

DOPING EFFECT OF PT ON CAPACITANCE-VOLTAGE PROPERTIES OF METAL-SEMICONDUCTOR-METAL DEVICE

Itsara Srithanachai¹, Surasak Niemcharoen¹, Narong Sangwaranatee^{2,*} and Prongsak Auttaphut³

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Abstract

This paper present the effect on capacitance-voltage (C-V) characteristics of metal-semiconductor-metal (MSM) by Pt doping. Platinum atom dope on back side of substrate and drive in by using rapid thermal annealing (RTA) process around 5 mins, then, diffuse into silicon structure. The influence of doping atom will change structure of silicon and impact to electrical properties of device. Pt atom will induce trapping center in silicon band and will help in switching time of MSM device. The ultimate goal of this paper will focus on C-V characteristics and simulation result of Pt atom to confirm diffusion range. Moreover, we will measure resistance of silicon substrate before and after Pt-doped to confirm diffusion range.

Keywords: Platinum diffusion, Switching time, MSM, C-V characteristics

Introduction

Semiconductor technologies still improve performance for long time and continue until now because demand from user would like to get high performance, high responsibility and still has higher demand every year. Device has use in many application that high popular in new trend of technology such as security

(Rudy *et al.*, 2008), telecommunication (Ackerman *et al.*, 2001), agriculture (Macedo *et al.*, 2008), transportation (Lee *et al.*, 2017), education (Cheong, 2016), and cosmetics (Raj, 2012). From the example of technology, semiconductor research will continue to research for long term. The report of

¹ Department of Electronics, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand. E-mail: srithanachai@gmail.com

² Applied Physics Research Group, Faculty of Science and Technology, Suan Sunandha Rajabhat University, Bangkok 10300, Thailand. E-mail: narong.sa@ssru.ac.th

³ Department of Electrical Technology, Faculty of Industrial Technology, Suan Sunandha Rajabhat University, Bangkok 10300, Thailand. E-mail: pungsak.au@ssru.ac.th

* Corresponding author

technology 2017 show emerging opportunities for semiconductors device. While the price of DRAM and NAND still increases because use for flash memory, the overall for last 5 years still continue increase because the vendor has high demand to support smartphone technology, PCs and servers.

Photodetector is one of device that use for sensor technology and apply to many application. Detector trend will focus on low power, small size and high speed sensitivity. Now, researcher try to reduced switching time to get high speed device, large area to get more signal and use low energy as well. For the example of optoelectronics company want to use large active area and high speed silicon detector to reliably support short-haul data communications application (Akinlar, 2016). All exhibit to get low dark current (leakage) and low capacitance (Milano *et al.*, 1982). The basics of photodetectors, a junction of device is and intrinsic that behaves similarly to an ordinary signal diode. On the other hand, it will generates photo current whenever has the light absorb in the depletion region of device junction. That is necessary to able to get determine the level of output current to expect and responsivity based upon the incident light. The relation between output current, dark current and photo current show in Equation 1. (Srithanachai *et al.*, 2012).

$$I_{Out} = I_{Dark} + I_{PD} \quad (1)$$

The example for photodetector circuit as show in Figure 1. The reverse current flows through photodetector when it is sensing light. The sensitivity of device depends on the wavelength as well. The absorption of device refer to substrate material, silicon providing to use in wavelength around 350-1,000 nm and InGaAs will apply to use 800-1,700 nm (Akano *et al.*, 1995). For both material substrate will use same design structure is PIN, the p-i-n diode is refer to the ordinary PN junction diode. The basic of PIN diode will operate under high injection. (Berz, 1997).

Metal-semiconductor-metal (MSM) is the photodetector design that focus on switching time because spacing between metal

contacts are close. Therefore, electron will move to another contact to fast that make this design has high speed. The basics of MSM design consist of 2 metal Schottky electrode and has space for the active area to absorb the light. For 2 electrode have bias with different type are reverse and forward bias. Figure 2 show sample design of MSM. (Zamani *et al.*, 2017).

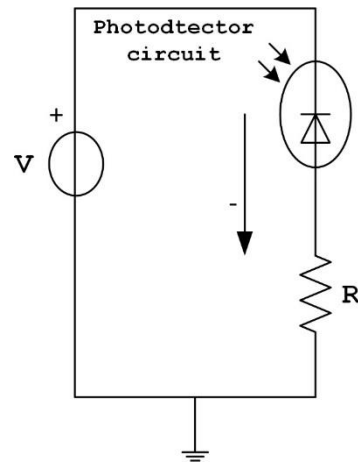


Figure 1. Example Photodetector circuit

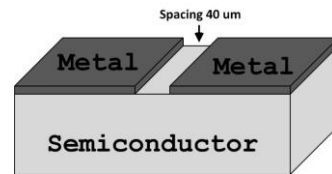


Figure 2. MSM photodetectors design

Experimental

The preparation of Al/n-Si/Al fabricate will follow step by step: (a) clean n-type silicon (100), thickness 400 μm , resistivity 7-20 $\Omega\text{-cm}$ with DI water and ultrasonic for 5 mins, (b) doping platinum on back side of substrate, (c) annealing by using RTA process at 800 $^{\circ}\text{C}$ for 5 mins, (d) coating Al on top of silicon, (e) photolithography and open active area, (f)

sintering with 500°C in nitrogen environment, (g) the last step for checking adhesion on metal contact by using 3M sticker stick with contact and pull off. (Prabket *et al.*, 2012).

