RCA clean is silicon wafer cleaning technology developed by an US company named RCA, it is applied in the manufacturing of RCA component in 1965 and the cleaning process is published in 1970. RCA clean contains two steps: wet oxidation and complexation reaction. RCA clean can effectively clean the dust, organic compound, and metallic ion contamination on the wafer, it is normally called standard clean.

The crystalline particle arrangement is not so perfect. It is thought that the atom structure start re-arrangement, and crystals of Dislocation Free defects start to be generated: but the annealing temperature is not high enough to support enough energy for perfect crystallization.

Perfect Poly-SiGe crystal can be seen from figure 3-3(a), not only high crystalline particle but also perfect arrangement can be seen, it is the most perfect annealing parameters for Poly-$Si_{0.82}Ge_{0.18}$ thin film crystallization. When the annealing time is increased gradually, we can see from figure 3-4(b)(c) that the surface of Poly-$Si_{0.82}Ge_{0.18}$ thin film starts to become flat and smooth. From a comparison in figure 3-4 we know that, when the annealing temperature is increased to over 60minutes, the crystalline particles on the surface of the Poly-$Si_{0.82}Ge_{0.18}$ thin film start to become unclear, it is thought to be due to over time annealing, it is assumed that the energy supplied from outside is too much to generate defects in the material.

We find that at 900℃, no crystal particles can be seen on the surface of Poly-$Si_{0.82}Ge_{0.18}$ thin film, it is assumed that the energy supplied from outside is too much to generate defects in the material.

The results observed from AFM data and from the drawing and table support the conclusion obtained from SEM result, this also proves our previous deduction.

The first requirement of surface study is to prepare a surface with representative structure and composition, especially to clean the surface and preserve it for a long time for further analysis. Therefore, the test wafer in the current experiment has been cleaned by sputtering etch for 300 seconds before measurement in order to remove surface impurity (such as carbon).

From figure 3-19 and 3-20, we know that Ge ion has optimum diffusion depth at annealing temperature of 800℃ and time of 30 minutes. Through comparison, Ge can have best and even distribution in Poly-$Si_{0.82}Ge_{0.18}$ thin film of 150nm at annealing temperature of 800℃ and time of 30 minutes.

The more even the atom distribution inside the thin film, the better characteristics it is for the component made; therefore, from the SIMS data that annealing temperature of 800℃ and time of 30 minutes is the best parameter.

Then we observe the curve obtained for annealing at 300℃ in N_2 ambient for one hour, we find that sheet resistance shows a decreasing trend as compared to that before annealing; along with the increase in substrate temperature, we can also see the decrease in the sheet resistance, it reaches a table trend at about 300℃.

From XRD, we can clearly measure how many directions of crystallization exist on the thin film surface.

When the substrate is not in heating, In_2O_3 (222) and In_2O_3 (440) have the same strength of crystallographic facet. Along with the increase in substrate temperature, In_2O_3(440)shows an increasing strength, In_2O_3(222)shows a decreasing strength, it shows the most obvious trend when the substrate temperature reaches 200℃; when the substrate temperature exceeds 200℃, the situation starts to change, In_2O_3 (440) shows a gradually decreasing trend and In_2O_3 (222) shows a gradually increasing trend.

Moreover, for the two smaller crystallographic facets In_2O_3(211) and In_2O_3 (400), no matter it is before or after annealing, when the substrate is at a temperature of 200℃, it has the strongest crystallographic facet.

The elements on the test wafer, in addition to original In, Sn, O_2, there is additional N_2.

r_p is the incident number of photons per second, r_e is the number of generated electrons per second.

The definition of response coefficient is as in the following: The detected amplitude of photo current per unit of incident light power.

Aluminum metal has been used for the interconnect material in IC in the begging, this is because of its low electrical resistivity and its compatibility to silicon and wafer process. Generally speaking, since Al is suitable for the main IC process and is not expensive, it is thus the metallization choice in the early stage of IC manufacturing. This experiment uses evaporation method to prepare the Al metal electrode for the device.

