Au Nano-Wire Transferring onto HSQ by Nano Imprinting Technology

Jen Fu Liu[1], Yung Jen Hsu[1], Henry J. H. Chen[1, 2], Fon Shan Huang[1], and Sun Zun Chen[2]
[1]Institute of Electronics Engineering, National Tsing Hua University
[2]Center for Nano-Science and Technology, University System of Taiwan;
Engineering Building III, National Tsing Hua University,
Hsinchu, Taiwan, ROC, chchen@ee.nthu.edu.tw

ABSTRACT

In this paper, we present the technique of transferring Au nano-wire on HSQ by using nano imprint. The Au nano-wires were fabricated by immersion plating and investigated by TEM analysis. The stable nano imprinting process of HSQ was also investigated to have effective transferring condition. The Au nano-wires transferring results were also investigated by using SEM photography and optical microscope.

Keywords**:** Au nano-wires, HSQ, Nano Imprint.

1 INTRODUCTION

As conventional projection lithography reaches its limits, imprinting lithography has the potential to be a cost-effective solution. Nanoimprint lithography, proposed by S. T. Chou et al. in 1995, uses a solid mold, such as silicon or nickel. It creates a resist relief pattern by deforming the resist physical shape with embossing, rather than by modifying the resist chemical structure with radiation or self-assembly. A variety of different devices, such us ring transistors, MOSFET, MESFET, have been fabricated by a number of different researchers using this approach. The arrays of 10-40 nm period holes were also imprinted in PMMA on Si or gold substrates. The PMMA, polystyrene, and polycarbonate microring resonators were also demonstrated [1].

In 2001, room temperature NIL (RT-NIL) has been demonstrated by S. Matsui et al., using spin-on-glass or hydrogen silsesquioxane (HSQ), instead of PMMA. The nano-transfer printing technology utilizing the adhesion characteristics of HSQ was also demonstrated by transferring the photoresist and Au pattern from a mold to a substrate [2]. However, the SOG/HSQ is unstable using the low-temperature prebaking and RT-NIL process. More stabilized SOG/HSQ NIL or metal transferring process has to be developed for the future ULSI metallization applications.

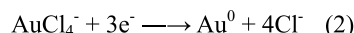
2 EXPERIMENTAL

Figure 1 shows the reaction diagram of Au immersion plating. The electrochemical reaction principle of Au replacement reaction on Si surface is one kind of oxidation-reduction reaction between Si and Au. The half reaction and overall reaction are shown as following:

Anode (oxidation reaction):

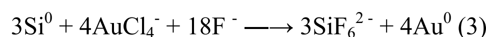
$$Si^0 + 6F^- \longrightarrow SiF6^{2-} + 4e^- \quad (1)$$

Cathode (metal-reduction reaction):



$$AuCl_4^- + 3e^- \longrightarrow Au^0 + 4Cl^- \quad (2)$$

Overall reaction:



$$3Si^0 + 4AuCl_4^- + 18F^- \longrightarrow 3SiF_6^{2-} + 4Au^0 \quad (3)$$

In the $AuCl_4$ solution, the Si and Au will not react naturally. The HF chemical was used as the oxidant to oxidize Si to SiF_6^{2-} ions and to release electrons to reduce the Au ions in the solution. Usually, the electron exchange rate is much higher than the diffusion of Au is. Therefore, the reaction is dominated by the diffusion of Au. While the deposition layers

of Au atom on the Si surface increase, the diffusion of reactant from solution to the Si surface become difficult. The deposition rate will also decrease. The reaction will remain till the seed layer is run out.

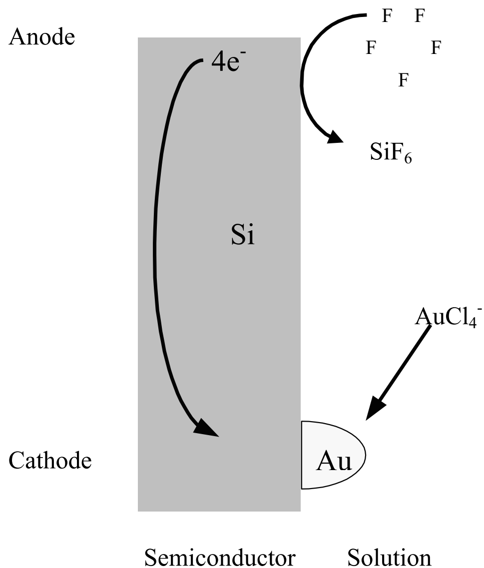


Figure 1: Reaction diagram of Au immersion plating.

Figure 2 shows the fabrication of Au nano-wire by using E-beam lithography and Au immersion plating. The photoresist (DSE 1010) with the thickness 350 nm was spin-on coated on Si (100) wafer and exposed by E-beam lithography. After the developing, the sample was immersed into the plating solution and the Si was replaced by Au. Then, the PR was striped and the Au nano-wire, with thickness is about 100-200 nm, was formed.