Figure 3. Shows Pt doping process on back side of silicon substrate. Pt will diffuse into silicon by RTA process after doping with high energy. The process for Pt doped by using ion implantation with high energy around 120 keV. The spacing between metal contact of this experiment around 40 μm and metal contact size 1 mm^2 (Srithanachai *et al.*, 2012). Sheet resistance of silicon wafer after doped by Pt measure by 4-point probes technique to confirm Pt diffuse into substrate.

After fabrication finished, the device will measure capacitance-voltage characteristics under dark environment compare between Pt-doped and undoped. Use HP4156B to measure on wafer with bias step of 0.1 V from reverse to forward voltage in the range of -10 to +10 V. (Ueamnpong *et al.*, 2012).

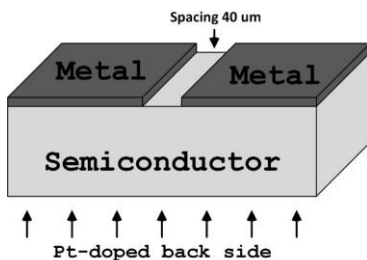


Figure 3. Pt-doped on back side of silicon substrate

Results and Discussion

From simulate results of ion trajectories show that Pt-doped diffusion range in silicon substrate structure. The concentration of doping atom has high concentrate close of surface and decrease when deep to bulk.

The trajectory of Pt atom random diffuse such a collision model. The trajectories described for the ion through the silicon bulk are complex and cannot describe in a simple due to large atom number has physical variables that may relate to electrics field.

From Figure4 shows that Pt atom diffused to silicon bulk around 0.45 μm without temperature induce. (Baliga and Sun, 1977).

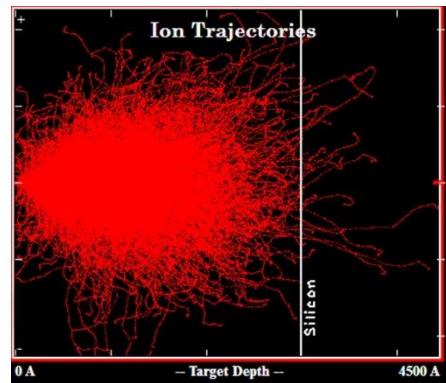


Figure 4. Ion trajectory of platinum atom in silicon substrate

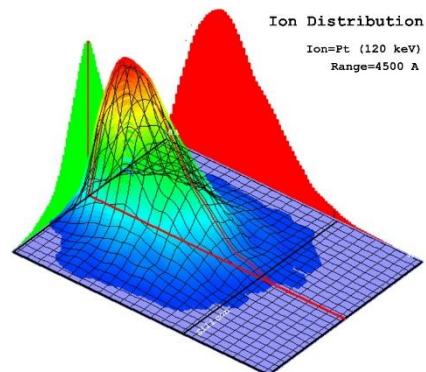


Figure 5. Ion distribution of Pt atom

Ion distribution of Pt atom in silicon bulk shown in Figure 5 (Vobecky and Hazdra, 2002). From picture show distribution of atom after doping by using high energy. When Pt atom are incorporated into silicon lattice, atom are locate at substitutional sites, replacing and cause to increase of internal stress. The diffuse properties of Pt in substrate will described by kick-off and dissociative mechanism. The temperature of RTA relate in kick-off mechanism of Pt atom in silicon structure, at above 900°C (Zimmermann and Ryssel, 1992). The temperature that suggest to use for RTA

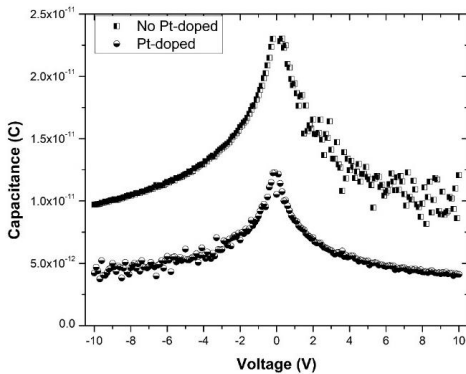


Figure 6. C-V characteristics of MSM between doped and undoped of Pt

around 850°C. After doping and drive-in process, the sheet resistance of substrate increase around 4 Ω/sq from 44.43 to 48.39 Ω/sq .

The switching time of device relate with capacitance-voltage properties of device. Important of MSM device is low capacitance by comparing with PN, PIN device. The capacitance-voltage characteristics of MSM design with interdigitate electrodes is usual smaller than pin design with equal active area and leads in very high sensitivity (An *et al.*, 2013). From Figure 6 shows capacitance of device compare between undoped and Pt-doped. The results show that undoped device has capacitance around 2.3×10^{-11} F at 0 V. On the other hand, capacitance voltage reduced after doped by Pt, the results show around 1.2×10^{-11} F. The capacitance reduced around 2 times after doped by Pt. From this results can explain that the switching time of Pt-doped condition will higher than undoped (Lepselter *et al.*, 2008). Moreover, depletion region of Pt-doped also higher than undoped around 2 times are 0.99 μm and 0.48 μm , respectively.

Conclusions

This paper is clearly presented that Pt-doped in MSM device has lower capacitance-voltage characteristics more than undoped condition around 2 time. The, depletion region (active

area) has increase 2 times as well. The depletion region of device increase will get more light current in active area. The capacitance reduce will increase switching time of MSM device. Pt atom in silicon mechanism will create trapping center and reduce lifetime for fast recovery of MSM device.

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