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IMPACT OF RADIO FREQUENCY POWER AND DEPOSITION TIME ON SPUTTERED GOLD THIN FILM GROWTH

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ABSTRACT

The viability of Au thin film systems is decided by the growth parameters related diffusion mechanism where the gold layers can be made extremely thin without sacrificing their reliability. Controlling the characteristics of this process for Au over the various one- and two-layer base metal systems is challenging. Furthermore, Au acts as an important catalytic component in nanostructured material fabrication. Conventionally, catalyst assisted vapor-liquid-solid (VLS) process is used to synthesize semiconductors nanowire. In the VLS process, growth catalysts such as Au, Sn and In are exploited as energetically effective site for vapor-phase elements adsorption. Moreover, they require low eutectic temperatures where Au is highly suited. Thus, the size control of the metal catalyst is essential for semiconductors nanostructures growth. Selection of right deposition time and optimum RF power is very crucial to achieving the high quality Au catalyst thin film. The RF power and deposition time dependent morphological evolution of magnetron sputtered gold thin film is reported. Samples are prepared on a Si(100) substrate with varying deposition time (5 s, 10 s, and 20 s) and RF power (20 W, 30 W and 50 W). FESEM micrograps clearly manifested the formation of gold droplet, where the density of these droplets is found to increase with increasing deposition time. RF power of 50 W and 20 s deposition time produced smooth Au thin film surface devoid of droplets. Results suggest that for high quality Au catalyst thin film formation RF power and deposition time must be optimized.

Keywords: Gold for nanostructured; RF magnetron sputter; RF power; deposition time; FESEM;

INTRODUCTION

The usefulness of precious noble metal gold (Au) cannot be overemphasized. Other than glittering eye-catching jewelleries made of Au it is considered to be a material with unique characteristics applicable in diversified fields. Gold is the most malleable among all materials. It can even be beaten enough to appear transparent, transmit greenish blue light and reflects yellow as well as red glow. These notable features make Au very useful for infrared shield in visors of heat resistance suits and in sun-visors for space suits. In nanostructured materials research, gold is the most well-known catalyst than Cu, Sn, In, Ga, and Al [1-4]. Magnetron sputtering being an easy, economic and environmental friendly method can be used to synthesise high quality Au catalyst as nanosized droplet on the substrate. Sputtering is a physical vapour deposition (PVD) process, where materials are deposited onto a substrate by materials atoms ejection and their subsequent condensation via accelerated Argon (Ar) ions collision with the target. Atoms progressively coalescing on the substrate in turn begin to bind each other at the molecular level and thereby form a tightly bound atomic layer. Through precise control of processing parameters (Ar flow rate, sputtering time, RF power, substrate temperature etc.) one or more thin film layers with precise thickness can be produced. We deposit gold thin film on a Si(100) substrate using magnetron sputtering, where the RF power and deposition time are varied to optimize the growth. Samples morphology are characterized using emission scanning electron microscopy (FESEM). The objectives of this paper is to analyze the influence of deposition power and time towards the morphology of the Au thin film and to determine the most suitable parameters in producing the Au catalyst for silicon nanowire growth using magnetron sputtering.

EXPERIMENTAL

Gold thin films were deposited on p type Si (100) wafer. The substrates were first cleaned in ultrasonic bath using Bransonic CPX1800H-E and then soaked into HF acid solution for 10 minute to remove any native oxide that built up on the samples from air exposure. The substrates were then dried using high purity nitrogen before being transferred into the magnetron sputter's vacuum chamber for samples deposition. The deposition was performed using an Au target (99.9 % purity, Ted Pella Inc). The system was pumped down to 5×10^{-5} torr and Au thin film was deposited with argon plasma by varying the sputtering power and deposition time as summarized in Table 1.

Table 1: Details of processing parameters and sample codes

Sample No.	Power (Watt)	Time (s)
S1	20	10
S2	30	10
S3	50	5
S4	50	10
S5	50	20

Samples surface morphology was examined using FESEM (Zeiss Supra 35 VP). The influence of deposition time and the sputtering power on the growth of nanostructured Au thin films is determined.