Figure 3 shows the process of transferring Au nano-wires on HSQ by nano imprint. The HSQ, the thickness was around ~250-600 nm, was diluted in MIBK (1:0~ 4:5) and spin-on coated on Si (100) wafer. The prebaking temperature of HSQ was around ~50-150℃. The imprinting system used in this experiment was Nanonex NX-1000. After the prebaking of HSQ, the Au nano-wires were imprinting transferred from the Si mold into the HSQ with the imprinting temperature was around ~25-180℃ and the imprinting pressure was around ~ 1-2.5 MPa.

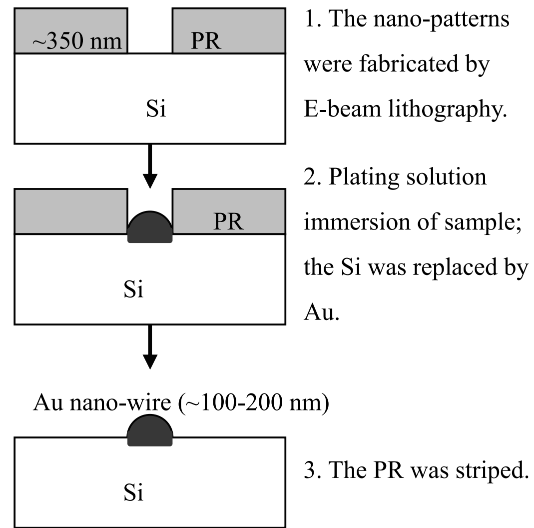


Fig. 2: The fabrication of Au nano-wires.

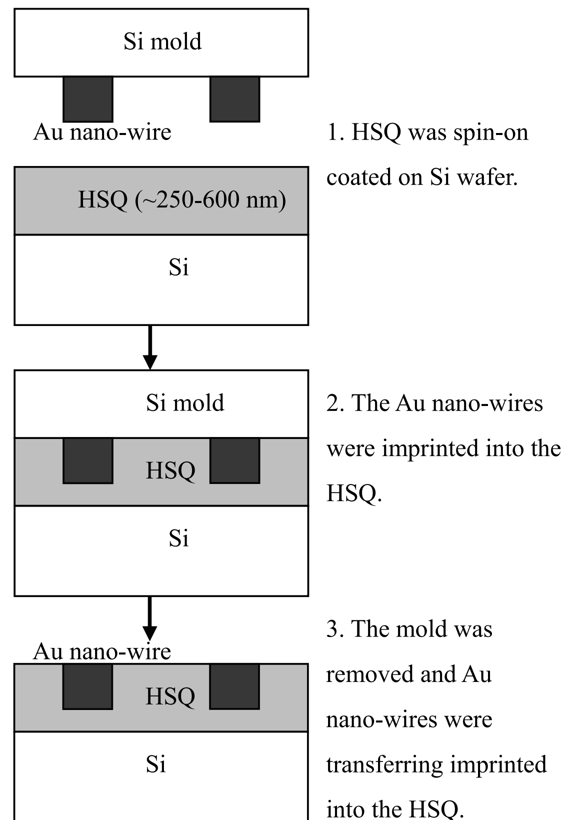


Fig. 3: The process of transferring Au nano-wires on HSQ by nano imprint.

3 RESULTS AND DISCUSSIONS

Figure 4 shows the TEM photograph and diffraction pattern of Au nano-wires fabricated by immersion plating. The width of Au nano-wire is about 150-200 nm and the diffraction pattern showed the Au grains exist in the nano-wire. As the results indicate, the immersion plating by using Au replacement reaction on Si surface was a useful method for Au nano-wire fabrication.

Before the Au nano-wires were transferred imprint on HSQ, the HSQ trenches fabricated by nano imprint were first demonstrated using Si nano mold. The Si-mold was also fabricated by E-beam lithography and RIE dry etching. Figure 5 shows the SEM photography of nano-scale HSQ trenches fabricated by imprinting.

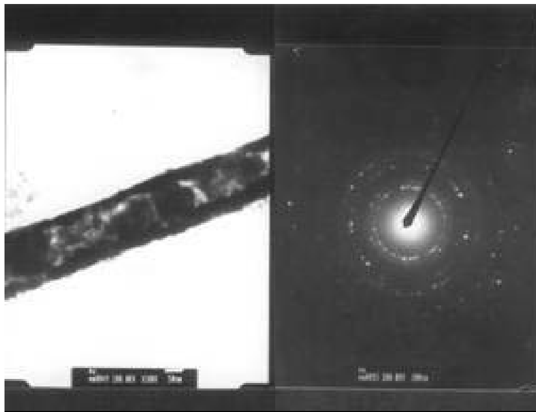
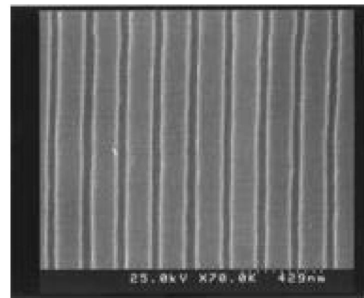
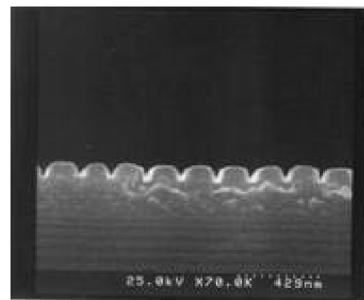


Fig. 4: The TEM photograph and diffraction pattern of Au nano-wires fabricated by immersion plating.

