Received: 4 December 2023 | Revised: 18 January 2024 | Accepted: 28 February 2024 | Published online: 5 March 2024

Journal of Optics and Photonics Research
2024, Vol. 1(3) 99–108
DOI: 10.47852/bonviewJOPR42022233

BON VIEW PUBLISHING

REVIEW

Hybrid Nanoplatforms and Silica Nano-hole Particles Intended for Enhanced Energy Modes: Light-Scattering Studies Toward Lasers Developments

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Abstract: In this short review, it was communicated about the design and synthesis of optical active nanoplatforms for light scattering studies highlighting holed nanoarchitectures as main sources of potential additional resonances and enhanced phenomena. In this regard, the nanoplatforms were based on varied materials such as silicon compounds, silica, modified organosilanes, noble metals, and organic materials as well; such molecular and polymeric spacers, chromophores, etc. Thus, it was discussed how it could be recorded enhanced light-scattering signaling from hybrid nanoplatforms and nano-hole particles; from where it was produced constructive wavelengths with a consequent amplification. In this context, it was afforded to the discussion of examples of laser light-scattering properties and optical approaches already developed. In addition, it was showed new developments within nano-optics to be considered for further studies and applications. And, in this direction, it was considered the study from single nanoplatforms toward higher sized modified surfaces and 3D substrates. In this manner, it was leaded to the design of nano-optical resonators as well as nano-arrays resonators. Thus, it was evaluated varied materials to incorporate and evaluate the next generation of nano-optical platforms by controlling nano-chemistry and beyond for targeted photo-physics. The variable materials showed differences between varied modes of resonances and expected performances.

Keywords: optical active nanoplatforms, nano-hole particles, nanoresonators, confined light, enhanced light-scattering, light-scattering

1. Introduction

Light scattering is a phenomenon related to energy matter interaction from the molecular level [1]. In this manner, each functional group formed by variable atoms could generate different and specific signals that could be used for varied studies and applications. Even, these types of signals are not so high sensitive; it is very valuable and used due to any matter composition could be produce it. So, in this perspective it was studied and managed this energy matter interactions to develop many studies and spectroscopical techniques as well. In this context, dynamic light scattering afforded to low cost size particle determinations within colloidal dispersions in the nano-scale and beyond [2]. Moreover, Raman scattering spectroscopy and Rayleigh scattering techniques and methods related are largely used in fundamental research, chemical characterization, and chemical sensing applications too [3, 4]. In these perspectives, it is of high interest the developments of new optical setups and approaches from the control of the nano-scale in order to enhance light scattering [5]. Thus, the control of the chemical matter composition by wet-chemical methods and laser-assisted techniques could provide alternative designs and strategies to increase scattering [6, 7]. In this way, it could be noted many strategies; however, it should be highlighted "surface-enhanced Raman scattering" (SERS) with the incorporation of plasmonics nanomaterials [8, 9]. Plasmonics is a high impact research field related to the generation of high intense electro-magnetic fields from electro-active materials such as metals, high conjugated organic molecular structures, and semiconductors [10, 11]. The higher intensities could interact within its close surrounding, known as the near-field, and modify the physical properties of the related materials in contact. In addition and in similar manner, the use of confined resonant silica structures showed interesting results related to amplified scattering signaling such as silicon Raman lasers, laser Rayleigh properties, and applications [12–14]. The mentioned phenomena are currently being studied and require new approaches and methodologies to lead about tuning and control of enhanced light scattering. And, there is challenge and interest to generate new constructive energy modes from light–matter interactions that could lead to amplified signals [15].

In this manner, in this research review manuscript, it was afforded to discuss and propose new prototypes of innovative enhanced light-scattering nanoplatforms and confined nano-hole particles synthesis based on nano-template methods. It was showed and discussed some

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examples with their characterizations, and kinetics of formation, leading the discussion toward potential uses for enhanced light properties by proper chemical surface modifications, controlling sizes, shapes, confined volumes with molecular reporter modifications, as well as other approaches. It is mentioned the formation of silica hole nanoarchitectures by applying CeO@g-CN double-shelled spheres as templates (Figure 1). The nano-hollowed particles diminished the inner filter effect but also maximized the electroluminescence emission of targeted dyes interacting [16].

In this context, it should be highlighted the need to develop methods of synthesis within colloidal dispersions due to the challenge associated with aggregation, deformation, and lack of well-defined structures. However, considering metallic nanoparticles could provide more stable structures but adding additional optical properties. So, the strategy to generate optical active nano-holed structures by using non-optical active silica structures with enhanced light scattering properties based on electronic resonances is of high interest. In a similar manner, the tuning of bandgaps involucred in the electronic processes is expected to be controlled considering single crystals, morphologies associated, and materials grafted on surfaces [17]. By this manner and varying optical approaches and support materials, such as varied Lasers, polymers and technological materials associated, it could be tuned signals as well [18]. Therefore, it was introduced to light scattering and enhanced strategies for the design of optical active nanomaterials for varied studies and applications by combining different materials.