Then four layers of n^+/n/p/p^+-Poly-$Si_{0.82}Ge_{0.18}$ thin film are continuously deposited on SiO_2. From SEM thickness measurement we find that the four layers of Poly-$Si_{0.82}Ge_{0.18}$ thin film has a thickness of 503.50nm, it is a little bit different than 600nm in the experiment design stage, it should be caused by non-homogeneous deposited film thickness.

Use green wavelength filter to filter out the green wavelength needed in the experiment from the tungsten light source. Figure 5-8 shows the transmission of the filter used in the experiment, it has a band pass range of 500-570nm, wherein the average transmission in 536-550nm range is 91.47%.

When the optical illumination is 3.0μW, APD device annealed in N_2 ambient at 800℃ for 30 minutes can generate maximum photocurrent （143.75μA）, meanwhile, it has a smaller threshold voltage（About 2.5V）.

Compare figure 5-14 to 5-17, we can see that, at smaller optical illumination, the device itself will have larger response coefficient, besides, the response coefficient shows a rising trend with the increase of voltage; Poly-$Si_{0.82}Ge_{0.18}$ APD annealed at N_2 ambient at 800℃ for 30 minutes shows maximum response coefficient relative to other parameters. Since the response coefficient has the definition of "The detected amplitude of photo current at unit incident photo power", it is a very important index for optical device; under the same outer condition, device with higher response coefficient will have better optical sensitivity.

Figure 5-18 is the response coefficient curve of Poly-$Si_{0.82}Ge_{0.18}$ APD measured using green light filter at optical illumination of 3.0μW for different annealing conditions, we find that device annealed in N_2 ambient at 800℃ for 30 minutes has the highest response coefficient of 47.92(A/W). By comparing figure 5-14 to 5-18, annealed in N_2 ambient at 800℃ for 30 minutes is the optimum parameter to make APD with best optical sensitivity. This result supports the observed conclusion in figure

5-9 to 5-13 in the previous section.

By comparing figure 5-19 to 5-22, we can see that, APD device shows higher quantum efficiency at smaller optical illumination; Poly-$Si_{0.82}Ge_{0.18}$ APD annealed in N_2 ambient at 800℃ for 30 minutes shows the highest quantum efficiency. Figure 5-23 shows the quantum efficiency of Poly-$Si_{0.82}Ge_{0.18}$ APD at different annealing conditions by using green light filter at optical illumination of 3.0μW, we find that APD annealed in N_2 ambient at 800℃ for 30 minutes has highest quantum efficiency (82.94%). Since the definition of quantum efficiency is ”The number of electron and hole pairs that can be generated in average for each incident photon”, however, APD device can generate large number of electron and hole pairs through avalanche effect, it thus has very high quantum efficiency. By comparing figure 5-19 to 5-23 we can see that device annealed in N_2 ambient at 800℃ for 30 minutes can have the optimum quantum efficiency.

We can see from figure 5-24, along with the rise in the optical illumination in the experiment, the Gain Ratio of APD will rise gradually and finally reach a stable state; as compared to other annealing parameters, the Gain Ratio of Poly-$Si_{0.82}Ge_{0.18}$ APD annealed in N_2 ambient at 800℃ for 30 minutes is 142.75, it is far larger than that annealed at other conditions (it is about 8.04 times the Gain Ratio of an un-annealed APD), it has optimum photo dark current ratio.

We find from comparisons that Poly-$Si_{0.82}Ge_{0.18}$ APD annealed in N2 ambient at 800℃ for 30 minutes has, in the same time, the maximum photo current, maximum response coefficient, optimum quantum efficiency and maximum photo dark current ratio, therefore, this experiment adopts this parameter as the optimum parameter for preparing APD device. We think that annealing in N_2 ambient at 800℃ for 30 minutes is the best parameter of this experiment because of the following reasons: first, this condition is the best analysis condition of Poly-$Si_{0.82}Ge_{0.18}$ thin film material（can be seen from chapter 3 of this thesis）; secondly, the dopant atoms in this condition can just reach optimum depth distribution, it is very helpful in enhancing the optical sensitivity of APD device, therefore, this experiment adopts annealing in N_2 ambient at 800℃ for 30 minutes as the optimum parameters for preparing APD device.