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Study of Biomedical uses of Inorganic Nanoparticles

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Abstract
This paper aims to understand a variety of inorganic nanomaterial's such as nanoparticles and nanotubes. They have been created or modified to obtain superior properties with greater functional versatility. A wide variety of inorganic nanoparticles (NPs) are currently used for biological applications. Inorganic nanoparticles are non- toxic, hydrophilic, biocompatible, and highly stable compared to organic materials. In biomedicine are plasmatic nanoparticles, which offer many advantages in biomedical research due to their unique feature, that is, displaying localized surface Plasmon resonance (LSPR) bands in the UV–visible-near IR spectral range.
Keywords: *Inorganic nanoparticles, Biomedical, biological application, LSPR.*

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I. INTRODUCTION

A nanoparticle is a small particle that ranges between 1 to 100 nanometers in size. Inorganic nanoparticles (NPs) including those derived from metals (e.g., gold, silver), semiconductors (e.g., quantum dots), carbon dots, carbon nanotubes, or oxides (e.g., iron oxide), have been deeply investigated recently for diagnostic andtherapeutic purposes in oncology. Compared to organic nonmaterial, inorganic NPs have several advantages and unique characteristics for better imaging and drug delivery. Still, only a limited number of inorganic NPs are translated into clinical practice. Undetectable by the human eye, nanoparticles can exhibit significantly different physical and chemical properties to their larger material counterpart Depending on the application (i.e. diagnosis, imaging, or therapy), different types of NPs have been proposed, being some of them used for more than one aim. Nanoparticles are divided into two main groups: organic and inorganic NPs. The first group includes micelles, dendrimers, liposomes, hybrid, and compact polymeric NPs. The second group includes fullerenes, quantum dots, silica, and gold NPs. A wide variety of inorganic nanoparticles (NPs) are currently used for biological applications. A more novel group in terms of their use in biomedicine is plasmonic nanoparticles, which offer many advantages in biomedical research due to their unique feature, that is, displaying localized surface Plasmon resonance (LSPR) bands in the UV–visible-near IR spectral range [1]. The assay was able to differentiate between live and dead bacteria due to the presence of vancomycincoatedmagnetic nanoparticles, which could bind and retain only live bacteria. As Au nanoparticles were used in the final stages for DNA annealing, a naked eye readout was obtained by adding dilute HCl, which results in aggregation of the Au NP. In addition to capture and detecting bacteria, two very different ways to capture the influenza virus have been described. The first method takes advantage of a well-known and simple biological assay known as the hemagglutinin assay. George Hirst originally described in 1941 the concentration-dependent aggregation of red blood cells (RBC) by the influenza virus [2]. The LSPR frequency is extremely sensitive to subtle changes in the physicochemical environment, for example, the distance between nanoparticles [3], and is also characteristic of their size and shape. Remarkably, in some cases, the associated plasmon shift is so dramatic that a color change can be read out by the naked eye and does not require expensive or sophisticated instrumentation [4]. In 1978 the Food and Drug Administration as an antitumor agent approved cisplatin. This application generated interest in exploring other metals for potential anti-cancer properties. Mainly, gold-based compounds demonstrated anti-cancer properties. The addition of gold (I) and gold (III) compounds enhanced the antitumor activity of the known antitumor compounds [5, 6]. Recent evidence inspires the future application of gold nanoparticles as a therapeutic molecule in angiogenesis-dependent disorders such as cancer and rheumatoid arthritis [7].Cancer cell targeting ligands are usually attached to the surface of the nanoparticles so that localized targeting can be carried out while limiting damage to surrounding healthy cells. An alternative method that is rarely applied to nanoparticles exploits the EPR effect, which has been used in the medical setting for over 30years to detect tumors via fluorodeoxyglucose positron emission tomography (FDG-PET) [8]. Inorganic nanoparticles could be useful to address cancer heterogeneity and applied for use in targeted therapy in specific tumor

environments (tumor stroma). Understanding the interactions between the stromal cells and tumor cells is important to develop an effective therapeutic strategy. In general, tumor microenvironments contain leaky vasculature and high permeability due to more angiogenesis triggered by different cytokines [9]. Molecular targeted therapy is an emerging cancer therapy strategy that possesses specific anticancer effects at cellular and molecular levels [10,11]. It could be used to identify specific cancerogenic targets of tumor cells or microenvironment (TME) and thereby provide negative control of the signaling pathways associated with cell proliferation and metastasis [12]. On the one hand, the significant inhibition of tumor cells' growth and metastasis is accomplished. On the other hand, the immune response could be simultaneously activated by molecular targeted drugs [13]. Recent Progress in the Development of Quinoline Derivatives for the Exploitation of Anti-Cancer Agents [14].In theranostics for cancer therapy, the inorganic nanoparticles can occupy various locations within the bilayer of liposomes. The inorganic nanoparticles could be present as embedded within the bilayer of liposomes, nanoparticles stabilized on the surface of liposome via chemical conjugation or adsorption, or nanoparticles encapsulated within the liposome (Fig. 1.1).

