《微纳光电子材料与器件工艺实验》
Laboratory of Micro- and Nanofabrication for Electronic and Photonic Devices

Lab 1 Photolithography（紫外光刻）

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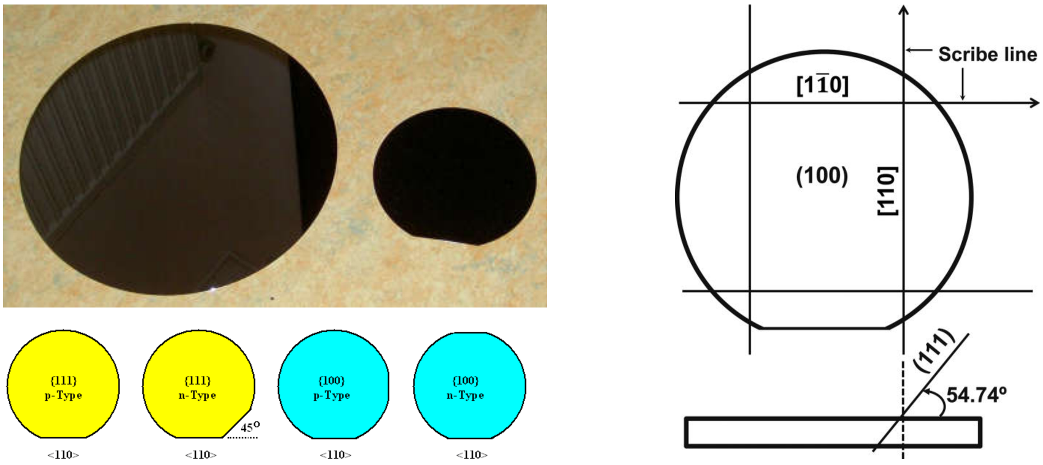
1. Objectives

In this lab, we introduce the photolithography method. We will learn to clean and cleave silicon wafers manually, spin coat positive photoresist films on silicon, expose the resist under UV radiation using a mask aligner, develop the resist, observe and measure the photoresist patterns.

2. Introduction

Silicon wafers and cleavage

Silicon is the most commonly used substrate material for microfabrication in semiconductor industry. It is widely used to form integrated circuits and photovoltaic cells. A silicon wafer is a single crystalline thin slice with a specific orientation, like (100), (110) or (111). Commonly used silicon wafers have diameters of 4 inch (100 mm), 6 inch (150 mm), 12 inch (300 mm), and even 18 inch (450 mm).



Photographs of silicon wafers, typical wafer types and flats, cleavage planes for a (100) wafer.

Due to its single crystalline structure, silicon wafers crack along specific directions under external forces. The separation planes are called cleavage planes. For example, (100) wafers cleave along two perpendicular [110] directions. In contrast, amorphous materials (for example, glasses) form cracks with random directions.

