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Protection Effect of Gold Nanoparticles Coated on Fruit and Vegetables Using PVD Method

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Abstract: Gold particles can be real jewels, specially at the nano size they are in great demand by scientists. A field that has showed fast growth over the past decades is the use of gold nanoparticles in biology, or life sciences. The aim of this work was to use, physical method to deposit gold nanoparticles as a protection layer on the fruits and vegetables. There is no any report about direct and physical vapor deposition on fruits and vegetables yet. Gold nanolayers of 40 nano meter thickness were coated on one side of apple, cucumber, lettuce and tomato, by Physical Vapor Deposition (PVD) method, in high vacuum condition at room temperature. Deposition angle of gold nanoparticles were vertical to all species. After coating we kept them in normal room temperature. Protection of gold nanolayers and time of these protections were investigated. Time length protection of gold nanoparticles has an increasing trend for apple, tomato, lettuce and cucumber.

Key words: Gold nanolayers, physical vapor deposition, high vacuum, nanoparticles

INTRODUCTION

Nanostructure materials have potentials application in many areas, such as biological detection, controlled drug delivery, low-threshold laser, machines to travel through the human body, small supercomputers, optical filters and also sensors (Kostoff *et al*., 2008; Andrievskii, 2003).

It is quite evident that some of the metallic compounds possess antimicrobial property. The application of nanoparticles as antimicrobials is gaining relevance in prophylaxis and therapeutics, in medical devices, food industry and textile fabrics. Au particles are particularly and extensively exploited in organisms because of their biocompatibility (Ravishankar Rai and Jamuna Bai, 2011).

In a review by Ravishankar Rai and Jamuna Bai (2011) the properties of different types of metallic nanoparticles such as copper, aluminium, gold, silver, magnesium, zinc and titanium nanoparticles were discussed and the mechanism of action of nanoparticles as bactericidal, antifungal and antiviral agents was mentioned. In a work done by Aviles *et al*. (2009) mechanical properties of 5-300 nm gold thin films deposited onto micrometer thick flexible polymer substrates were investigated. Siegel *et al*. (2011) studied the electrical and optical properties, density and crystalline structure of Au nanostructures prepared by direct current sputtering on glass. In a research by Espinosa and Prorok (2003), the Membrane Deflection Experiment was used to evaluate size effects on the mechanical response of suspended thin film Au membranes.

Because of excellent biocompatibility, unique structural, electronic, magnetic, optical and catalytic properties, Au nanoparticles (AuNPs) are very attractive material for biosensor, chemisensor and electrocatalyst (Ghindilis *et al*., 1997; Maye *et al*., 2000; Tang *et al*., 2006). Gold nanoparticles are in great demand by scientists. Today gold nanoparticle is being used for an ever-growing number of applications (Sperling *et al*., 2008).

A variety of shapes of gold nanoparticles are suitable for use in biological applications. Also they have a strong optical extinction peak that can be varied by control of particle morphology. They are 'electron dense' and radiopaque. In addition they manifest a low level of toxicity (Daniel and Astruc, 2004; Dietrich *et al*., 2005; Hirsch *et al*., 2003; Kelly *et al*., 2003; Liao and Hafner, 2005; Pissuwan *et al*., 2006; Skrabalak *et al*., 2007; Wu *et al*., 2005).

Gold metallic nanoparticles are commonly used in the lab as a tracer, to detect the presence of specific proteins or DNA in a sample. Gold nanoparticles have been used as a probe for the detection of various aminoglycosidic antibiotics like streptomycin, gentamycin and neomycin (Azarmi *et al*., 2008; Grace and Pandian, 2007). They are also used for identifying different classes of bacteria (Phillips *et al*., 2008; Bajaj, 2009).

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Gold is known as a shiny, yellow noble metal that does not tarnish, has a face-centered cubic structure, is non-magnetic, melts at 1,336 K and has density a 19.320 g cm^{-3} (Siegel *et al*., 2011). It has the resistivity of 2.0 μΩ cm. The vacuum work function is 5.31 eV (Lide, 2001).

Because this metal is chemically very stable, it isn't harmful for health, has the ability to retard oxygen diffusion (Lide, 2001) and is highly resistant to oxidation, even at elevated temperatures (Bond and Thompson, 1999). The aim of this work was to use, physical method to deposit gold nanoparticles directly as a protection layer on the fruits and vegetables. Protection of gold nanolayers and time of these protections were investigated.