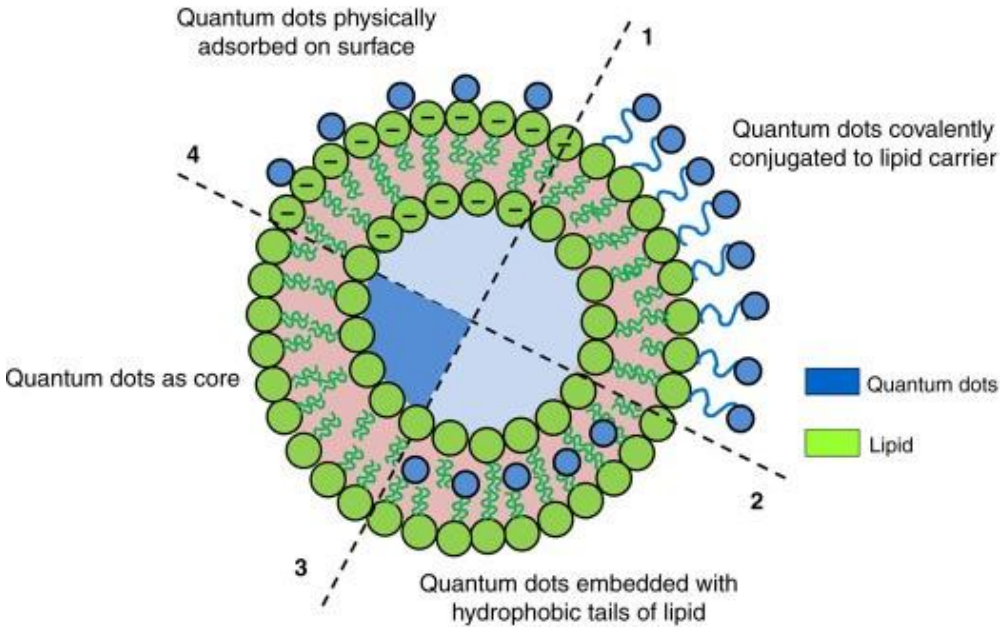

Figure 1.1 PLH architectures for theranostics

As observed with different PLH architectures, PLH for theranostics could also occupy different architectures. The quantum dots could be (1) chemically conjugated to the surface of the liposome, (2) embedded within thebilayer of liposome, (3) occupied as the core of LPH, or (4) adsorbed onto the surface of liposomes.

The characteristic LSPR band of gold (Au) and silver (Ag) nanoparticles can be used for sensing, to triggerlight-based events, or even for both actions simultaneously. Indeed, their optoelectrical properties render plasmonic no particles a most relevant building block in functional materials, while the fabrication and characterization procedures of such materials are currently changing according to the requirements of biomedicine [15,16,17].

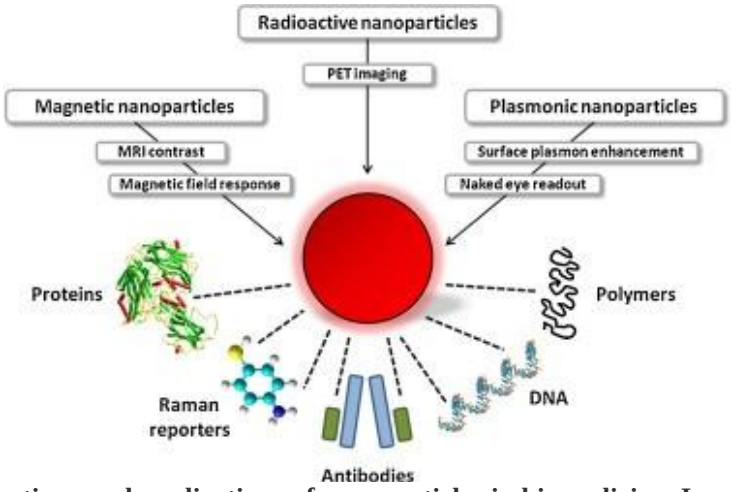

Figure1.2 Fictionalizations and applications of nanoparticles in biomedicine. Inorganic nanoparticles display different capabilities depending on the chemical composition of their cores. With the ever-growing use of nanoparticles in biomedicine, standard ligands (mostly alkanethiols terminated by a simple organic functional group) are replaced by biologically active molecules. This new paradigm connecting nanoparticles with medical practice is therefore changing the point of view as well as research practices of materials scientists.