RESULTS AND DISCUSSION

Figure 1 illustrates the FESEM images of samples synthesized at different deposition power (20 Watt, 30 Watt, and 50 Watt) under fixed deposition time of 10 s. The influence of sputtering power on the samples growth morphology is clearly evidenced. The existence of gold droplets or islands is manifested in Figure 1. The characteristic size and density of these islands are found to strongly depend on the sputtering power as summarized in Table 2.

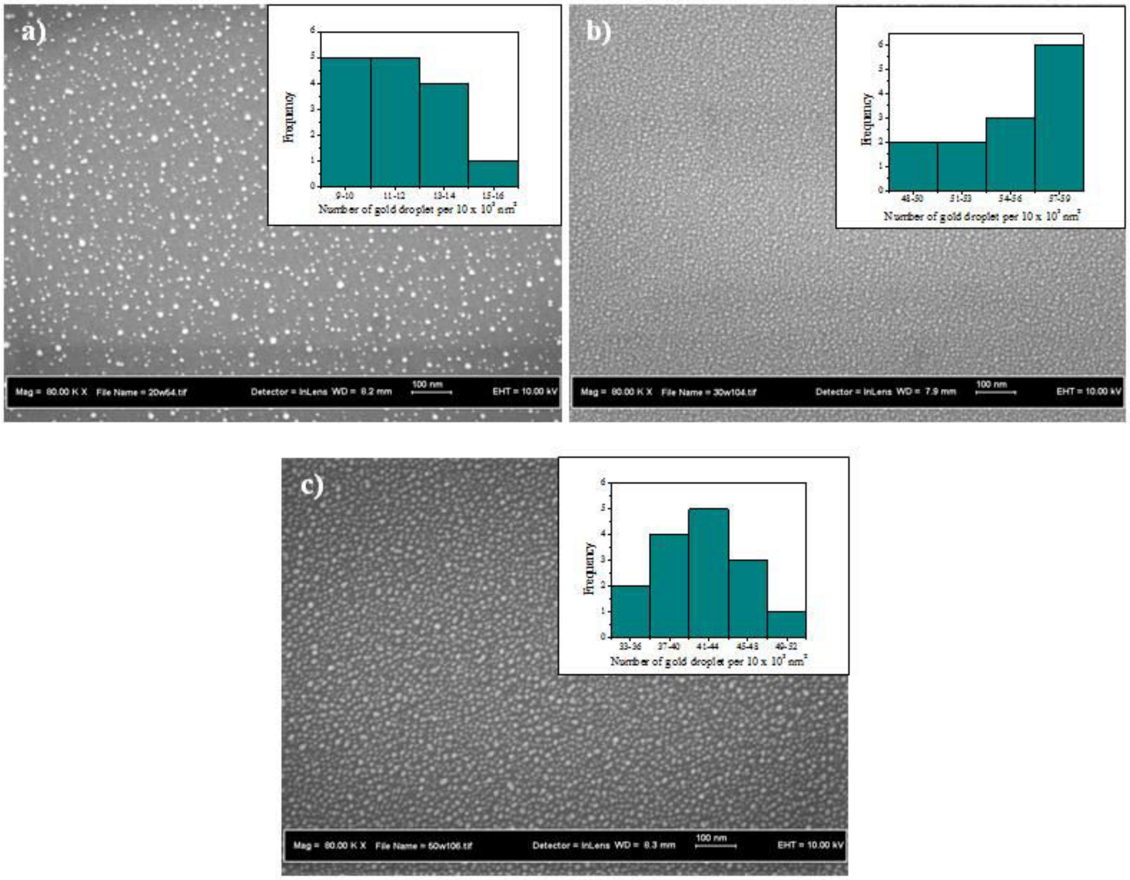

Figure 1: Samples FESEM images at fixed deposition time of 10 s and varying sputtering power of (a) 20 Watt, (b) 30 Watt, (c) 50 Watt

Table 2: Effect of sputtering power on the density of Au droplets (count per 10 × 10^3 nm^2) at 10 s deposition time

Power (Watt)	Average Number of Au Droplets
20	11
30	58
50	42

Figure 1 (a) and (b) shows the increasing of average number of Au droplet with the increasing of RF power where the average number of Au droplets for RF power of 20 watt, 30 watt and 50 watt are 11, 59 and 42, respectively. This phenomenon can be explained by the energy of argon over the target species. Lower RF power leads to a lower energy of argon hitting the target which exhibits to low deposition rate resulting the low number of Au droplets on the substrate [5]. Figure 1(b) and 1(c) on the other shows a completely different result where the number of Au droplets were lower with the increasing of RF power. This phenomenon is due to the enhancement of diameter of individual droplets which is presented in Figure 2 and Table 3.