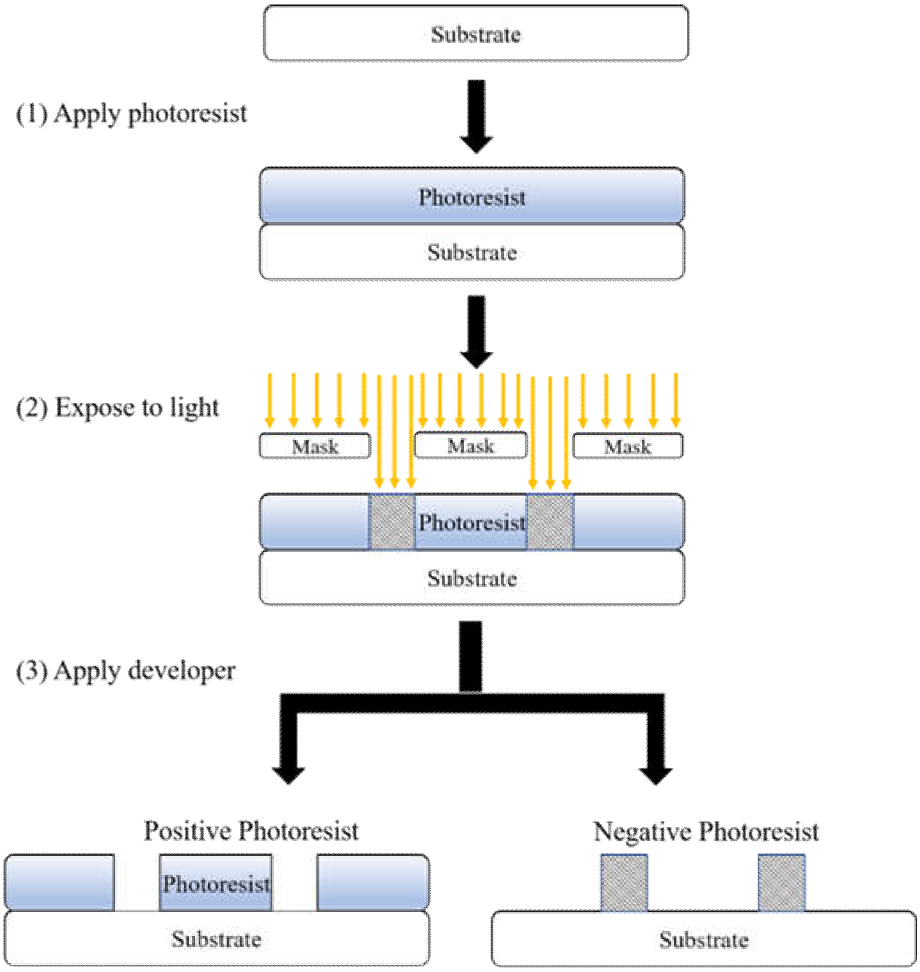
Cracks formed on a broken silicon wafer and a broken glass plate.

Silicon wafer clean

Impurities on silicon wafers will severely affect the product yield and device performance during the subsequent fabrication processes. For example, some metal ions can easily diffuse into the silicon crystals and create deep doping levels in the lattice, which work as carrier traps and degrade transistor performance. Unwanted particles on the sample surfaces will also form defects during lithographic steps and affect the designed patterns. Commonly used cleaning chemical recipes include:

- piranha etch (concentrated H_2SO_4 + H_2O_2): remove metal ions and organic residues;
- hydrofluoric acid (HF): remove native SiO_2;
- SC-1 (standard clean 1: NH_4OH + H_2O_2): remove organic residues;
- SC-2 (standard clean 2: HCl + H_2O_2): remove metal ions;
- acetone / isopropanol / ethanol: remove organic residues;
- deionized water: remove water soluble ions and organics.

Photolithography



3. Materials and Equipments

Materials

silicon wafers 4 inch (> 1)
glass slides 1×3 inch (>1 box)
acetone (a full bottle)
ethanol (a full bottle)
Deionized (DI) water (a full bottle)
large beakers (>3)
plastic funnels (>2)
petri dish, 4 inch (>10)
aluminum foil
paper cups (>5)
gloves (>2 boxes)
face masks (>20)
cleanroom white papers (>1 bag)
dust blowers (>2)
rulers (>5)
wafer tweezers (>5)
diamond pens (>5)
SPR220-3.0 photoresist (>1 bottle)
plastic pipette (>10)
photoresist developer MIF-300 (>1 bottle)
photomask 3 inch (>1)
Stop watches (>4)
cleanroom gowns (>7)
safety glasses (>5)

Equipments

hot plate
mask aligner
spare UV bulbs (>1)
UV dosimeter
N_2 gas gun
chemical hood
SC-1B spin coater
optical microscope
Dektak-150 profilometer