MRI Contrast agents

MRI is a non-invasive medical imaging technique based on the principle of nuclear magnetic resonance (NMR) [18]. In a strong magnetic field, hydrogen nuclei absorb resonant radiofrequency pulses, and subsequently, the excited nuclei return to the initial state by emitting the absorbed radiofrequency energy. MRI contrast is generated by the different relaxation characteristics of the hydrogen atoms in tissues that are affected by the presence of nearby magnetic materials. For example, paramagnetic materials enhance the longitudinal relaxation processes (also called T1 relaxation processes), producing brighter MR signals, while super paramagnetic and ferromagnetic materials accelerate the transverse relaxation processes (also called T2 relaxation processes), resulting in hypo intense MR signal. Using these properties, complexes of paramagnetic gadolinium ions (Gd3+) and super paramagnetic iron oxide nanoparticles (SPIONs) have been used as T1 and T2 contrast agents, respectively[19]. Recently, though, most nanoparticles-based MRI contrast agents have been withdrawn from the market, leaving Gd(III) complexes to dominate the current market for MRI contrast agents[20].

Respiratory diseases

The application of nanoparticles-based drug delivery approaches in respiratory diseases has been somewhat limited. The literature nevertheless contains several examples of therapies that have been effectively demonstrated for the treatment of allergic, genetic, and infectious diseases of the respiratory system [21, 22] demonstrated the use of a liposome-based nanoparticles system to inhibit inflammation in a murine model of allergic asthma. The strategy employed was to inhibit P-selectin receptors on activated endothelial cells in circulation, which mitigates interactions between endothelial cells and leukocytes. This, in turn, attenuates the development of peribronchial inflammation. The nanoparticles (average diameter of 73 nm) were designed to mimic the physiological P-selectin super ligands (PSGL-1) by incorporating fructose and sulfate ester groups on the liposome surface. Lung inflammation and airway hyperactivity were induced in mice by LPS and cockroach antigen. In both instances, the liposomal nanoparticles were observed to bind preferentially to selectins on activated endothelial cells (Figure 1.3). Histological analysis indicated a significant reduction in peribronchial inflammation and airway hyper-reactivity in mice treated with the nanoparticles compared with controls.

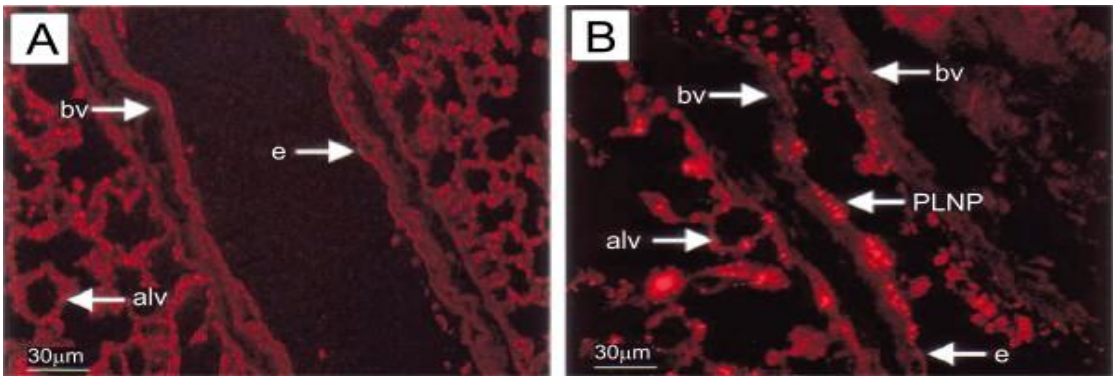

Figure1.3 Selective binding of liposomes presenting fructose and sulfate ester groups to activated endothelial cells in mouse lungs following allergen challenge. (A**) Negative control (liposomes without fucose and sulfate ester groups). (**B**) Liposomes with fructose and sulfate ester groups. Scale bars in bothimages = 30 μm.**

[23]. A polymer-drug conjugate, chitosan/interferon-γ pDNA nanoparticles, can reduce allergen-induced airway inflammation. It is known that allergic diseases (such as asthma) cause a drop in the production of interferon-γ (IFN-γ) in patients, leaving the patients susceptible to airway inflammation and hyper responsiveness. The approach of [23] aims to overcome IFN-γ deficiency by supplying it intranasal as a polymer-drug conjugate. In allergen-challenged mice, nanoparticles therapy resulted in increased IFN-γ expression by epithelial cells, thereby facilitating a reduction in inflammation and restoration of lung morphology within 3–6 hours.

