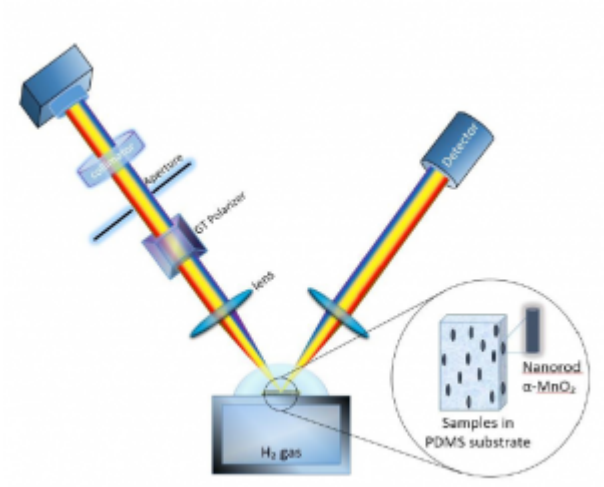
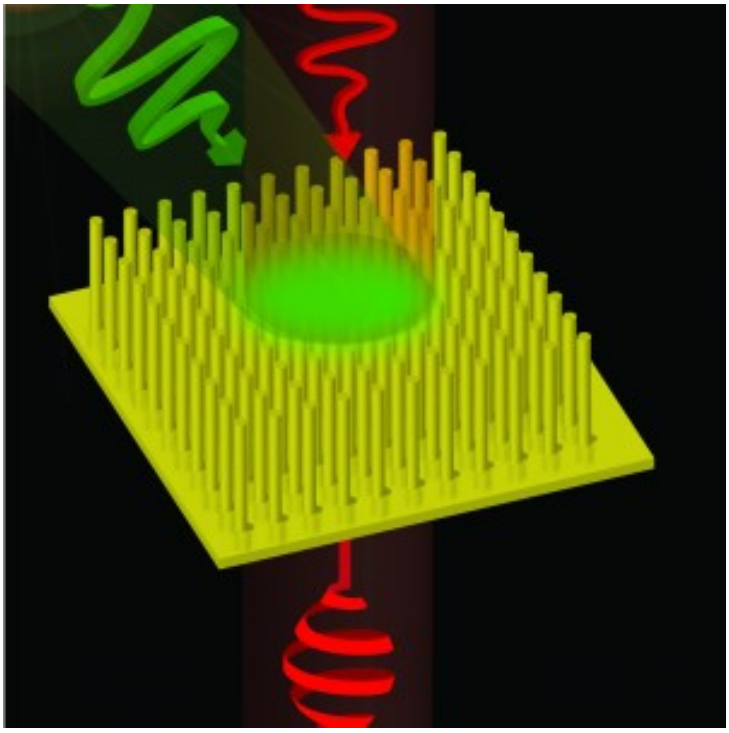
# Our new paper in Applied Physics A




Congratulations for the publication of paper”New generation of α-MnO2 Nanowires @PDMS composite as a Hydrogen gas sensor”, in journal of  Applied Physics A, by  Seyedeh Mehri Hamidi1, Alireza Mosivand1, Mina Mahbobi1, Hadi Arabi, Narin Azad, Murtada Riyadh Jamal.

Abstract—New hydrogen gas sensor has been prepared by α-MnO2 nanowires in polydimethylsiloxane matrix. For this purpose, the high aspect ratio α-MnO2 nanowires has been prepared by the aid of Hydrothermal method and then dispersed into Poly-dimethyl siloxane polymer media. In order to gas sensing, the samples have been exposed under different gas concentrations from 0 to 5%. The sensor responses have been examined by normalized ellipsometric parameter with respect to the chamber fill with N2 Gas. Our results indicate linear behavior of resonance wavelength in ellipsometric parameter as a function of gas concentrations which can open the new insight for the sample’s capability to hydrogen gas sensing applications.

# Scientists develop ultra fast method of changing fundamental property of light



Researchers from the Reactive Plasmonics team at King's College London have developed a new method for rapidly changing the polarisation of light, one of its fundamental properties. The research, published in Nature Photonics, could lead to much faster data transfer and advance research into nano-materials.