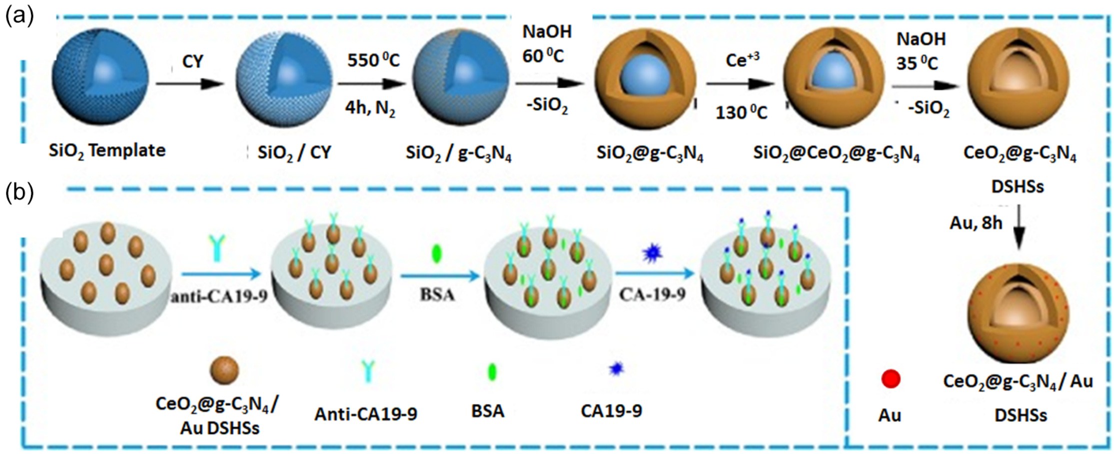
Finally, it is noted that it could be found from literature a high interest in these themes and topics related. These are based on the combination of light matter interactions, where depending of the intrinsic properties of matter involucred, it is the final energy mode excited. Therefore, the excited energy mode could be coupled with other radiant energy modes to improve, amplify, and enhance signaling. Light scattering from electron scattering could reflect so many times within holes creating electromagnetic waves and new levels of energies that produce from augmented scattering toward enhanced pathways. In a similar manner, absorbance in the basal state could be modified based on the different electronic properties generated from the whole nanomaterial. And, finally, it is highlighted that the incorporation of laser dyes could add extra modes of resonant energies with modified and enhanced luminescence emission. Therefore, in brief it is expected to open the attention in these types of new tuneable nanoarchitectures for future designs from the desk to the bench and optical setups too.

2. Enhanced Light Scattering from Nanoplatforms

From previous discussion, it was noted the importance of the matter bottom up to generate targeted signaling accompanied with perspective of enhanced properties. And in this context it was noted the meaning of enhanced for the cases under discussion in relation with increased characteristics by tuning matter in absence of chemical modification. These type of phenomena either are not related to metamaterials due to the enhancement or by interaction of matter conserving their intrinsic properties individually. Moreover, it should be noted the concept of amplification by augmenting the quantity of the physical events produced by multiple-matter interactions as occurred between multiple and variable mirror materials as, for example, applied for lasers developments.

In this regard and trying to present some insight in these phenomena, it was introduced the use of modified nanoplatforms in order to tune enhanced light scattering. The design of hybrid nanoplatforms based on varied modified matter in their close surrounding with smaller nanoparticles could lead to improved stimulation toward optical active properties. The improvements and enhanced light scattering could be leaded by tuning the nanomaterials incorporated. In this manner, it could be mentioned the light scattering generated from silica nanoplatforms that could generate modified light scattering signaling in the presence and absence of molecular reporters incorporated within the structure as well as on their nano-surfaces. It could be mentioned the light-scattering detection below the level of single fluorescent molecule for high-resolution characterization of functional nanoparticles [19]. In this report, it was analyzed siRNA cargo molecules within a continuous flow by side scattered of light generated from single silica and gold nanoplatforms indistinguishable from media using cytometry at the same time of fluorescence detection. This proof of concept showed interesting perspectives to tune properties and enhancements by varying strategies of physical phenomena involucred. It should be noted that silica is recognized as excellent dielectric material with optimal optical transparent properties;

Figure 1
(a) Schematic illustration for the synthetic processes of CeO@g-CN/Au DSHSs and (b) Construction processes of ECL biosensor for the detection of CA19-9



however, it showed to be high sensitive to the different energies applied for light-scattering stimulations [20]. Moreover, from the synthetic point of view, silica nanoparticles are largely used and relatively easily modified due to the presence of modifiable and chemically versatile silanol groups [21]. In general, silica nanoparticles were obtained by the Störber method (Figure 2) and then by a proper chemical interaction, the deposition of smaller nanoparticles [22]. In this manner, silica could incorporate optical active nanomaterials in order to combine properties and uses from both materials joined [23].