Immunoassays

Due to the high natural specificity of antibodies [24], their use in commercial analytical assays to detect bimolecular at nanomolar concentrations is commonplace in biological laboratories. Antibodies can also be tagged with a range of detection moieties including radioactive isotopes, enzymes, and fluorophores, thereby achieving low limits of detection (LOD) that can be determined using simple plate readers equipped with corresponding filter bands. Collectively known as enzyme-linked immunosorbant assays (ELISAs), various types exist such as direct immunoassays involving a single antibody, or sandwich assays in which the molecule of interest is literally sandwiched between capture and a detection antibody (Fig. 1.4). The combination of plasmonic nanoparticles with such immunoassay systems has been quoted as plasmonic ELISAs. Plasmonic ELISAs have opened up new possibilities for detection of pathogens at low LOD and detection 'in the field' where complex detection systems are often inapplicable. Importantly, rather than detecting with a spectrophotometer or a similar detector, the transition between aggregated and non-aggregated nanoparticles results in a visible color change that can be read by the eye, giving a simple yes or no result.

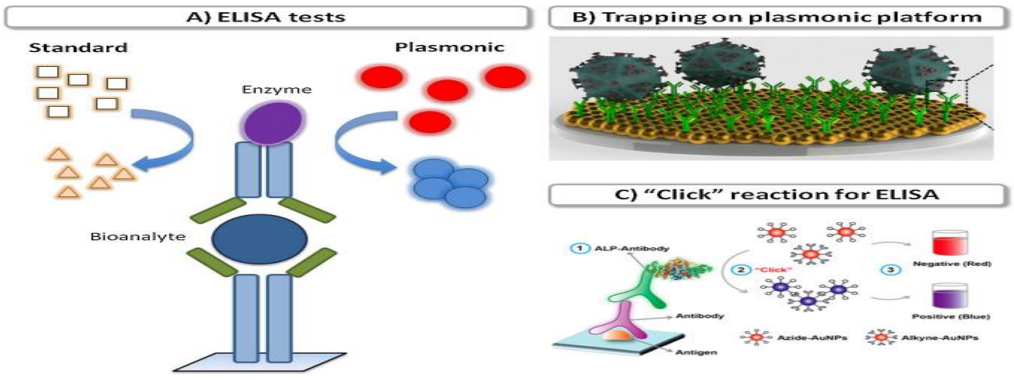

Figure 1.4. Novel immunoassays based on plasmonic nanoparticles. (a) Scheme comparing the standard ELISA with an enzyme catalyzing the production of a colored molecule and the plasmonic ELISA, based on the different aggregation states of Au nanoparticles in the presence of the analyze. (b) A monolayer of Au nanoparticles functionalized with antibodies against different HIV types selectively captures the corresponding viruses leading to an LSPR shift [25]. Copyright 2013, American Chemical Society. (c) A variation of the plasmonic ELISA skips the conjugation step of the enzyme to the antibody. The ALP-antibody catalyzes a 'click' reaction between Au nanoparticles, through intermediate chemicals as Cu+ and ascorbic acid, leading to a clear color change [26]. Copyright 2014, American Chemical Society.

Several examples of plasmonic immunoassays with visible readouts have been developed for HIV detection [27], [28], [29] (Fig. 1.4). In the work by Stevens and colleagues, the capsid HIV-1 antigen p24 was detected in human plasma down to a concentration of 10−18 g mL−1 [27],a viral load that is undetectable by other standard tests. The presence of an enzyme-linked antibody controlled the growth of Au nanoparticles due to the presence (or not) of hydrogen peroxide, a reducing agent for the production of Au NPs. When hydrogen peroxide was present, well-defined and non-aggregated Au NPs were formed yielding a distinct red solution, while a blue solution composed of aggregated Au NPs formed when no peroxide was present. Importantly, in this assay, the analyze is a component of the virus itself, the antigen p24. Another commonly used method to perform an ELISA is to measure the level of antibodies, that is, to detect antibodies in the blood serum of an infected individual, thereby determining whether they have been previously exposed to the pathogen. Nie et al. showed that antibodies produced against *Treponema palladium*, the bacterial species causing syphilis, can be detected via an acetyl cholinesterase-antibody catalyzing the hydrolysis of acetylthiocholine to produce abundant thiocholine [30]. As previously reported by Coronado-Puchau et al. [31], thiocholine binds the Au NP surface leading to aggregation, which can be detected by UV–vis spectroscopy.