A light wave undulates in different ways – known as its polarisation. The polarisation of light is changed by the material it passes through, so we can use it to learn about unseen nano-scale worlds such as drug chemistry and quantum electronics. Switching polarisation is also used to transfer digital information along fibre optic cables.

The electronic methods currently used to control the light

polarisation in such applications is reaching its physical speed limit.  Researchers at King's have overcome this problem, allowing polarisation to be switched at timescales of less than a millionth of a millionth of a second – hundreds of times faster than current electronic methods.

This will allow us to 'see' very fast nano-scale processes such as chemical reactions for the first time, by illuminating them with rapidly changing light. This helps us to understand the difference in formation of nasty chemicals and life-saving drugs, and allows us to study new materials that will bring about the next technological revolutions.  This will also represent a major advance in data transfer speeds. By rapidly changing the polarisation of light – to represent a one or a zero – data can be passed along fibre optic cables and into your living room more rapidly. This will help meet growing data sharing demands driven by streaming and cloud services.

The team designed nano-structured materials that can control light polarisation using light itself – a technique known as 'all-optical polarisation control'.  These nano-structures are known as metamaterials: materials with optical properties not available in nature. These thin, lightweight materials are constructed from elements smaller than a thousandth of a millimetre in order to create exotic optical effects.

In this case, the metamaterial is constructed of gold nano-particles. A high intensity light pulse is fired into the metamaterial, injecting energy into electrons in gold particles, which in turn changes the refractive index of the material.

A second pulse is fired at the metamaterial at the same time. As this pulse passes through the material, the change in refractive index changes its polarisation. This all happens instantaneously, allowing polarisation to be changed trillions of times per second.  By simply shining two beams of light through the material, one beam is able to control the

polarisation of the other at ultrafast speed.

The effect can be observed even with one beam. In this case, the polarisation of the light transmitted through the metamaterial changes with the intensity. It is like polaroid sunglasses which adjust themselves to remove glare whenever it is too much sunlight.

Luke Nicholls, the PhD student who carried out these experiments, said, “With everybody using more and more data, streaming videos, music and sharing pictures, we are fast approaching a point where the current internet infrastructure will not be able to cope. All-optical control provides an answer to this looming problem and hopefully sees an end to staring at the infuriating buffer wheel.”

This research also has potential beyond how many box sets we can download. Control of light at such short time scales could also feed into quantum information processing, where controlling the polarisation of light is integral for building successful quantum computing devices.

Reactive Plasmonic’s PI Anatoly Zayats of King’s College concludes: “This effect opens up many opportunities for new applications which can directly impact everyday life. The faster you can control light polarisation, the faster you can use light to transmit data and make measurements.”

more information:


- *Nature Photonics* **volume 11**, pages 628–633 (2017)
- doi:10.1038/s41566-017-0002-6

