many of these products to market.

In this document are presented just a few of the products (nanoparticles) currently developed or under development around the world. We have actively refrained from listing many known or under development application of listed nanoparticles. This is deliberate as we would want to encourage readers to think about possible applications of nanoparticles listed below and create new avenues for technology commercialization.

List given below names all rare nanoparticles explained in this document:

1. **Nanovolcanoes**

NOVOCUS LEGAL LLP has conducted detailed patent landscaping, technology white spacing, technology cluster commercialization studies for each of the Nanoparticles mentioned in this document.

We would be happy to share our research with interested readers. Please contact Author (email provided) for details.

Rest of the document would explain aforementioned nanoparticles briefly.

NANOVOLCANOES

Nanovolcanoes are very rare. We are presenting 4 types of Nanovolcanoes in this document.

1. Zinc Oxide (ZnO) Nanovolcanoes[1]
2. Light Carved Nanovolcanoes[2],[3]
3. Silver Nanovolcanoes[4],[5]
4. Helium Ion Nanovolcanoes[6]

All types have been studied for various applications like drug delivery.

ZINC OXIDE NANOVOLCANOES

[1] https://books.google.co.in/books?id=uX3RBQAAQBAJ&pg=PA477&lpg=PA477&dq=NANOVOLCANOES&source=bl&ots=pmMdrfzSLV&sig=osgUKrs7VKj-277kg5Vd8ecP7-o&hl=en&sa=X&ved=0ahUKEwjG8dvKrZ3aAhWLpY8KHQqmBv0Q6AEIYTAN#v=onepage&q=NANOVOLCANOES&f=false

[2] https://news.ncsu.edu/2013/06/wms-chang-nano-volcano/

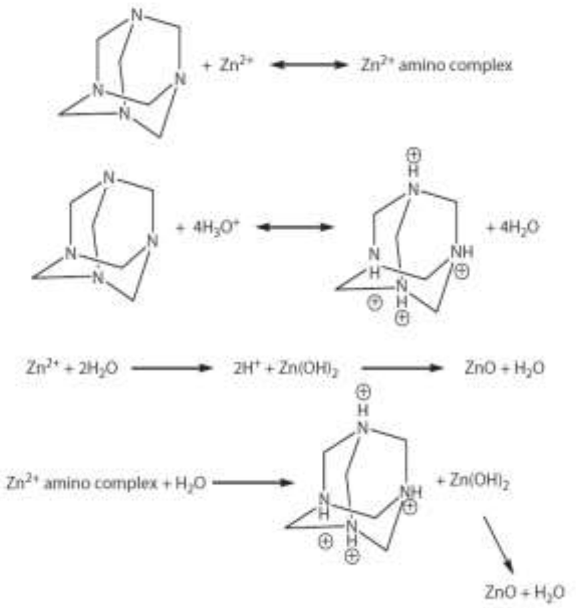
[3] https://www.photonics.com/Article.aspx?AID=54160

[4] https://www.nature.com/articles/srep34769

[5] https://www.realclearscience.com/journal_club/2016/10/10/silver_erupts_like_a_volcano_at_the_nanoscale.html

[6] https://avs.scitation.org/doi/10.1116/1.5001927?af=R

ZnO nanovolcanoes (ZnO) (depicted in image below) among other nanostructures, were grown (Reactions depicted below) using the hydrothermal technique from zinc nitrate and hexamethylenetetramine (HMT) as precursors. It was established that, by increasing the reaction time, the volcano-like and tube-like ZnO structures were formed due to the Ostwald ripening process and the selective adsorption of the complexes. In addition, the formation of large features at the edges of nanopores in freestanding silicon nitride membranes, called by authors "nanovolcanoes," was studied. It was established that the rate at which the nanopores open or close was strongly influenced by sample temperature. In addition, volcano size and closing rates were found to be dependent on the initial pore size.



The figure presented above depicts reactions that have been used for creating nanovolcanoes using Zinc Oxide.

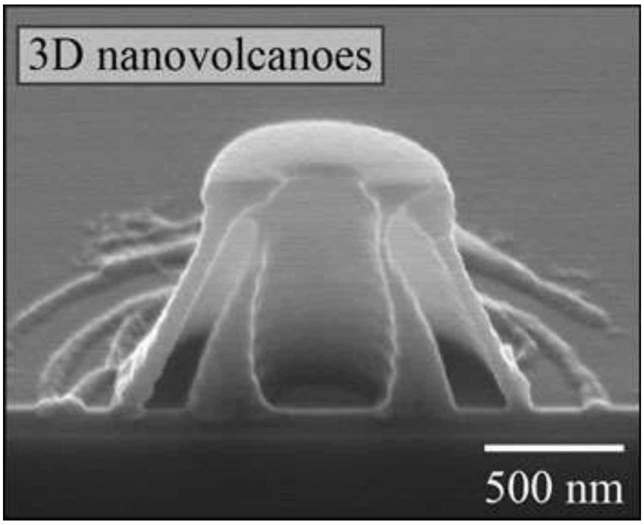
LIGHT CARVED NANOVOLCANOES

Researchers from North Carolina State University have developed a method for creating "nano-volcanoes" by shining various colors of light through a nanoscale "crystal ball" made of a synthetic polymer. These nano-volcanoes can store precise amounts of other materials and hold promise for new drug-delivery technologies.