II. CONCLUSION

Inorganic Nanoparticles have been found to possess great potential for a broad range of applications, particularly in the biomedical field. Various inorganic nanoparticles have been developed and used as probes for in vivo biomedical imaging. For MRI and CT, several nanoparticles-based contrast agents have been shown to outperform conventional small molecule-based contrast agents in terms of imaging quality. Moreover, they are less toxic and easier to functionalize with targeting or stimuli-responsive ligands for effective treatment. The use of QDs or UCNPs for optical imaging also works as a good alternative to optical imaging by organic dyes. AuNPs present a highly attractive platform for a diverse array of biological applications both in vitro and in vivo. A variety of chemical synthesis methods have been developed to produce AuNPs of different sizes and shapes. types of AuNPs, spherical AuNPs, Au Nano rods, Au nanoshells, Au nanocages, and hollow AuNPs, have been reproducibly synthesized in large amounts and been extensively explored for their biomedical applications. Many gates the toxicity of AuNPs. In general, it can be stated that AuNPs are regarded as biocompatible, showing no acute cytotoxicity. All biomedical applications of AuNPs except for radio sensitizing agent make use of their SPR effect, a strong enhancement of absorption and scattering of light in resonant with the SPR frequency, with which AuNPs are explored for light-based biomedical applications, Due to enhanced properties and less toxicity core/shell nanoparticles have better biomedical applications over nanoparticles. Recommended Use of nanoparticles in drug delivery. The successful translation of inorganic NPs to the clinic requires the development of a simple, safe, cost-effective, eco-friendly mode of synthesis, and a better understanding of the safety mechanisms, bio distribution, and pharmacokinetics of NPs. However, more attention should be given to concerns on long-term toxicity, carcinogenesis, immunogenicity, and inflammation, and tissue damage. Although some inorganic NPs, which were promising in the preclinical phase, were found not to be successful when translated to the clinic, several encouraging NPs are currently being developed for treatment and cancer care, and a wide variety of other diseases.

REFERENCES

[1]. M A Garcia (2011) "Surface plasmons in metallic nanoparticles: fundamentals and applications" J. Phys. D: Appl Phys. 44 283001.
[2]. GK.Hirst (1942) "ANTIBODY RESPONSE OF HUMAN BEINGS FOLLOWING VACCINATION WITH INFLUENZA VIRUSES" J, Exp. Med. 75 49.
[3]. P.K. Jain, M.A. El-Sayed(2010)" Plasmonic coupling in noble metal nanostructures"Chem. Phys. Lett., 487, p. 153.
[4]. Y. Song, W. Wei, X. Qu (2011) "Colorimetric biosensing using smart materials"Adv. Mater., 23, p. 4215
[5]. Berners-Price SJ, Norman RE, Sadler PJ.(1987) "The autoxidation and proton dissociation constants of tertiary diphosphines: relevance to biological activity." J Inorg Biochem.; 31:197–209.
[6]. Haiducand C, Silvestru I.(1989)" Rhodium, iridium, copper and gold antitumor organometallic compounds" (review) In Vivo.;3:285– 294.
[7]. Mukherjee P, Bhattacharya R, Wang P, Wang L, Basu S, Nagy JA, Atala A, Mukhopadhyay D, Soker S.(2005)" Antiangiogenic properties of gold nanoparticles" Clin Cancer Res.;11:3530–3534.
[8]. G.J. Kelloff, et al. Clin. (2005)"Progress and promise of FDG-PET imaging for cancer patient management and oncologic drug development "Cancer Res. 11 2785.
[9]. Patra CR, Bhattacharya R, Mukhopadhyay D, Mukherjee P. (2008)" Application of gold nanoparticles for targeted therapy in cancer"J Biomed Nanotechnol.;4:99–132.
[10]. Lee, Y. T., Tan, Y. J., and Oon, C. E. (2018)" Molecular Targeted Therapy: Treating Cancer with Specificity" Eur. J. Pharmacol. 834, 188–196.
[11]. Goyal, L., Kongpetch, S., Crolley, V. E., and Bridgewater, J. (2021)" Targeting FGFR Inhibition in Cholangiocarcinoma" Cancer Treat. Rev. 95, 102170.
[12]. Yang, M., Cheng, K., Qi, S., Liu, H., Jiang, Y., Jiang, H., et al. (2013)." Affibody Modified and Radiolabeled Gold-Iron Oxide Hetero-Nanostructures for Tumor PET, Optical and MR Imaging. Biomaterials" 34, 2796–2806.
[13]. Liu, J., Xu, M., and Yuan, Z. (2020)" Immunoscore Guided Cold Tumors to Acquire "Temperature" through Integrating