# Unusual scaling laws for plasmonic nanolasers beyond the diffraction limit

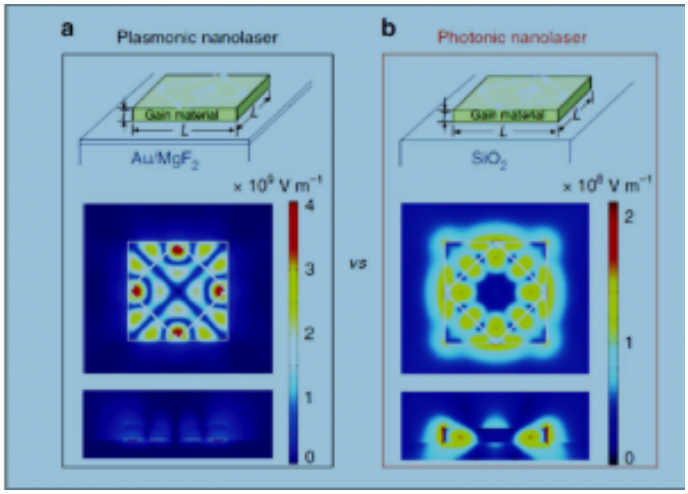



Fig. Schematic of plasmonic and photonic lasers and their cavity modes. a Top: schematic of the plasmonic nanolaser devices consisting of a nanosquare gain material on top of metal separated by a few nanometers of dielectric. Bottom: top and side views of electric field (|E|) profiles of a cavity mode in a 700 × 700 × 100 nm plasmonic cavity. b Top: schematic of the photonic nanolaser devices consisting of a nanosquare gain material on top of dielectric. Bottom: top and side views of electric field (|E|) profiles of a cavity mode in a 700 × 700 × 100 nm photonic cavity. In both panels, L and T are the length and thickness of the nanosquare, respectively, and TIR represents total internal reflection.

Plasmonic nanolasers are a new class of amplifiers that generate coherent light well below the diffraction barrier bringing fundamentally new capabilities to biochemical sensing, superresolution imaging, and on-chip optical communication. However, a debate about whether metals can enhance the performance of lasers has persisted due to the unavoidable fact that metallic absorption intrinsically scales with field confinement. Here, we report plasmonic nanolasers

with extremely low thresholds on the order of 10 kW cm−2 at room temperature, which are comparable to those found in modern laser diodes. More importantly, we find unusual scaling laws allowing plasmonic lasers to be more compact and faster with lower threshold and power consumption than photonic lasers when the cavity size approaches or surpasses the diffraction limit. This clarifies the long-standing debate over the viability of metal confinement and feedback strategies in laser technology and identifies situations where plasmonic lasers can have clear practical advantage.

more information on: https://www.nature.com/articles/s41467-017-01662-6 ,

DOI: 10.1038/s41467-017-01662-6

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# thesis defense

congratulations to Ms. Asgari , Ms. Mahboubi, Ms. Gachilou and Mr. kouhestanian, for defending your dissertation at approved

times.

| Defense time | | |
|---|---|---|
| Mr. Kouhestanian | 96/10/23 | 10:00 |
| Ms. Gachilou | 96/10/23 | 13:30 |
| Ms. Mahboubi | 96/10/23 | 15:00 |
| Ms. Asghari | 96/10/25 | 8:30 |

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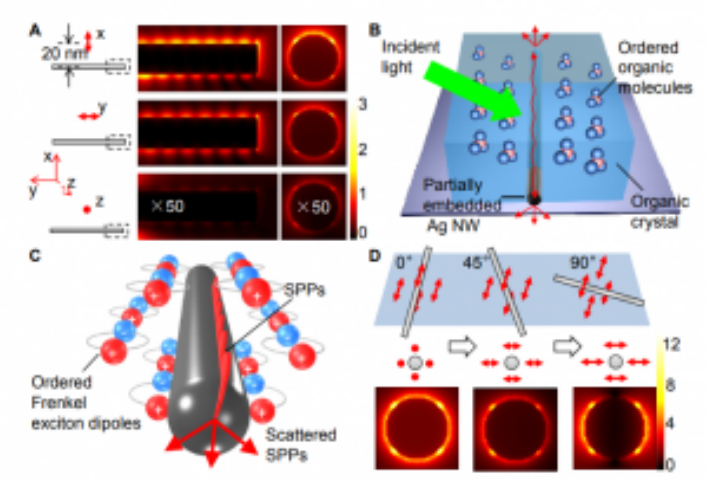
# Orientation-Dependent Exciton-Plasmon Coupling in Embedded Organic/Metal Nanowire Heterostructures




Organic/metal nanowire heterostructures for the study of orientation dependent exciton-plasmon coupling. (A) Numerically simulated |E| 2 distribution of SPPs at the end of a 200-nm-diameter and 6 μm-long AgNW, where SPPs are launched by a dipole oriented along three coordinate axes x, y, and z, respectively. The dipole is positioned at the middle of the wire with a distance of 20 nm. (B) Schematic illustration for the proposed heterostructure with orderly arranged molecules around a partially embedded AgNW. (C) Oriented Frenkel typeexciton dipoles created around the AgNW by irradiation of an incident light at the junction. SPPs can be efficiently launched by the exciton dipoles, which will subsequently propagate along the AgNW and scatter into free space at the distal ends. (D) SPPs coupling by multiple exciton dipoles. The cross angle between the AgNW and the polarization of dipoles are 0°, 45° and 90°.