The researchers have created the nano-volcanoes by placing spherical, transparent polymer nanoparticles directly onto the flat surface of a thin film. They then shine ultraviolet light through the transparent sphere, which scatters the light and creates a pattern on the thin film. The thin film is made of a photoreactive material that undergoes a chemical change wherever it has been struck by the light. The researchers then submerge the thin film in a liquid solution that washes away the parts of the film that were exposed to light. The material that remains is shaped like a nanoscale volcano.

The pattern of light may be controlled by changing the diameter of the nanoparticle spheres, or by changing the wavelength – or color – of the light that is shinned through the spheres. This way the shape and geometry of these structures, such as how big the cavity of the nano-volcano will be may be controlled. The researchers developed a highly accurate computer model that predicts the shape and dimensions of the nano-volcanoes based on the diameter of the nanoscale sphere and the wavelength of light. These structures have precisely measured hollow cores, and precisely measured openings at the "mouth" of the nano-volcanoes, they are good candidates for drug-delivery mechanisms. The size of the core would allow users to control the amount of the drug a nano-volcano would store, while the size of the opening at the top of the nano-volcano could be used to regulate the drug's release.

According to Dr. Chih-Hao Chang, an assistant professor of mechanical and aerospace engineering at NC State - The materials used in this process are relatively inexpensive, and the process can be easily scaled up. In addition, we can produce the nano-volcanoes in a uniformly patterned array, which may also be useful for controlling drug delivery."



Cross-section of a nanovolcano carved using UV light. The Nanovolcanoes have precisely measured hollow cores and openings at their "mouth," which make them a good candidate for drug-delivery mechanisms, its developers at North Carolina State University say. Courtesy of Chih-Hao Chang, NC State.