MATERIALS AND METHODS

Materials and devices: Materials used for this research were, fresh, apple, cucumber, lettuce and tomato, as four different kinds of fruits and vegetables. Either pure pieces of gold or a tungsten boat were used. An ETS 160 (Vacuum Evaporation System) coating plant with a base pressure of 3×10^{-5} mbar was used for direct evaporation. The substrate holder was a disk of 36.5 cm in diameter with adjustable height up to 50 cm and also adjustable holders for placing any kind of substrates. The distance between center of evaporation boat and center of the substrate was 40 cm. Hard vacuum of chamber provided by rotary vain pump and high vacuum of chamber provided by turbo molecular pump. The pressure of chamber evaluated by pirani and pening pressure indicators and at least a quartz crystal microbalance technique used to determined gold nanoparticles thicknesses and their deposition rate.

Experimental details: Gold nanoparticles were deposited on one side of four different materials, as apple, cucumber, lettuce and tomato, by using resistive evaporation method (Faurie *et al*., 2006), from tungsten boats, at room temperature, we use vertical deposition angle for coating. The research was done at the faculty of science, University of Tehran, Tehran, Iran, in summer of 2011. Thickness of gold nanolayers were almost the same and other deposition conditions such as deposition rate, vacuum pressure and substrate temperature were the same in all species. The deposition rate for gold nanoparticles were 1.2 Å sec^{-1}. Time of coating was 3 min and thickness of gold nanolayer was 40 nm, for all species. Table 1 shows the coating (deposition) details, investigated in this research.

RESULTS

In this study gold nanolayers of 40 nm thickness were coated on one side of apple, cucumber, lettuce and tomato, by Physical Vapor Deposition (PVD) method. After coating they were kept in normal room temperature. Protection of gold nanolayers and time of these protections are investigated.

Figure 1 shows the comparison between gold deposited and normal sides of an apple during eighty four

Table 1: Coating details for different samples

Samples	Vacuum pressure (mbar)	Deposition rate (A/S)	Time of deposition (min)	Deposition temperature (°C)	Thickness of gold nanolayers (nm)
Apple	3×10^{-5}	1.2	3	25	39.5~40
Cucumber	3×10^{-5}	1.2	3	25	39.3~40
Lettuce	3×10^{-5}	1.2	3	25	39.4~40
Tomato	3×10^{-5}	1.2	3	25	39.7~40

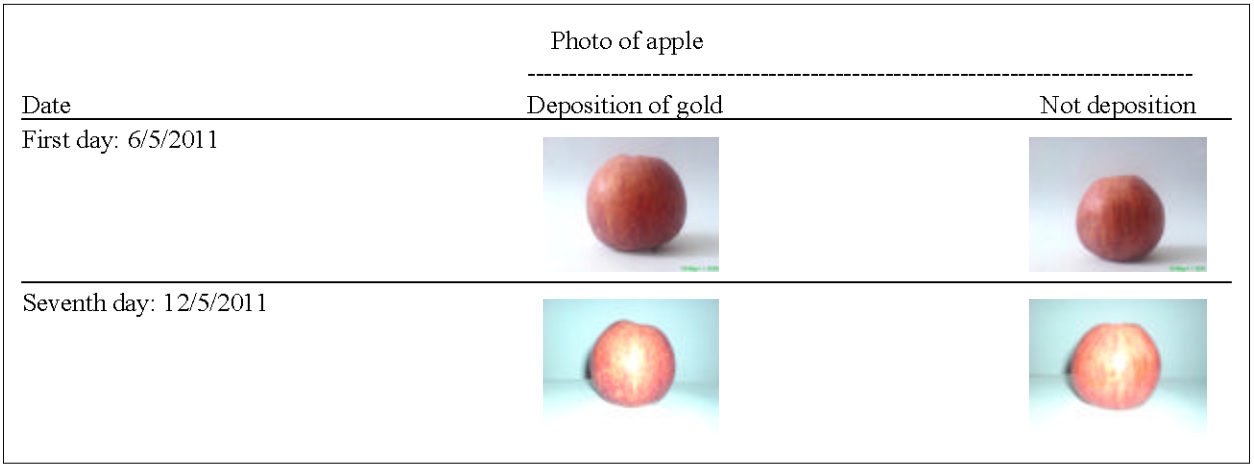


Fig. 1: Continue

Date	Photo of apple: Deposition of gold	Photo of apple: No deposition
Thirteenth day: 18/5/2011		
Nineteenth day: 24/5/2011		
Twenty fifth day: 30/5/2011		
Thirty first day: 5/6/2011		
Thirty seventh day: 11/6/2011		
Forty thirst day: 17/6/2011		
Forty ninth day: 23/6/2011		
Fifty fifth day: 29/6/2011		