In addition, the possibility to organize the obtained hybrid silica NPs as hybrid silica nano-arrays could lead to modified surfaces and substrates for improved resonances and increased signaling from the surface, across, and through the materials by different approaches such as photonics surfaces, materials, and waveguide substrates (Figure 2 (i)) [24].

In a similar manner, other core nanoplatforms could be used to design other hybrid nanoparticles, such as metallic nanoplatforms with varied optical active properties. Thus, plasmonic nanoparticles have shown many studies and applications related to their absorption characteristics and spontaneous high electromagnetic fields within the near field with consequent enhanced signaling in the far field. As it is known, the near field is related with shorter lengths within the nano-scale than the far field associated with lengths in the µm and higher length ranges of surfaces and volumes [25].

Moreover, using plasmonic cores for the nano-surface modification with other types of metallic nanoparticles could be afforded to dual plasmonic properties. This dual properties could participate in different other energy modes and non-classical light and electronics pathways (Figure 3). These multi-modal structures are not all well developed and they are of high interest for the near future and for long-term perspectives due to the potential capability to modify nano-optics of surfaces for enhanced light-scattering approaches.

In this context, it is mentioned, bi-metallic core–shell nanoparticles of gold and silver via bioinspired polydopamine layers were synthesized as SERS platforms [26]. And it should be noted that in this research work after the addition of silver onto the Au NPs, remarkable enhancement was detected in the SERS activity. Moreover, it was showed the importance of the molecular spacers and linkers added between gold and silver. A thin layer of bioinspired polydopamine (PDOP) as an interface was used and highlighted the role as stabilizing and reducing agents for the reduction of silver ions and adsorption of silver nanostructures. Moreover, it was noted differences in the desired physical properties depending of the nano-architectures involucrated. In this way, it was noted that bi-metallic core-shell nanoparticles vs bi-metallic alloys showed different implications for plasmonic enhancement and photothermal properties generations [27]. While alloys permitted to record intermediate plasmonics properties between both metals incorporated, the bi-metallic core-shell nanoparticles afforded to dual behavior depending of the plasmonic center excited. By this manner, they were combined strong plasmonic properties for chemical sensing from silver cores with improved photothermal heat transfer by the incorporation of gold. From these results, it should be highlighted the importance and impact of the chemical nano-surface modification, molecular and shell spacers, passivation agents, and further controlling toward switch on/off systems activated by different stimulus.

In addition, as it was mentioned materials, sizes, shapes, and nanoarchitectures could lead to other new properties that need to be developed and study for targeted functions and applications. Therefore, hybrid nanoparticles could be obtained by different synthetic pathways in order to achieve different nanoarchitectures such as spherical core-

Figure 2
Schema of synthesis of silica nanoplatforms by the Störber method and modified with metallic nanoparticles to form hybrid SiO2–Au NPs. (i) It corresponds to hybrid silica nano-arrays

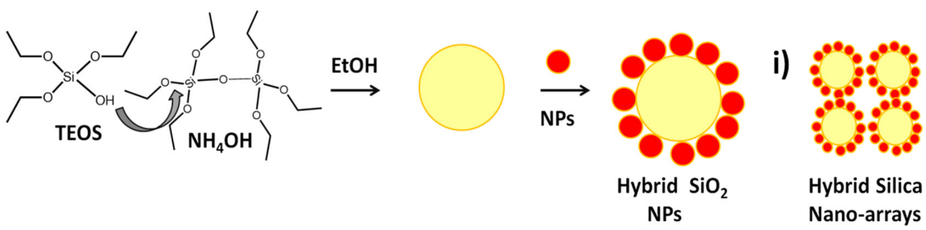


Figure 3
Schema of synthesis of hybrid metallic NPs. Red and grey colors correspond to gold and silver nanoparticles. It is shown a reduction method for metallic NPs and representative covalent or non-covalent linking of smaller NPs by incorporation of molecular and polymeric linkers