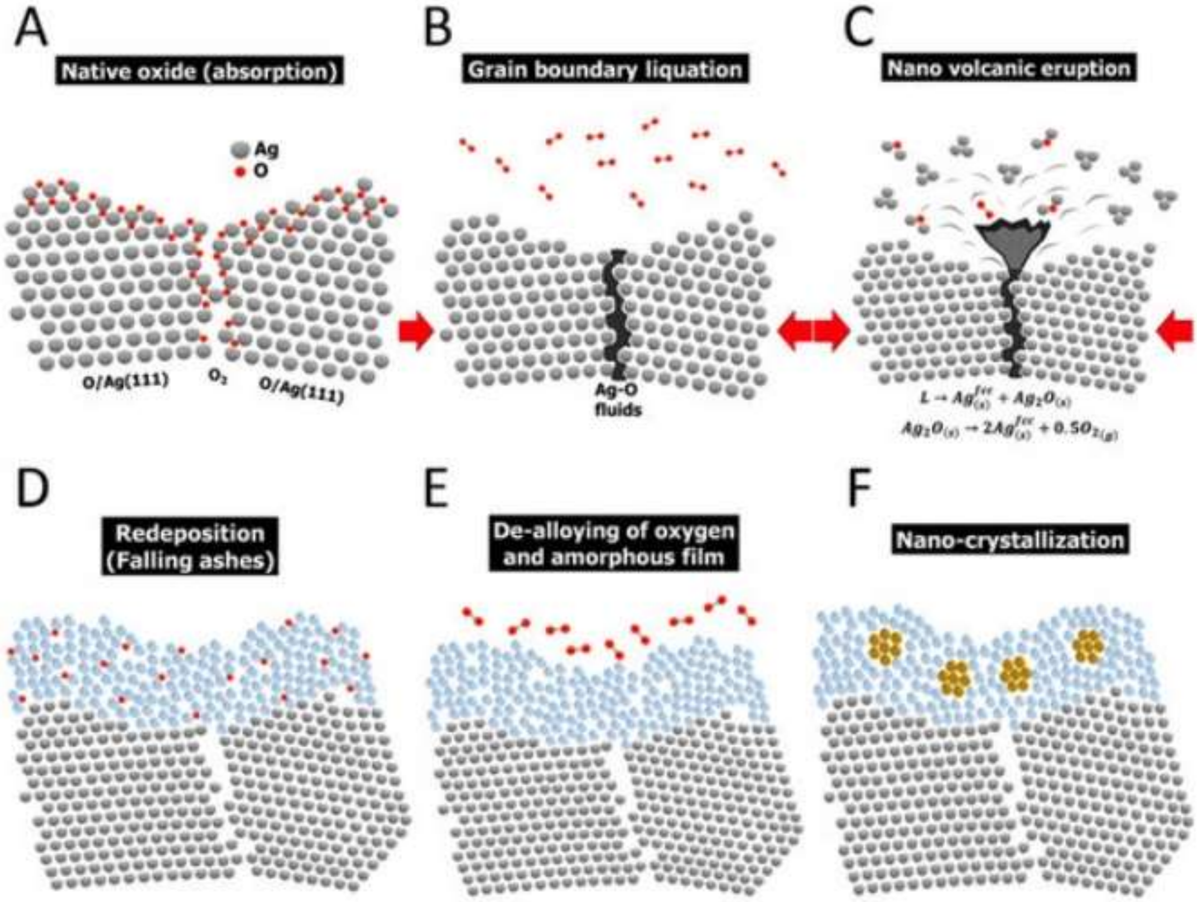
SILVER NANOVOLCANOES

Silver (Ag) is one of the seven metals of antiquity and an important engineering material in the electronic, medical, and chemical industries because of its unique noble and catalytic properties. Ag thin films are extensively used in modern electronics primarily because of their oxidation-resistance. Here we report a novel phenomenon of Ag nano-volcanic eruption that is caused by interactions between Ag and oxygen (O). It involves grain boundary liquation, the ejection of transient Ag-O fluids through grain boundaries, and the decomposition of Ag-O fluids into O2 gas and suspended Ag and Ag2O clusters. Subsequent coating with re-deposited Ag-O and the de-alloying of O yield a conformal amorphous Ag coating. Patterned Ag hillock arrays and direct Ag-to-Ag bonding can be formed by the homogenous crystallization of amorphous coatings. The Ag "nano-volcanic eruption" mechanism is elaborated, shedding light on a new mechanism of hillock formation and new applications of amorphous Ag coatings[7].

A team of Japanese and Taiwanese researchers has observed silver erupting like a volcano at the nanoscale. The researchers blended oxygen atoms into liquid and poked and prodded the mixture at various temperatures and pressures until they witnessed a surprising series of events (illustrated in the figure below).

The Ag-O liquids that are ejected from grain boundaries are transformed into oxygen gas and free silver and siiver-oxide clusters, exactly as in a volcanic eruption. The suspended silver and silver-oxide clusters are then re-deposited on the silver film, just as ash falls after a volcanic eruption, forming a conformal Ag-O coating[8].

[7] https://www.nature.com/articles/srep34769
[8] https://www.realclearscience.com/journal_club/2016/10/10/silver_erupts_like_a_volcano_at_the_nanoscale.html



HELIUM ION NANOVOLCANOES

Both helium and gallium ion beams were employed to fabricate nanopores. Herein, three-dimensional nano-volcano-shaped nanopores (3D-NVNs) were directly formed using helium ion beam with no precursors required, while the gallium ion beam produced V-shaped nanopores. Hundreds of 3D-NVNs were fabricated with a mean diameter of 229 ± 7 nm, where the He ion beam milling rate for the 3D-NVNs was 3.6 ± 0.2 µm3/µC. The height of the 3D-NVNs was greater than their depth when the dose range was 0–10 nC/µm2, while the height remained constant for doses above 10 nC/µm2. Trajectory simulations of the ion bombardment into the gold film clarified that ion implantation could primarily account for the volcano-shaped nanopore formation[9].

[9] https://avs.scitation.org/doi/10.1116/1.5001927?af=R

CONCLUSION

Apart from 4 types of Nanovolcanoes listed above, various other types of self-assembled Nanovolcanoes have been observed and studied for optoelectronic applications.

A host of less-common nanostructures have been synthesized and characterized by a series of modern techniques. a considerable number of reported nanostructures have been obtained accidentally. Size and shape of formed nanostructures obviously depend on reaction conditions as in standard chemical reactions: concentration of precursors, temperature, pressure, process duration, and mixing rate.

These nanostructures are applied or can be applied in diverse fields, including templating and superhydrophobic coating, nanocatalysis, surface functionalization, spintronics, quantum computing and data (or energy) storage media, gas sensors, optoelectronic devices, sensors, fuel cells, field emitter or other thin-film, functional polymer composites, and superconductivity, drug delivery among many others.

ABOUT THE AUTHOR

Mrs. Ruchica Kumar - An Intellectual Property professional and a registered patent agent who been working in the highly specialized and focused field of Patent Management. As a registered patent agent she has drafted and prosecuted various patent applications. Her work is focused on technical and strategic facets of patent management involving patent analytics, acquisition and management. Her area of specialization is patinformatics wherein, she leverages technical aspects of patent drafting, patent valuation and patent citations to generate comprehensive patent intelligence data. Her sound technical skill set amalgamated with a strong patent knowledge base provides her good understanding of dynamics of cross industry innovation.

Her competencies include:

- Innovation Forecasting – Analyzing knowledge spill-overs and externalities for forecasting new innovation areas for an organization using patents as indicators
- Patent Drafting in fields of Medical surgical devices and implants, cardiac rhythm management devices, urology, gynecology.
- Patent Invalidation and Patentability assessment
- Technology infusion and diffusion studies using patents as indicators
- Licensing and Technology Transfer in fields of general engineering
- Indian Patent filing and prosecution
- Technology Mapping
- Pre-litigation due diligence

DISCLAIMER