The excitation of surface plasmons by optical emitters based on exciton-plasmon coupling is important for plasmonic devices with active optical properties. It has been theoretically demonstrated that the orientation of exciton dipole can significantly influence the coupling strength, yet systematic study of the coupling process in nanostructures is still hindered by the lack of proper material systems. In this work, researchers have experimentally investigated the orientation-dependent exciton-plasmon coupling in a rationally designed organic/metal nanowire heterostructure system. The heterostructures were prepared by inserting silver nanowires

into crystalline organic waveguides during the self-assembly of dye molecules. Structures with different exciton orientations exhibited varying coupling efficiencies. The near-field exciton-plasmon coupling facilitates the design of nanophotonic devices based on the directional surface plasmon polariton propagations.

**this research has published as a paper.**

more information:https://www.ncbi.nlm.nih.gov/pubmed/28930431

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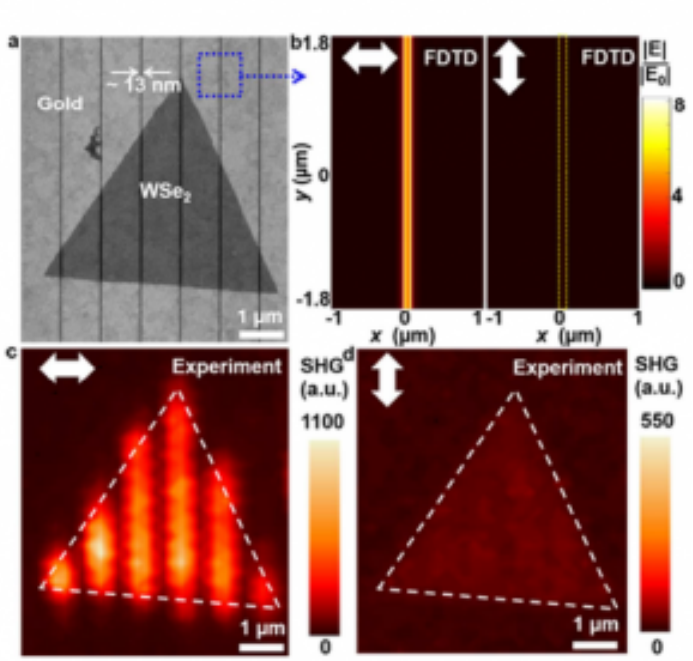
# Selectively Plasmon-Enhanced Second-Harmonic Generation from Monolayer Tungsten Diselenide on Flexible Substrates




. Pump-laser-polarization dependent SHG mapping. (a) SEM image of single-crystalline monolayer WSe2 flake on trenches with a pitch of 910 nm. (b) Simulated electric field distribution at a plane 1 nm above the surface of gold substrate with pump laser polarized perpendicular (left panel) and parallel (right panel) to the trench. The dotted line outlines the geometry of the trench. (c,d) Corresponding experimental SHG mappings of the exact WSe2 flake on trenches as shown in the SEM image in (a) under resonant and non-resonant excitations, respectively. White dashed lines outline the WSe2 flake. The white arrows show the polarization directions of the pump laser.