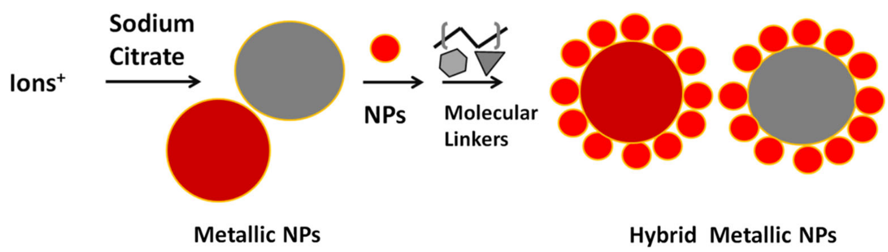
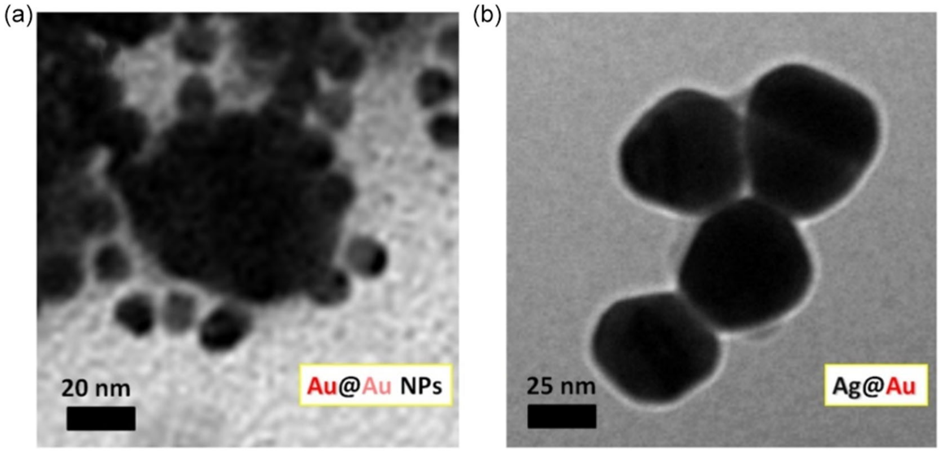


Figure 4
TEM image of hybrid metallic nanoparticles with different nanoarchitectures: (a) Spherical core-nano-shell particles (Au@Au NPs) and (b) Bi-metallic silver core-gold shell nanoparticles



nano-shell particles (Au@Au NPs) (Figure 4(a)); and bi-metallic silver core-gold shell Nanoparticles, recently developed both by Bracamonte et al. (Figure 4(b)) varying the chemistry of nano-surfaces based on previous reports [28, 29]. In this manner, it is intended to activate new enhancement phenomena from interaction of both materials, sizes, and shapes. Current research with these perspectives is in progress. And, it should be noted that light-scattering properties could be highly affected by the material topography and chemical modification on it.

Additional resonant energy modes afforded not only to scattering light shifts, as well from resonant structures produced enhanced signaling. These phenomena could be higher by a proper nano-array formation based on resonant energy modes [30]. In literature, it could be found many communications related; however, there are a lot of new different nano-architectures and strategies not assayed yet. Experimentally, it could be observed improved absorbance accompanied with the generation of new bands depending of the 3D structure obtained and materials assembled, covalently linked or incorporated such as alloys. In a similar manner, higher intensities could be achieved from light-scattering signaling. The challenge is to tune these properties and control them.

In this regard, enhanced light scattering modifications could be generated from the molecular scattering by targeted dyes, as well as 3D supramolecular architectures such as circular polymeric structures that amplifies scattering after interactions and joined at the same time with to SERS active substrates made of silver core gold satellite nanocomposites modified silicon wafer (Ag–Au NPs@Si), with SERS enhancement factor of approximately unless 5×10^6 [31]. These high values were not recorded in the absence of one of the components mentioned. Thus, it was showed how molecules, structures, and nanomaterials joined together could add particular enhanced new combined strategies. It seems a simple concept, however; it is not to find the right tuning for improved signaling. As for example, one of the main properties of lasers is the coherence of the signal related with well-resolved high intense emissions lines. This property could be tuned varying the nano- toward the micro-scale; highlighting by this manner the importance of materials, sizes, shapes, and 3D distributions in space. In this context, it was showed how ZnO nanoparticles were agglomerated to form clusters whose size varied from half a micron to a few microns with different emission intensities [32]. But it was highlighted that not always higher pump and frequencies produced the higher intensities. The 0.2 nm sizes well distributed within confined volumes generated the highest intense clusters with single laser emissions. And, by improved distribution of optical active nano-assemblies appeared a second resonant sharp emission. Thus, curves of the total emission intensities as a function of the pump intensities exhibited distinct slope changes at the threshold where sharp spectral peaks appeared. These are highlights that showed the high sensitivity depending on the design and strategy applied.

The non-classical light generation should be produced from the atomic, molecular toward the nano-scale where the spatial disposition defines the differentiation of the light scattering, electronic excitations, and logically final properties [33]. Then, the spatial distribution within higher sized surfaces or 3D substrates should be contemplated for potentials amplifications [34]. In these perspectives, in the next sections, it was afforded to this discussion related.