4. Procedures

Preparation

- turn on chemical hood
- turn on gas tank valve, test the N_2 gun
- prepare bottles of acetone, ethanol and DI water
- turn on hot plate, set at 110 °C
- turn on the spin coater, test it
- turn on mask aligner's vacuum pump and trigger power supply
- turn on the microscope and the computer
- turn on the Dektak profilometer and the computer

Silicon and glass sample preparation

- use diamond pens to cleave silicon wafers, obtain silicon pieces with a size of about 1 cm ×1 cm, make at least 2 pieces per person
- use diamond pens to cut glass slides. Note the differences between silicon and glass

Silicon sample clean

- hold silicon pieces with tweezers
- clean them with acetone, alcohol, DI water, in turn
- dry with N_2 gun (the silicon should be placed at dust-free paper)
- dehydration bake on the hot plate at 110 °C for ~ 10 mins
- clean and blow dry the photomask

Photolithography

- place silicon onto the spin coater
- drop SPR220-v3.0 onto the sample surface
- spin coat, 500 rpm 5 sec, then 3000 rpm 40 sec (SPR220-v3.0 thickness 3 um)
- take out the sample, move it onto the hot plate, soft bake at 110 °C for 1.5 mins
- install the photomask onto the mask aligner
- put the sample onto the mask aligner
- align, contact, and expose (exposure dose 300 mJ/cm^2) (note: our mask aligner has a power density of about 1.5 mW/cm^2, the exposure time should be around 200 s)
- post-exposure bake the sample, 110 °C for 1.5 mins
- place the sample into the MIF300 developer for 1 min, take out and clean with DI water, dry it with N_2 gun

Sample characterization

- observe the developed sample under microscope, take photos
- make sure the exposed photoresist part is fully developed. If not, put it into the developer for additional time and check again

- measure the photoresist step height using the Dektak profilometer, record the results
- hard bake the samples at 110 °C for 30 mins

Lab cleanup

- turn off hot plate, N_2 gas valve, chemical hood, spin coater, mask aligner, microscope, profilometer, and computers
- dispose the trash
- save the silicon samples with photoresist patterns for future use

5. Results

Thickness of photoresist films = __________ nm

References

[1] http://novawafers.com/resources-about-silicon.html

[2] http://www.microchemicals.com/downloads/application_notes.html

[3] https://en.wikipedia.org/wiki/RCA_clean

[4] https://en.wikipedia.org/wiki/Piranha_solution

[5] https://en.wikipedia.org/wiki/Photoresist

附录一：匀胶机的使用

1. 选择合适大小的片托(片托需要小于样片片)，将缺口对准螺钉，片托安装时一定要到底

2. 设置参数

- 打开匀胶机后方电源，变频器显示“0.00”（可调），按下 MODE 键，显示“F××”，继续按此键至显示“P 00”
- 通过▲▼键调整屏幕闪烁字样，设置两步匀胶的速度和时间，其中 P17、P18 分别表示两步匀胶转速设置，P81、P82 为对应的时间设置，找到后按 ENTER 键，通过▲▼键进行设置，设置后按 ENTER 键确认，屏幕显示“END”，再按 MODE 键返回
- 转速设定方法：参数值＝转速÷58.83。如设置转速 500 转/分，时间 8 秒，则变频器参数为 500÷58.83≈8.5Hz，在 P17 中设置参数为 8.5，在 P81 中设置参数为 8
- 一般的参数为：第一步:慢速 500 转/分,5s，（P17 = 8.5, P81 = 5s）；第二步，3000 转/分，40s,（P18 = 51，P82 = 40s)

3. 匀胶

- 检查光刻间的房门是否关闭
- 从冰箱中取出光刻胶 SPR220-v3.0(待其至常温)
- 将烘干的样片放置于匀胶机吸盘中心位置上，打开真空泵，按下吸片键
- 按下启动键，检验两步的转速和时间
- 用吸管在样品表面滴光刻胶，保证 80%覆盖样品表面
- 按下启动键，进行匀胶
- 完毕后，关闭吸片键，用镊子轻轻取下样品
- 结束后，关闭电源，机械泵，光刻胶放回冰箱