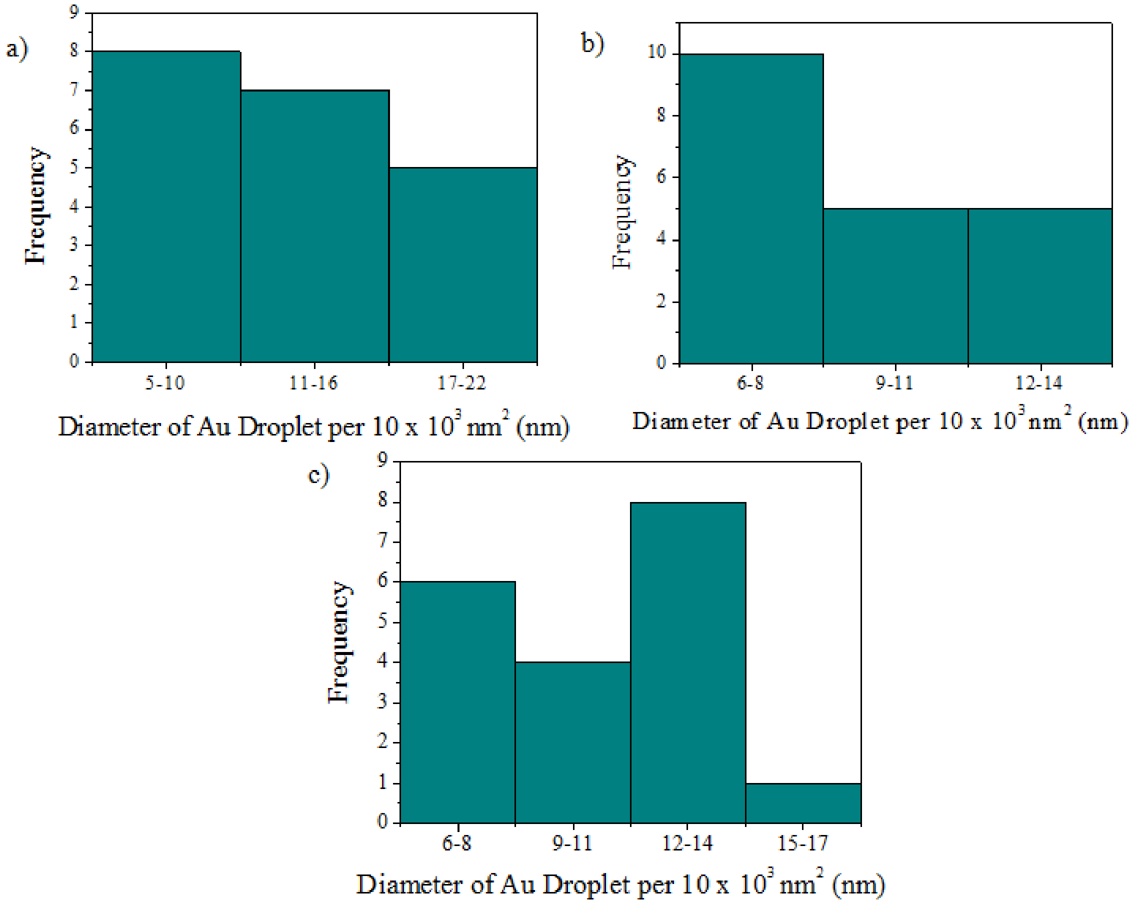

Figure 2: Histogram of diameter of sputtered Au droplets prepared at fixed deposition time of 10 s and varying sputtering power of (a) 20 Watt, (b) 30 Watt, (c) 50 Watt