3. Nano-hole Particles

Light scattering could be affected from chemical reporters and chemical modifications of varied surfaces and substrates. These modifications come from accurate light absorption and emission depending on materials involucrated. So, sizes, shapes, geometries, and designs could affect the signal produced. In this manner, when light enters within confined volumes or spaces could be reflected, re-absorbed, modified, and re-emitted several times affecting wavelengths, phases, and frequencies. Thus, constructive wavelengths could be formed and associated with higher intensity signals. For example, it could be mentioned the surface enhanced Raman signaling generated within nano-holes [35]. There are not so many approaches like these ones reported in literature, and consequently there have been relatively few studies developed. However, there are many reported research works related with micro-, and nano-porous materials. In this context, it is mentioned as, for example, the processing of nano-holes and pores on SiO_2 thin films by MeV heavy ions [36]. In this report, it was described how scanned beams of 0.1 MeV/u197Au ions were employed for the bombardment of silicon oxide films thermally grown on silicon substrates. By scanning force microscopy and transmission electron microscopy, images of etched films revealed conical holes with diameters from 20 to 350 nm, depending on HF concentration added and etching time. These type of materials and similar were not evaluated for light-scattering applications, but it could be used for fundamental studies. In addition, it should be noted that wet chemical methods as well as laser-assisted techniques could be used to generate nano-holed materials and porous materials [37].

Other example not evaluated yet for enhanced Raman scattering and related light-scattering techniques is the wet chemical pathway to generate nano-hole particles of varied sizes within the nano-scale based on a nano-metallic template methodology. These nano-hole particles were nominated as core-shell nanoparticles and leaded to determination of metal-enhanced fluorescence enhancement factors (MEF_{EF}) [38]. The synthetic methodology was developed by the synthesis of metallic nanoparticles that could be obtained by varied reduction reactions and methodologies related, to then being modified with Silica spacers to obtain core-shell nanoparticles. These nanoarchitectures in the presence of sodium cyanide etched their metallic cores and produced silica nano-holes (Figure 5) [39].

These core-less nanoparticles (Figure 6(a)) are obtained within colloidal dispersions and their surfaces could be chemically being modified to control inter-nanoparticle interactions to form nano-holed aggregates and arrays [40, 41]. The chemical modification could be done based on varied strategies such as bioconjugation. Thus, biomolecules could act as spacers and self-assembly agents to interact with other modified nano-hole particles (Figure 6(b)). This is the challenge to evaluate further properties from the light matter interaction within confined nano-holes and resonances between them (Figure 6(c)).

In order to conclude this section, it should be mentioned that resonant modes could act in different applications by controlled effects by chemical surface modifications controlling opto-electro-active components. In this way, it was reported the topology optimization set for whispering gallery mode resonator circuits incorporating surface effects [42]. In this manner, the effect of total internal reflection at the surfaces of dielectric disks was simulated by modeling clearly defined dielectric boundaries in the process of optimizing the topology. The electric field intensity in an optimal resonator became more than 20 times larger than the initial intensity. This theoretical study showed how excellent dielectric materials such as silica could produce enhanced light-scattering phenomena. Moreover, it should be highlighted that these important optical effects could be recorded from optical transparent materials with proper chemical surface modifications in the absence of higher optical active or electron dense materials such as plasmonics [43]. So, the addition or combination of varied materials could lead to new optical active metamaterials that could produce even more enhancements, improvements as well as the generation of new energy modes. In these perspectives, it is noted more complex architectures such as cavity-coupled conical cross-section of gold nano-holed array fiber tips localized on surfaces for enhanced resonant sensing applications [44]. In this context, the resonant structures from nano-holed materials are of high impact for the tuning of light-scattering enhancements within hole arrays and over their surfaces as well. Actually, there is a huge research focused on the new analytical technique nominated as SERS and all related variants based on the same physical principle that governs the enhanced phenomena.

4. Laser Light-Scattering

In the perspective to generate enhanced non-classical light emission from light-matter interactions, it should be leaded to the

Figure 5

Schema of synthesis of nano-hole particles based on a nano-templated method. The metallic nanoparticles (NPs) were modified with silica layers by addition of tetraethyl orthosilicate (TEOS) in basic and ethanolic (EtOH) media to obtain metallic core-silica shell NPs. After that by sodium cyanide addition it was obtained the core-less NPs or nano-hole particles. (i) Corresponds to hole silica nano-arrays that could be achieved by surfaces or by controlling nano-aggregation within colloidal dispersions

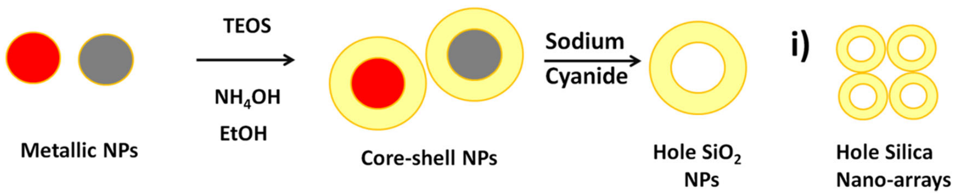
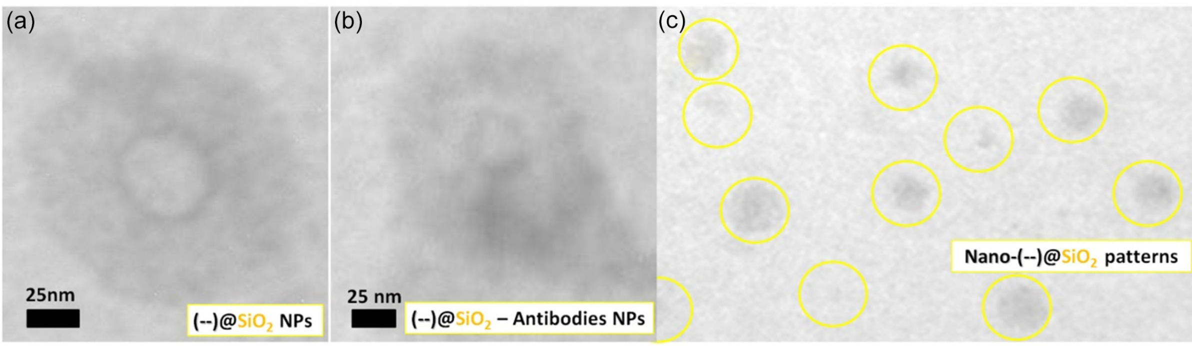