注意

- 匀胶过程中可以按下变频器上的 STOP 键停止匀胶
- 匀胶转速、时间可随时调节，调节时注意把真空泵关掉
- 开机前要保证吸片键处于关闭状态

附录二：光刻机的使用

- 打开光刻机下方的插线板，打开左下方机械泵
- 打开紫外汞灯电源，长按触发键，触发成功后松开，等待 5~10 分钟使光源强度稳定
- 打开左侧光刻机电源
- 在光刻机右侧面板处，设置曝光时间
- 放置样品，按下吸片键
- 安装掩膜版，注意使图形面朝下（与样品表面接触）
- 调节掩膜版和样品的位置，进行对准
- 旋紧金属旋钮，使掩膜版与样品紧密接触
- 按下曝光键
- 曝光完成后，取下样品

注：

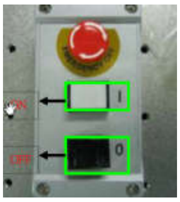
- 曝光时若数字计时不动，立即按下面板旁的红色触发，则数字计时会继续完成，总曝光时间误差为开始曝光到按下触发的时间间隔
- 曝光时间(sec) = 光刻胶所需曝光剂量(mJ/cm^2)÷光源强度(mW/cm^2)
- 光源强度(mW/cm^2)用标准紫外探测器进行测试标定，我们使用的光刻机紫外光照（365 nm）强度约 1.5 mW/cm^2

附录三：光学显微镜的使用

- 打开左后方显微镜电源
- 打开电脑，密码：edfa
- 打开 Nikon USB 电源
- 打开软件‘上光’，密码为空格键，菜单选择‘文件’-‘打开捕捉窗口’
- 根据需要选择合适倍率的物镜，放置样片，转动方向旋钮找到要观察的位置，调节显微镜光源强度，调焦使物象清晰
- 使用显微镜右侧上方的推拉杆切换 USB camera / 目镜
- 调节成像效果，拍照并保存

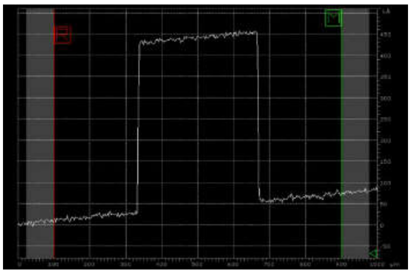
附录四：台阶轮廓仪的使用

- 打开电源开关



- 开启台式机，执行程序 Dektak
- 将样品台拉出，把测试样品放在样品台上，粗调 XY 轴使样品位于探针下方

- 按下 Tower Down 按钮，探针下移，碰到样品后会回弹，观察显示器，微调 XY 轴把待测图形移动到探针下方（扫描时探针向上方移动）
- 点击 Scan Routine Window，设置扫描参数
- 点击 Sample Positioning Window，回到样品图像窗口，微调样品位置
- 点击 Run Scan Routine Here，开始扫描
- 扫描结束后，Reference（R）和 Measurement（M）光标选取适当区域，点击 Level，将扫描图形拉平



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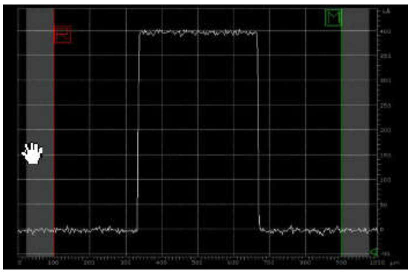

- 将 R 和 M 光标移动至需要测量的台阶处，软件左下方 ASH 值即为台阶的高度（即薄膜的厚度）
- 样品测试完毕，点击 Tower Up 按钮，探针上移，取出样品
- 按顺序关闭软件程序，关闭电源开关