Table 3: Effect of sputtering power on the diamter of Au droplets per 10 × 10^3 nm^2 at 10 s deposition time

Power (Watt)	Average diameter of Au Droplets (nm)
20	5.88
30	6.25
50	12.56

From Table 3, it can clearly be seen that as the increasing of RF power leads to the enhancement of diameter of Au droplets where at 20 watt, 30 watt and 50 watt, the average diameter of droplets were 5.88 nm, 6.25 nm and 12.56 nm respectively. This enlargement in diameter with the increment of RF power is attributed to the enhanced kinetic energy of Au particles arriving on the substrate, where particle can migrate more before they coalesce and form a bigger droplet [6].

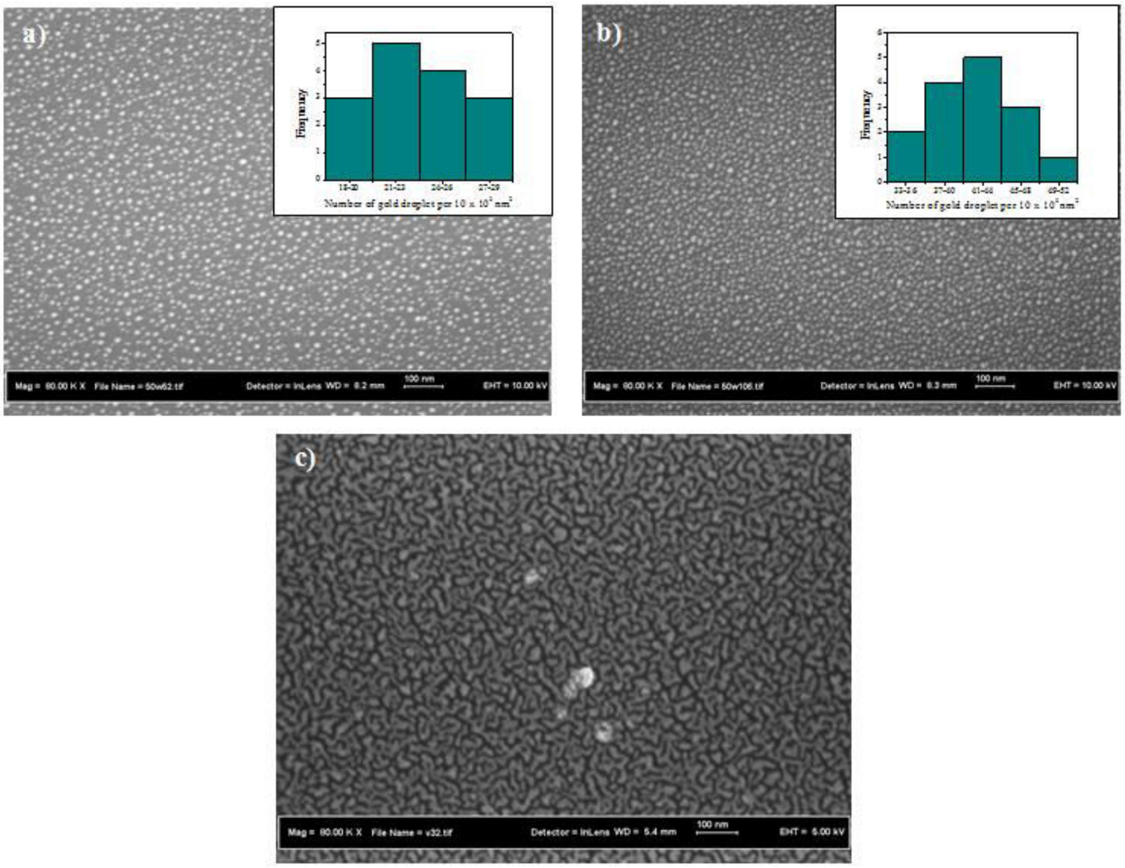

Figure 3: Surface morphology (FESEM images) at constant RF power (50 Watt) and varying sputtering time of (a) 5 s, (b) 10 s, (c) 20 s

Table 4: Effect of deposition time on the density of Au droplets (count per 10 × 10^3 nm^2) at 50 Watt RF power

Deposition time (s)	Average Number of Au Droplets
5	22
10	42

Figure 3 shows the effect of sputtering time on the samples surface morphology. The density of droplets at 10 s deposition is found to be higher than that of 5 s (Table 4). This is because, as the deposition time is increased, more droplets arrived on the substrate which explains the increasing of Au droplet's intensity. However, Figure 4 and Table 5 shows that the size of Au droplets is found to have no significant increase with the increase of deposition time where only 0.96 nm difference of average diameter of Au droplet between 5 s and 10 s deposition time.