Figure 6

TEM images of nanopatterns of nano-hole silica nanoparticles. (a) Single silica nano-hole particles, (b) Modified silica nano-hole particles with antibodies, and (c) Nano-hole patterns recorded by TEM



discussion about laser light-scattering developments as well. Varied optical approaches could be found in this research field, such as from modified silica substrates, surfaces, waveguides, optical resonators, and further setups reported [45]. For neophytes, a laser is a device that emits high energy light produced by optical amplification based on stimulated emission of electromagnetic radiation. The laser light should be coherent, property that is related to an ideal state of waves enabling stationary (i.e., temporally and spatially constant) interferences [46]. These characteristics are not easy to generate and depend on many factors such as materials and optical setups. In this context to achieve an optical gain or lasing from silicon is a continuous challenge because this material in bulk shows semiconductor bandgaps and very low light emission efficiency [47]. However, modified silica-based nanomaterials showed important gains and optical approaches reported. In particular, it should be mentioned the stimulated Raman scattering (SRS) that it showed light amplification and lasing [48–50]. In this context, it is mentioned the generation of a continuous-wave Raman silicon laser [51]. This development was based on laser cavities formed by coating the facets of a silicon waveguide with multi-layer dielectric films. Thus, it was showed a significative energy loss reduction. And, in this manner it was showed one of the major advantages related to the generation of coherent light in wavelength regions that are not easily accessible with other conventional types of lasers [52]. Moreover, it should be noted the particular need to avoid or diminish optical losses by the incorporation of optical active materials that enhance signaling. In a similar manner, it was designed a modified laser cavity with controlled dielectric films that avoided optical losses. This optical setup showed an experimental behavior compared with a theoretical model of free-carrier absorption arising from two-photon-induced free carrier generation inside the waveguide [53]. Therefore, optical losses associated with two-photon absorptions induced free carrier absorption that improved the fact related to the limitation of pulsed operation. The strategy contemplating a geometrical factor, size, and incorporation of different materials depending on the targeted function permitted the development of other non-classical light pathway and mechanism involucrated within the material.

In these perspectives, there are interesting reports and many other ones currently in progress based on optical resonators with varied sizes and designs. It could be mentioned heterostructures with incorporation of nano-cavities that leaded to silicon Raman laser signaling (Figure 7) [54]. The nano-hole was of 128 nm radius with spacers between varied intervals of lengths within 400–420 nm. This configuration afforded to the propagation of two energy modes such as stokes and pumped generation. Thus, the polarization of the light direction was orthogonal to the x–y plane in this geometry. In this manner, it was achieved an integrated optical circuits by using a (100) SOI wafer with a 45-degree-rotated top silicon layer with improved efficiency.

Moreover, it should be highlighted the importance of the accurate control of materials and spatial distribution, patterning, periodicity at the atomic, molecular, inter-layer distances, and other geometrical constrains such as angles between crystals incorporations and substrates [55]. The size of the holes could variate within the micro-meter interval of lengths. Thus, it was achieved ultra-low threshold Raman laser using spherical dielectric micro-cavities [56]. These higher sized holes afford to higher energy storage capacity that permits to further studies related to nonlinear coupling of light matter. In this manner, it was demonstrated by a micrometre-scale control, the generation of a nonlinear Raman source that had a highly efficient pump–signal conversion (higher than 35%) and pump thresholds nearly 1,000 times lower than shown before [57]. In addition, it was achieved improved cascade stokes and anti-stokes laser based on an optical resonator with a self-assembled organic mono-layers, as well as Raman laser from an optical resonator with a grafted single-molecule monolayer [58, 59]. So, the material and chemical modifications within the molecular level showed the importance of the amplified light scattering that afforded in the last years to many integrated Raman Lasers within waveguides [60]. In these perspectives, recently it was reported and showed the importance of material chemical modifications, and in particular surfaces with their modifications by small organic molecules, such as organic NLO molecules to generate a nano-ordering of the surface and SRS lasing efficiency by a cascade emission pathway [61]. This sensitivity permitted the development on devices by nanosurface grafting with photo switchable molecules that afforded to tune SRS. In a similar way, by using with well-known laser dyes as Rhodamine B (RhB), it was assisted the generation of narrow-band random Raman lasing from RhB