Fig. 1: Continue

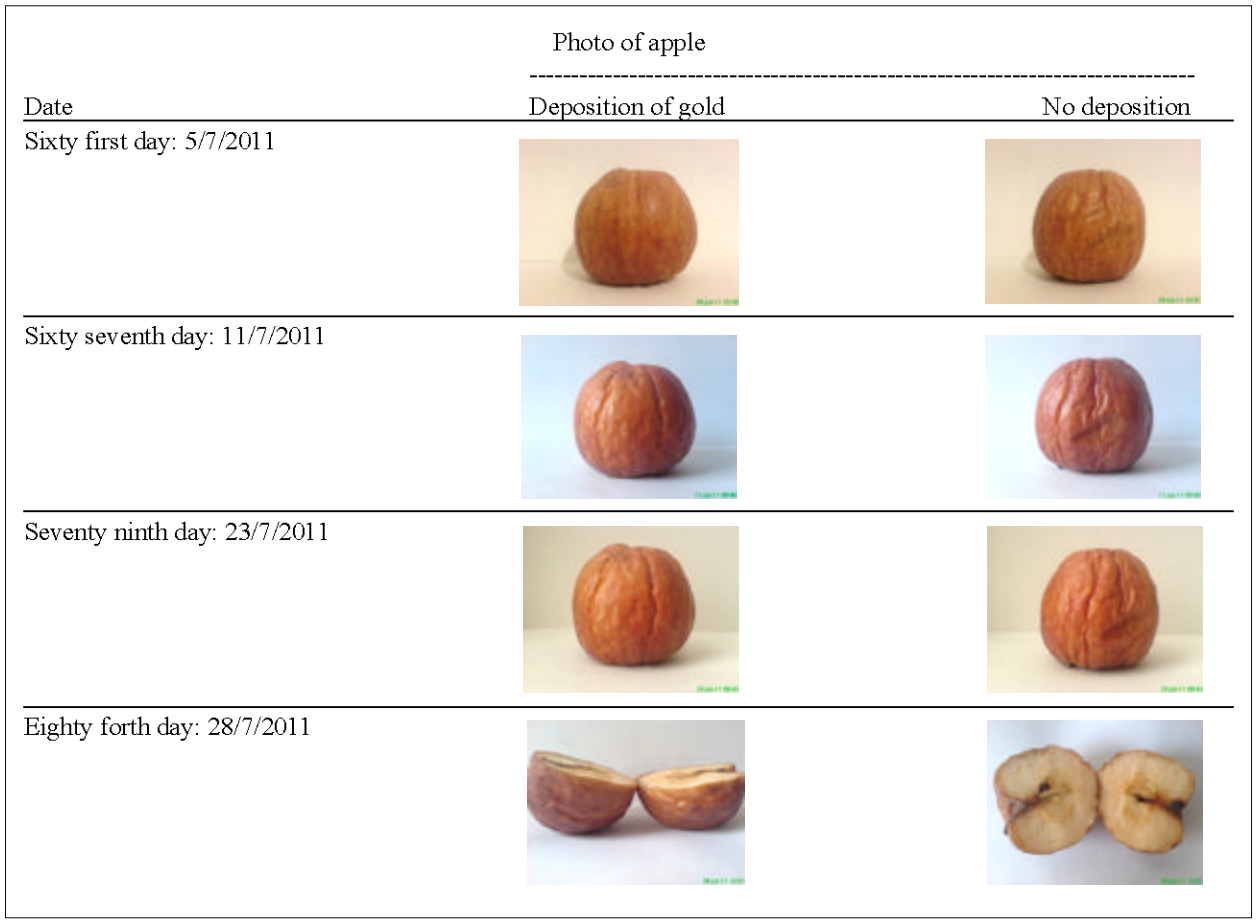


Fig. 1: Gold deposited and normal sides of an apple

days, thickness of gold nanolayers were about 39.5 nm. Physical coating plant was used for deposition at room temperature and high vacuum pressure. As it can be seen, in general, coated side is more fresh and less wrinkles appear, for example attention to photo of fifty fifth day, this difference is very clear. After eighty four days, the apple was cut; as it can be seen inside the coated side is more white and fresh. Figure 2 shows the comparison between gold deposited and normal sides of a cucumber, by same deposition conditions and 39.3 nm thickness gold nanolayers. Time length of protection cucumber was twenty two days, by passing time, mould inform on normal side of cucumber but gold deposited side has wrinkle and protected of mould (Fig. 2, after twenty two days). Figure 3 shows the comparison between gold deposited and normal sides of a lettuce. Thickness of gold nanolayer was 39.4 nm. As it can be seen after sixteen days gold deposited side is still green and normal side is dry. Time length protection of lettuce is also different. After twenty five days both sides of lettuce are dry. Figure 4 shows the comparison between gold deposited and normal sides of a tomato. Thickness of gold nanolayer was 39.7 nm. As it can be seen time length of protection for tomato is seventy days and is different from three other samples. As it can be seen clearly from photo of fifth day, the trend of wrinkles and drying is faster on the normal side. After seventy days, gold nanoparticle coated side is not completely dry but the normal side is completely dry and hard.