Monolayer two-dimensional transition metal dichalcogenides (2D TMDCs) exhibit promising characteristics in miniaturized nonlinear optical frequency converters, due to their inversion asymmetry and large second-order nonlinear susceptibility. However, these materials usually have a very short light interaction lengths with the pump laser because they are atomically thin, such that second-harmonic generation (SHG) is generally inefficient. In this research, Joel.K.W.Yangs group fabricated a judiciously structured 150-nm-thick planar surface consisting of monolayer tungsten diselenide and

sub-20-nm-wide gold trenches on flexible substrates, reporting ~7000-fold SHG enhancement without peak broadening or background in the spectra as compared to WSe2 on as-grown sapphire substrates. their proof-of-concept experiment yields effective second-order nonlinear susceptibility of 2.1 × 104 pm/V. Three orders of magnitude enhancement is maintained with pump wavelength ranging from 800 nm to 900 nm, breaking the limitation of narrow pump wavelength range for cavity-enhanced SHG. In addition, SHG amplitude can be dynamically controlled via selective excitation of the lateral gap plasmon by rotating the laser polarization. Such fully open, flat and ultrathin profile enables a great variety of functional samples with high SHG from one patterned silicon substrate, favoring scalable production of nonlinear converters. The surface accessibility also enables integration with other optical components for information processing in an ultrathin and flexible form.

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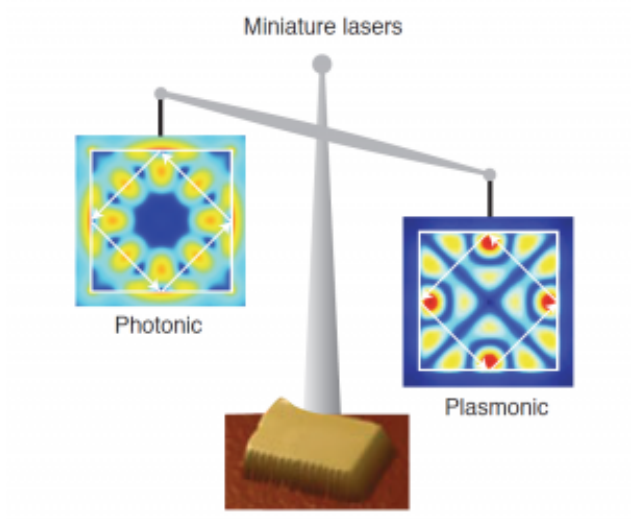
# Is metal a friend or foe?




A long-standing question debated among the nanophotonics community is whether size matters and helps to reduce the

threshold ofmicrometre- and submicrometre-sized lasers, and whether the presence of metal interfacing the gain medium harms or improves the laser performance. In a work published in Nature Communications, Ren- Min Ma and colleagues1 address this issue through a thorough experimental study, and conclude that when the device dimensions approach the diffraction limit, plasmonic (metal-based) lasers have superior performance over traditional photonic lasers as they are faster and have lower threshold and lower power consumption (Fig. 1). A laser has two major components: (i) a gain medium providing for stimulated emission and light amplification, and (ii) a resonator facilitating stimulated emission feedback (loosely speaking, reflecting generated photons to the place of their origin and, in many cases, enabling a coherence of laser radiation). The most basic laser cavity supporting standing-wave oscillation modes consists of two parallel mirrors, the distance between which is equal to an integer number of 'half-wavelengths' (λ/2) of laser radiation. Therefore, the minimum distance between the mirrors is equal to λ/2, which is equivalent to ~250 nm in the visible part of the spectrum – an order of magnitude larger than the typical size of a modern transistor. This hinders the dream of keeping up with the Moore's law by replacing electronic circuits with much faster optical circuits2, which would require laser-based sources and amplifiers of
coherent light. A novel solution to the size problem was put forward in 2003 by Bergman and Stockman3, who proposed to change the feedback mechanism and replace a set of large (by the nanoworld standards) mirrors with a nanoscopic metallic structures
that support resonant oscillations of free electrons (weakly) coupled to modes of electromagnetic radiation – the phenomenon known as a localized surface plasmon. The proposed device, termed spaser, which can be as small as a few nanometres, was primarily intended to generate surface plasmons (rather than photons) and be directly integrated into optical frequency circuits4. The first experimental demonstration, in 2009, of