Figure 7

(a) Schematic of a heterostructure nanocavity, (b) Band diagram of the nanocavity, and (c) Schematic of the in-plane Raman scattering for the cavity's x-direction being parallel to the (100) direction of crystalline Si

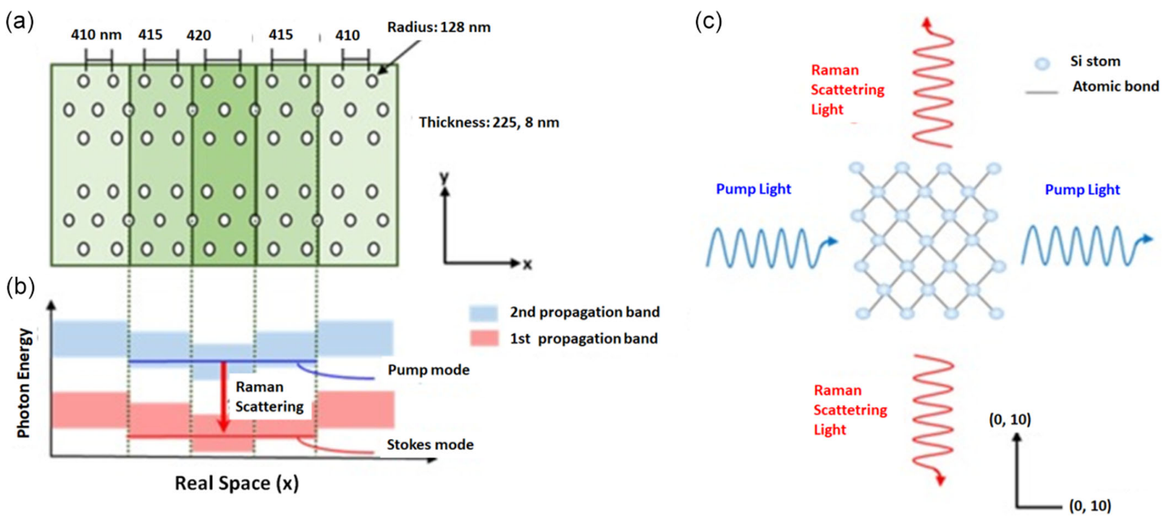
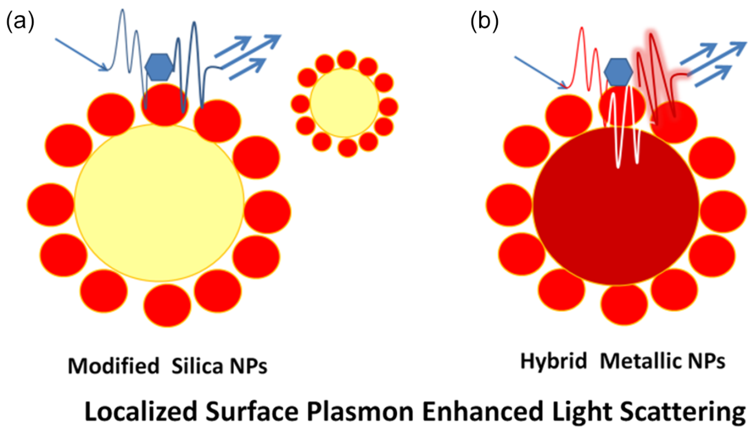


Figure 8

Schema of enhanced light scattering developed on modified nanoplatforms in the presence of a molecular reporter represented with a blue hexagon: (a) Modified Silica NPs with tiny gold nanoparticles and (b) Hybrid metallic NPs based on modified gold nanoplatforms with tiny gold NPs



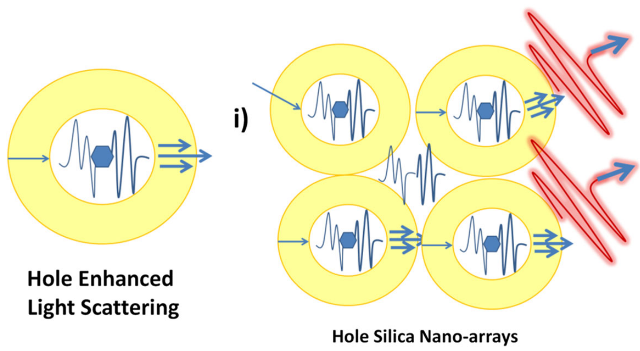
dyes by cascaded SRS effect [62]. The molecular control with an effect in the laser emissions could permit to other types of developments related to the control of the non-classical light phenomena generated by external activation based in varied strategies. Thus, it could be mentioned the control of MEF phenomena by a molecular switch on/off using a simple chemistry reaction of reduction/oxidation [63, 64]. In this direction, and looking to control, tune, and enhance light scattering, the modified silica nanoparticles discussed in the previous section are potential light-scattering enhancers due to the plasmonics properties showed [65].