Physicochemical and Biological Methods". BIO. Integration. 1, 6–14. doi: 10.15212/bioi-2020-0002.
[14]. Ruo-Jun Man, Nasreen Jeelani, Chongchen Zhou, Yu-Shun Yang (2021) " Anti-Cancer Agents in Medicinal Chemistry" Volume 21,Issue 7.
[15]. P.D. Howes, S. Rana, M.M. Stevens (2013)" Molecular Targeted Therapy Plasmonic nanomaterials for bio diagnostics" Chem. Soc. Rev., 43 (2014), p. 3835.
[16]. N.E. Motl, et al.,(2014)" Spiropyran-based dynamic materials" Chem. Soc. Rev., p. 3823.
[17]. S.M. Lee, et al., (2014) "Stable corneal regeneration four years after implantation of a cell-free recombinant human collagen scaffold"Biomaterials, 35 (2014), p. 2272.
[18]. Brown, M. A.; Semelka, R. C. Wiley (2011" MRI: Basic Principles and Applications" Treating Cancer with Specificity" Eur. J. Pharmacol. 834, 188–196.
[19]. Modo, M. M. J.; Bulte, J. W. M (2007)". Molecular and Cellular MR Imaging" CRC Press.
[20]. Wang, Y.-X. J. (2011)" Superparamagnetic Iron Oxide Based MRI Contrast Agents: Current Status of Clinical Application. Quant. Imaging Med. Surg", 35−40.
[21]. Pison U, Welte T, Giersig M, Groneberg DA(2006)" Nanomedicine for respiratory diseases" Eur J Pharmacol. 533(1-3):341-50.
[22]. John AE, Lukacs NW, Berlin AA, et al.(2003)" Discovery of a potent nanoparticle P-selectin antagonist with anti-inflammatory effects in allergic airway disease" FASEB J.17:2296–8.
[23]. Kumar M, Kong X, Behera A, et al.(2003)" Chitosan IFN-γ-pDNA nanoparticles (CIN) therapy for allergic asthma" Genet Vaccines Ther.;1:3.
[24]. L.M.Weiner, R. Surana,S.Wang (2010)" Monoclonal antibodies: versatile platforms for cancer immunotherapy."Nat. Rev. Immunol., 10, p. 317.
[25]. F. Inci, et al.(2013)"Nanoplasmonic Quantitative Detection of Intact Viruses from Unprocessed Whole Blood" ACS Nano, 7, p. 4733.
[26]. Y Xianyu, Z Wang, X Jiang(2014)"A plasmonic nanosensor for immunoassay via enzyme-triggered click chemistry" ACS Nano 8 (12), 12741-12747.
[27]. R. de la Rica, M.M. Stevens (2012) "Plasmonic ELISA for the detection of analytes at ultralow concentrations with the naked eye" Nat. Nanotechnology. 7, p. 821.
[28]. C.D. Chin, et al.(2011)*"* Microfluidics-based diagnostics of infectious diseases in the developing world *"*Nat. Med., 17, p. 1015.
[29]. W. Qu, et al.(2011)" Metal-linked Immunosorbent Assay(MeLISA): the Enzyme-Free Alternative to ELISA for Biomarker Detection Serum"Angew. Chem. Int. Ed., 50, p. 3442.
[30]. Nie X-M,Huang R,Dong C-X,Tang L-J,Gui R,Jiang J-H (2014)"Plasmonic ELISA for the ultrasensitive detection of Treponema pallidumtrepon "Biosens Bioelectron 58:314-319.
[31]. M. Coronado-Puchau, *et al.(2013)"* Enzymatic modulation of gold nanorod growth and application to nerve gas detection*"* Nano Today, 8, p. 461