the spaser-based nanolaser5, in which the 14-nm Au plasmonic nanoparticle, providing for a stimulated emission feedback, was surrounded by the 44-nm dye-doped silica shell, providing for gain, was followed by a rapid development of a variety of micrometre- and submicrometre-sized plasmonic lasers (or spasers)6, bringing the dream of nanocircuitry operating at optical frequency closer to reality. Besides the very possibility of having a laser whose size is not limited by λ/2 – which, not coincidentally, is close to the diffraction limit for light (the minimum area into which the light can be focused) – the heuristic expectation that a smaller volume laser can have a lower power consumption is one of the prime motivations for laser miniaturization1. This poses the following dilemma: on one hand, surface plasmons, supported by metallic particles and structures, allow lasers to be small, giving the hope of a low power consumption and high speed. On the other hand, metals are known to have large optical loss, which tends to increase the threshold pumping power (the laser threshold) and the overall power consumption. Therefore, do metals and surface plasmons help or harm miniature lasers and does the answer to this
question depend on the laser size? Ma and co-authors fabricated and characterized an impressive sum of 170 optically pumped plasmonic and photonic lasers based on rectangular CdSe slabs placed on top of MgF2/Au and SiO2 substrates, respectively (with the thickness of the slabs varied between 50 nm and 1,000 nm, and their length varied between 0.8 μm and 6 μm). The key difference between the metal-assisted lasers in this work and the spaser3 is that while the volume of the mode is comparable or less than λ3, the demonstrated lasers are subwavelength only in one vertical dimension, while in-plane they are larger than λ and exhibit standard multiple resonances due to reflections from the cavity edges. As a result, only a small fraction of light energy penetrates into the metal and the losses are substantially reduced in comparison to the metallic structures that are sub-wavelength in all three dimensions7. The

stimulated emission threshold power density Pth/S (kW cm−2), the power consumption at the threshold Pth (mW) and the emission lifetime τ (ns) have been studied as the function of the CdSe slab's volume V (measured in units of λ3). Furthermore, the emission lifetime τ was studied and correlated with the threshold power density Pth/S for multiple slab thicknesses T. It has been shown that although Pth and Pth/S in large (V ≥ 5λ3) photonic lasers are comparable or even superior to those in plasmonic counterparts, these quantities increase dramatically at smaller laser volumes (particularly if the CdSe slab's thickness approaches the diffraction limit). At the same time, in small plasmonic lasers (T ≤ diffraction limit), the growth of Pth/S with the reduction of V is much less dramatic and the power consumption Pth decreases with the reduction of V, justifying the quest for laser miniaturization. This allowed Ma and co-workers to demonstrate a low lasing threshold of ~10 kW cm−2 in a plasmonic laser operating below the diffraction limit (V ~ λ3 and T ~ 100 nm). According to Purcell8, spontaneous emission lifetime in a cavity (in the absence of non-radiative decay) is roughly proportional to the mode volume Vm and, since the emitter is broadband, inversely proportional to the quality factor Q, defined as Q = ω/Δωsp, where ω is the frequency and Δωsp is the spontaneous emission bandwidth. Hence, the lifetime is predicted to decrease with the reduction of the physical volume of the CdSe slabs, in both photonic and plasmonic lasers1. This prediction was in good agreement with the experimental emission lifetimes measured in lasers of different sizes. Furthermore, the threshold was experimentally demonstrated to grow with the reduction of the spontaneous emission lifetime, in good agreement with 'old school' laser science9. Importantly, it has been experimentally shown that sub-diffraction plasmonic lasers can have shorter lifetimes than photonic lasers, for the same threshold value. Therefore, plasmonic lasers can be faster and, at the same time, have lower threshold than photonic lasers when the cavity volume approaches or becomes smaller than the diffraction limit

cubed. The results reported by Ma and coauthors1 are of high importance, as they demonstrate the advantage of plasmonic lasers over photonic lasers (of the same sub-diffraction size) and pave the road to their further miniaturization. The next critical step in this direction would be an experimental study of the size dependence of plasmonic lasers, which are sub-diffraction in all three dimensions, and a comparison of the results with the theoretical predictions10.
In the long term, however, achieving electrically pumped plasmonic nanolaser operation will truly open the doors for practical applications of these devices.

more information on : https://www.nature.com/articles/nmat5065.