These properties were related to the material incorporated and their inter-nanomaterial interactions. Thus, the deposition molecular reporter or targeted molecules could produce light-scattering modification by an enhancing pathway (Figure 8(a)) such as SERS [66, 67]. These pathways of enhancements could be generated between different nanomaterials as well as similar materials but with varied geometries or sizes. The tuning of these properties could generate different plasmonic energy modes within different wavelength intervals (Figure 8(b)).

Moreover, to amplify the signal generation from nanocavities, it could be applied nano-optical resonators that produce laser properties such as silicon Raman lasers [68]. This design, as an optical cavity, could reflect light waves many times within a confined gaining media enhancing the confined light with a given resonance frequency. In a similar manner, it could be mentioned the design of an optical cavity, resonating cavity, or optical resonator that it is an arrangement of mirrors that forms a standing wave cavity resonator for light waves [69]. Thus, optical cavities are a major component of lasers with a controlled material composition that modify the surrounding gain medium and provide the laser light pathway [70]. In this context, it could be noted that the radiation patterns which are reproduced on every round-trip of the light through the resonator are the most stable, and these are the eigenmodes, known as the energy modes, of the resonator [71]. So, from single nano-hole particle, it could be developed resonances through nano-assembling (Figure 9). In this manner, it could be coupled few nanoresonators within small-sized nano-assembled structures toward bigger nano-arrays supported by modified substrates. Thus, photonics materials and surfaces could show enhanced light scattering. And, depending of matter constitution the generation of laser emissions are potential challenges to afford (Scheme i) in Figure 9. The design mentioned could be the strategy for many combinations of nanomaterials and the generation of varied light pathways.

Figure 9

Schema of enhanced light scattering developed within nano-hole particles in the presence of a molecular reporter represented with a blue hexagon. (i) Schema of nano-hole particle arrays or hole silica nano-arrays



So, the generation of laser properties is not easy even understanding the phenomena and controlling the incorporation of varied materials and variables. Either, the enhancement of non-classical light; and the improvement of well-known phenomena related, could not always tune this optical property. But, it should be highlighted that the challenge is there and it is of high interest from the point of view of knowledge as well as impact in potential further developments.

It was briefly introduced and discussed some of the most important reports recently published in this context; by this way, it was noted the importance to design innovative nanoarchitectures for optical resonant structures. These studies will lead to study new materials, metamaterial, and evaluation of potential applications too.

5. Concluding Remarks

From the discussion and examples showed it could be highlighted the importance of the material design for enhanced light-scattering assays. This was showed by chemical modification of surfaces and substrates such as silicon-based materials with incorporation of molecular entities that acted as reporters as well as to deposition of single molecules as targeted chemical species. Moreover, it was noted that the use of optical active nanomaterials such as plasmonics materials and considered non-optical active materials as silica afforded to enhanced light-scattering signaling. This fact was even more augmented if the non-classical light generated was confined and reflected several times within optical resonators that acted as gaining media for lasing. In this manner, amplified light scattering signals were generated and laser devices were designed. These approaches leaded to varied geometries and sizes with consequent different and controlled wavelength emissions. In this context, it was showed different new nanoarchitectures that could show potential enhanced light-scattering developments based on hybrid silica nanoparticles decorated with tiny plasmonic nanoparticles, hybrid metallic nanoplatforms, and nano-hole particles. Thus, from the control of single nanoplatforms toward the formation of higher sized nano- or micro-hole arrays, it could be studied and generated different resonant energy modes for laser Raman scattering and other enhanced light-scattering phenomena related.

Acknowledgments

The author gratefully thanks Professor Denis Boudreau from Laval University, Quebec, and Professor Cornelia Bohne, University of Victoria, British Columbia, for Postdoctoral Research positions in Canada.

It is acknowledged to Professor Burkhard König from University of Regensburg, Bayern, Germany; and to Professor Nita Sahai from University of Akron, and NASA Astrobiology Institute, Ohio, United States; for Research visitor opportunity and Postdoctoral position respectively.

Ethical Statement

This study does not contain any studies with human or animal subjects performed by the author.

Conflicts of Interest

The author declares that he has no conflicts of interest to this work.

Data Availability Statement

The data that support the findings of this study are openly available and it could be provided by the corresponding author.

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How to Cite: Bracamonte, A. G. (2024). Hybrid Nanoplatforms and Silica Nano-hole Particles Intended for Enhanced Energy Modes: Light-Scattering Studies Toward Lasers Developments. *Journal of Optics and Photonics Research*, *1*(3), 99–108. https://doi.org/10.47852/bonviewJOPR42022233