DISCUSSION

Gold nanoparticles have many applications in biology, including immunostaining and delivering drugs or DNA into cells. A field that has showed fast growth over the past decades is the use of gold nanoparticles in biology, or life sciences. Taking gold nanoparticles to the cancer cell and hitting them with a laser has been shown to be a promising tool in fighting cancer. The growth inhibitory capacity of nanoparticles against microbes has led to the researches on nanoparticles and their potential application as antimicrobials. Gold nanoparticles (GNPs) are considered a potential probe to detect cancer. Patra *et al.* (2007) investigated whether GNPs, even in the

Date	Photo of cucumber: Deposition of gold	Photo of cucumber: No deposition
Fourth day: 9/5/2011		
Seventh day: 12/5/2011		
Tenth day: 15/5/2011		
Thirteenth day: 18/5/2011		
Sixteenth day: 21/5/2011		
Nineteenth day: 24/5/2011		
Twenty second day: 27/5/2011		

Fig. 2: Gold deposited and normal sides of a cucumber

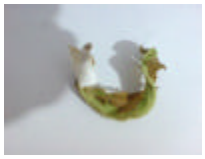
Date	Photo of lettuce: Deposition of gold	Photo of lettuce: No deposition
First day: 6/5/2011		
Fourth day: 9/5/2011		
Seventh day: 12/5/2011		
Tenth day: 15/5/2011		
Thirteenth day: 18/5/2011		
Sixteenth day: 21/5/2011		
Nineteenth: 24/5/2011		
Twenty second day: 27/5/2011		
Twenty fifth day: 30/5/2011		

Fig. 3: Gold deposited and normal sides of a lettuce

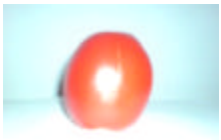
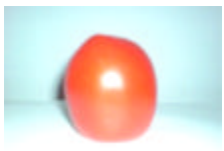
Date	Photo of tomato: Deposition of gold	Photo of tomato: No deposition
First day: 6/5/2011		
Fifth day: 10/5/2011		
Ninth day: 14/5/2011		
Thirteenth day: 18/5/2011		
Seventeenth day: 22/5/2011		
Twenty first day: 26/5/2011		
Twenty fifth day: 30/5/2011		
Thirty day: 4/6/2011		

Fig. 4: Continue

Fig. 4: Gold deposited and normal sides of a tomato

absence of any specific functionalization, induce any cell specific response. In another research (Fu *et al*., 2005) Biomedical Applications of Gold Nanoparticles Functionalized Using Heterobifunctional Poly (ethylene glycol) Spacer were discussed.

In the present work we coated gold nanoparticles on apple, cucumber, lettuce and tomato directly in vacuum conditions by using physical vapor deposition method (thermal evaporation). Direct deposition on fruits and vegetables is a new investigation which is not reported by any other researchers. Coated gold nanoparticles have ability to retard oxygen diffusion and it is highly resistant to oxidation. The sides coated with gold nanoparticles in all samples were fresher with less wrinkles and no any mold and it takes long time to decompose.

It's obvious that duration of protection by gold nanoparticles depends to kind of experimented samples. As it can be seen it takes 84 days for apple, 22 days for cucumber, 25 days for lettuce and 70 days for tomato. As researchers reported gold nanoparticles are used as biomedicals (Fu *et al*., 2005; Salata, 2004; Patra *et al*., 2007; Azarmi *et al*., 2008; Grace and Pandian, 2007), even eating gold nano particles have benefits for human health and they have antibacterial properties (Ravishankar Rai and Jamuna Bai, 2011; Phillips *et al*., 2008; Bajaj, 2009). In our work the protection of fruit and vegetables by gold nanoparticles and nanolayers was investigated. In comparison to the previous works of using gold nanoparticles in biology our work is in good agreement with them.

CONCLUSION

The physicochemical properties of the nanoparticles with the growth inhibitory capacity against microbes have led to the increase in the research on nanoparticles and their potential application as antimicrobials. Physical vapor deposition was used as a direct deposition method for the first time in this research. Gold nanoparticles and nanolayers can be used as a protection of fruit and vegetables. Time length of protection by using these nanoparticles, depends to, different materials and different deposition conditions that we choose for coating. Time length protection of gold nanoparticles has an increasing trend for apple, tomato, lettuce and cucumber. May be eating gold coated fruits and vegetables have benefits for human body and its health, because we use extendedly gold nanoparticles in medical science as sensors in human body and for destroying cancer cells and etc. In this work we used a physical way for investigation of gold nanoparticle protections. It has the ability to retard oxygen diffusion and it is highly resistant to oxidation and we investigate the relation between physics and biology and we got good results as we discussed before.

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