To remove the solvent content in the SOG/HSQ, the HSQ should be prebaking (50-150℃) before the imprinting process begins [2]. As the prebaking temperature increases, the hardness of HSQ will also increase. The process pressure (2.5-4 MPa) has to increase to imprint suitable depth. Therefore, the prebaking temperature has to be as low as possible, for example, 50℃. However, such low-temperature prebaking and high pressure RT-NIL HSQ imprint process is unstable. In our experiment, the RT-NIL HSQ patterns distorted after 4 days exposing in the air. In the low pressure and high temperature imprinting process, typically around 2.5 MPa, 150-200℃, the HSQ patterns didn't distort after 4 days exposing in the air. The low pressure and high temperature imprinting process is still necessary for HSQ naon imprinting process.



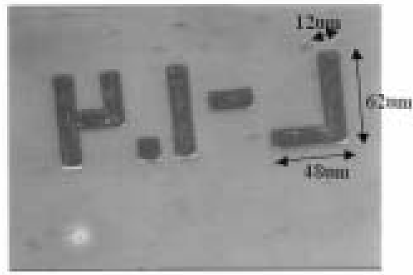
(a)



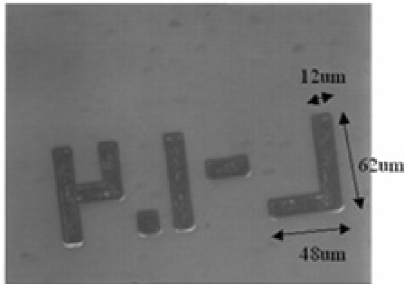
(b)

Fig. 5: The SEM photography of nano-scale HSQ trenches fabricated by imprinting.

Figure 6 shows the OM photography of Au lines fabricated by imprinting transferring before and after 4 days exposing in the air. The Au lines were transferred on HSQ successfully by 2.5 MPa, 150-200℃ imprint and the patterns were nearly the same after 4 days exposing in the air.



(a)



(b)

Fig. 6: The OM photography of transferred Au lines on HSQ fabricated by imprinting (a) before and (b) after 4 days exposing in the air.

Figure 7 shows the SEM photography of transferred Au nano-wire on HSQ by nano imprint. The nano-wire width is about ~197 nm.

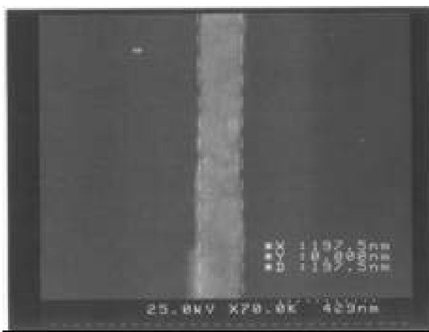


Fig. 7: The SEM photography of transferred Au nano-wire on HSQ fabricated by nano imprint.

There are several major advantages are described here. The first is the mold fabrication. The metal nano-wire mold was fabricated by e-beam lithography and electroless plating. The mold fabrication can be also modified to first use the e-beam lithography to fabricated the Si-mold, then use the NIL (with Si-mold) to fabricate the resist and then use the electroless plating to fabricated the metal nano-wire mold. The e-beam lithography process can be used just only one time. This will save the process cycle time and the cost.

The second is low pressure and low temperature process. The HSQ is diluted with MIBK and prebaked at suitable temperature. This makes the pressure (~2.5 MPa) used in this invention is lower than the previous investigator (2.5-4 MPa) and the temperature (150-200℃) is much lower than the conventional metallization process (~ 450℃).

4 CONCLUSIONS

In conclusions, the transferring Au nano-wire on HSQ by nano imprint is proposed. The low pressure and high temperature imprinting process is suitable for the future ULSI interconnection applications.

5 ACKNOWLEDGMENT

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6 REFERENCE

[1] S. Y. Chou, et. al, “Sub-10 Imprint Lithography and applications, ” J. Vac. Sci. Tech. B 15(6), 2897(1997).

[2] S. Matsui, et. al, “Room-Temperature Nanoimprint and Nanotransfer printint using HSQ, ” J. Vac. Sci. Tech. B 21(2), 688(1997).