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# Developing Gold Nanoparticle-Embedded Dielectric Thin Films

research on noble metal nanoparticles has always remained interesting because of their optical and electronic properties. Gold nanoparticles (AuNPs), in particular, have been intensively studied for their fascinating localized surface plasmon resonance (LSPR) peak in the visible region of electromagnetic spectrum. The tunable nature of LSPR of AuNPs leads to a large number of applications of AuNPs in the fields of plasmonics and bioscience.

The LSPR peaks of AuNPs can be tuned from the visible to the near-infrared region by controlling the shape, size, and structure of the particles. Another way of changing the optical properties is to change the surrounding of AuNPs as

the LSPR peak is also very sensitive to the dielectric properties of the surrounding medium. The later method becomes an easy and superior one when the nanoparticles are embedded in a dielectric matrix. If the surrounding matrix is a transparent one, at least in the region of the spectrum where LSPR occurs, it becomes an added advantage for many photonic and plasmonic applications.

In order to explore and control the effects of shape, size, structure and dielectric media on LSPR properties, several preparation methods are used to form hybrid structures of nanoparticles and dielectric interfaces. In the present work, different ways of tuning LSPR positions of metal-dielectric nanocomposite thin films have been demonstrated with AuNPs embedded indium oxide (Au:IO) thin films as a case study. Au:IO thin films have been prepared by a sequence-specific sandwich method. The films were characterized by glancing angle x-ray diffraction (GXRD), optical absorption, high-resolution transmission electron microscopy (HRTEM) and Rutherford backscattering spectrometry (RBS). The advantages of the sandwich method have been shown by comparing the optical properties of Au:IO thin films so formed with that of Au:IO films formed by the most commonly used co-sputtering method.

**Importance of the work**

The work in the publication titled “Tailoring plasmonic properties of metal nanoparticles embedded dielectric thin films: The sandwich method of preparation” by Ranjit Laha et al. reports the experimental ways of tuning plasmonic positions (following a derived working formula) of AuNP embedded metal oxide thin films. The novelty lies in followings

- A specific sequence of the sandwich method has been suggested that enables the many independent ways of

tuning the plasmonic positions. The different steps involved such as thermal evaporation, sputtering and intermediate annealing are common techniques used in industry as well as research & development laboratories. Therefore, it is not very difficult to adopt the method.

- Controlled agglomeration-cum-self assembling process has been used as an advantage in tuning the plasmonic properties against the common belief that "agglomeration of small particles into big ones is a disadvantage in many nanoparticles research problems".
- The shape of the embedded AuNPs has been characterized to be oblates by a combination of HRTEM and RBS studies. Normally, characterizing shape of buried particles is a difficult proposition.
- An empirical working formula has been derived for tailoring the plasmonic position of any pair of the metal-dielectric nanocomposite. Thus, by knowing the shape and volume fraction of the embedded nanoparticles, plasmonic position can be worked out.
- To the best of our belief, the work will have impact among the researchers working on nurturing the nanoscale properties in photonic and plasmonic applications.

This study, Tailoring plasmonic properties of metal nanoparticle-embedded dielectric thin films: the sandwich method of preparation was recently published in the *Journal of Nanoparticle Research*.

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# Nano aluminium offers fuel

# cells on demand – just add water

The accidental discovery of a novel aluminium alloy that reacts with water in a highly unusual way may be the first step to reviving the struggling hydrogen economy. It could offer a convenient and portable source of hydrogen for fuel cells and other applications, potentially transforming the energy market and providing an alternative to batteries and liquid fuels.

“The important aspect of the approach is that it lets you make very compact systems,” says Anthony Kucernak, who studies fuel cells at Imperial College London and wasn’t involved with the research. “That would be very useful for systems which need to be very light or operate for long periods on hydrogen, where the use of hydrogen stored in a cylinder is prohibitive.”

The discovery came in January, when researchers at the US Army Research Laboratory at Aberdeen Proving Ground, Maryland, were working on a new, high-strength alloy, says physicist Anit Giri. When they poured water on it during routine testing, it started bubbling as it gave off hydrogen.