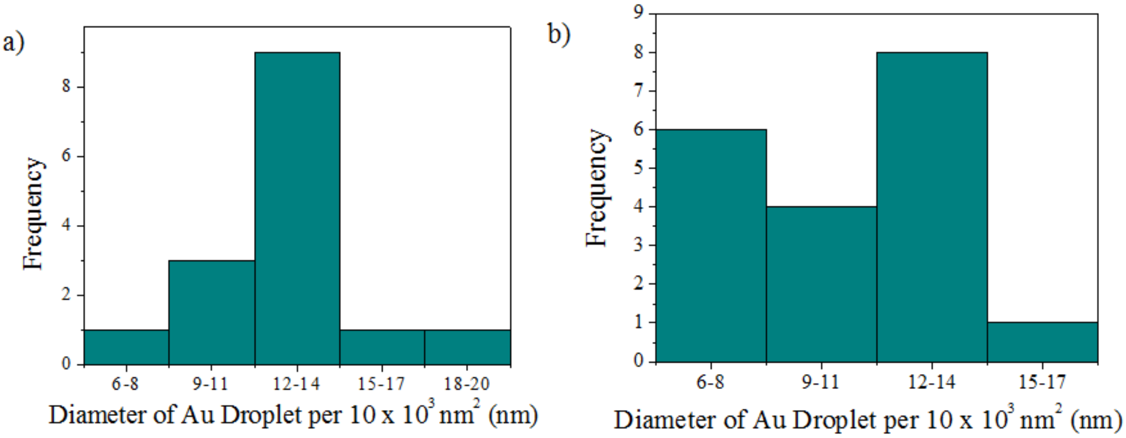

Figure 4: Histogram of diameter of sputtered Au droplets prepared at fixed RF power of 50 Watt and deposition time of (a) 5 s, (b) 10 s

Table 5: Effect of deposition time on the diamter of Au droplets per 10 × 10^3 nm^2 at 50 Watt RF power

Deposition time (s)	Average diameter of Au Droplets (nm)
5	11.6
10	12.56

The relatively similar diameter of Au droplets is due to no energy changes of argon energy hitting on the target resulting to a same kinetic energy of Au particle arriving on the substrate hence explaining to a relatively similar diameter of Au droplets in Figure 3 (a) and (b). However, at higher deposition time (20 s), the surface of the samples showed a worm-like structure. Generally, the formation of island or droplets is due to the Volmer-Weber form of growth where the adatom-adatom interaction is stronger, resulting to the formation of three dimensional adatom cluster as seen in Figure 3 (a) and (b). However, at higher deposition time (20 s), the growth phase of Au altered from electrically discontinuous to continuous layer to achieve worm-like structure Figure 3 (c) [7-9].

CONCLUSION

The influence of varying RF power and deposition time on the morphological properties of magnetron sputtered gold thin film on silicon substrate is reported. An increase in RF power enhanced the size and density of Au droplets on the thin film. This enhancement is ascribed to the higher kinetic energy of Au particle that arrived at the substrate. Conversely, the influence of sputtering power on the energy of argon ion hitting the target led to the change of sputtering rate. This in turn altered the sputtering rate and thereby affected the Au droplets density. Variation in sputtering time played a significant role during deposition, where the droplets are transformed to worm-like structure at higher deposition time. Deposition time of 10 s and RF power of 50 Watt is found to be optimum to produce Au droplets of uniform size and density. It is demonstrated that RF power and deposition time in magnetron sputtering are the most ideal parameters for Au catalyst fabrication useful for nanowire growth. The generated information may contribute towards the development of controlled growth of Au catalyst.

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