That doesn't normally happen to aluminium. Usually, when exposed to water, it quickly oxidises, forming a protective barrier that puts a stop to any further reaction. But this alloy just kept reacting. The team had stumbled across the solution to a decades-old problem.

Hydrogen has long been touted as a clean, green fuel, but it is difficult to store and move around because of its bulk. "The problem with hydrogen is always transportation and pressurisation," says Giri.

## Slow reaction

If aluminium could be made to effectively react with water, it would mean hydrogen on demand. Unlike hydrogen, aluminium and water are easy to carry – and both are stable. But previous attempts to drive the reaction required high temperatures or catalysts, and were slow: obtaining the hydrogen took hours and was around 50 per cent efficient.

The new alloy, which the team is in the process of patenting, is made of a dense powder of micron-scale grains of aluminum and one or more other metals arranged in a particular nanostructure. Adding water to the mix produces aluminium oxide or hydroxide and hydrogen – lots of it. "Ours does it to nearly 100 per cent efficiency in less than 3 minutes," says team leader Scott Grendahl. Moreover, the new material offers at least an order of magnitude more energy than lithium batteries of the same weight. And unlike batteries, it can remain stable and ready for use indefinitely.

The army team has used the material to power a small, radio-controlled tank. Grendahl doesn't see any practical issues with scaling up production to produce hundreds of tonnes of the stuff as it can be made from scrap aluminium, which is relatively cheap. The new material could power everything from laptops to buses and cars.

"In principle, the process should work," says Robert Steinberger-Wilckens, who directs a fuel cell programme at the University of Birmingham, UK.

But he cautions that a repeat experiment is needed to show that the reaction works the way it should. "There's a lot of stuff that works in the laboratory but not in the field."

If it does pan out, the powder could also be used as the raw material for 3D printing. The researchers have put forward proposals – now being considered by the army – for small air or ground robots that use their own structure as fuel. These self-cannibalising machines would be useful for one-way

intelligence-gathering missions, burning themselves up at the end to leave no trace.

more information: https://www.newscientist.com/article/2142693-nano-aluminium-offers-fuel-cells-on-demand-just-add-water/

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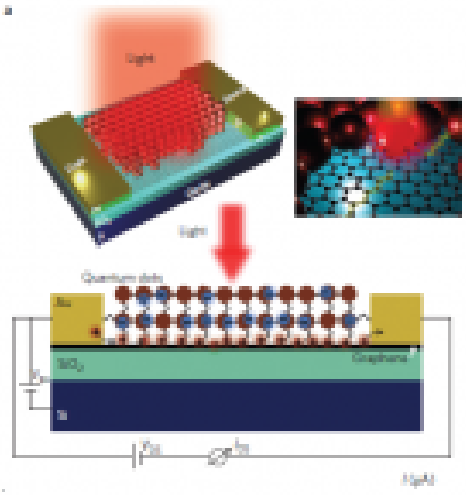
# Hybrid graphene–quantum dot phototransistors with ultrahigh gain



Graphene is an attractive material for optoelectronics1 and photodetection applications2–6 because it offers a broad spectral bandwidth and fast response times. However, weak light absorption and the absence of a gain mechanism that can generate multiple charge carriers from one incident photon have limited the responsivity of graphene-based photodetectors to

~1022 AW21. Here, this group demonstrate a gain of ~108 electrons
per photon and a responsivity of~107 AW21 in a hybrid photodetector
that consists of monolayer or bilayer graphene covered
with a thin film of colloidal quantum dots. Strong and tunable light absorption in the quantum-dot layer creates electric charges that are transferred to the graphene, where they recirculate many times due to the high charge mobility of graphene and long trapped-charge lifetimes in the quantumdot layer. The device, with a specific detectivity of 731013 Jones, benefits from gate-tunable sensitivity and speed, spectral selectivity from the short-wavelength infrared to the visible, and compatibility with current circuit technologies.

more information: Gerasimos Konstantatos *et al.* *nature nanotechnology*, DOI: 10.1038/NNANO.2012.60.