TEMPLATE

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1 Introduction

In this chapter, the previously characterised Surface Probe prototype indicated a removable window is prone to many issues, and a particle window deposited straight onto the chip could both solve these issues and produce a higher sensitivity.

CMOS Digital Image Sensor

How does it work

- Upgrade previously characterised window samples
- – why
-
- Goal: increased sensitivity – hit OD 5, keep film thin
- Goal: increased robustness – no longer removable window – e beam
- Goal: Biocompatibility – Al ox passivation layer

2 Material properties

This section names important material paramters in deposition and their relation to the final multilayer design. The understanding of those dependencies is of importance for the final forming result obtained.

The Biocompatibility The optical density The hardness/scratch test

2.1 First layer

theory of aluminium

thermodynamics of nucleaus formation

crystal growth

aluminium is not biocompatible so a passivation layer is needed to protect

aluminium oxide is chosen as it will develop a native oxide that will adhere

2.2 Passivation layer

3 Deposition techniques

what do we want? nanometer layers of material

most popular method?

must have clean substrate to reduce pinhole and hillocks ((WHY)) + HOW does it cause pinholes and hillocks vs ALD for example

PVD vs sputtering

3.1 Fundamentals

ebeam - measures thickness via quartz crystal -MASS- so check thickness with profilometer which measures physical thickness

4 Thickness measurement - NEEDED?

2 forms of physical measurement against simulation using Rakic Theory

thickness is a cruicial property in modelling the behaviour of thin films on substrates during nanoindentation. The metallic film samples were prepared in a way that an edge was masked by kapton tape. When the tape was removed, there was a clear step between film and substrate. The ?? Profilometer shown in Figure (?) was utilised.

4.1 Physical thickness measurement

4.2 Model for thickness measurement

FOUNDATION INFO on light INSERT Rakic theory

5 Method

This chapter is dedicated to a precise description of the thin film coatings, and employed experimental methods and analytical techniques.

Various thin film aluminium on glass substrate samples were prepared in different deposition parameters and serve as a basis for the structural investigation of the evaporated aluminium. This section provides an overview of the coating and ?? Section "1.1" addresses etc ((experimental set up eg dep rate))

5.1 Electron beam evaporation of Al

Electron beam (e-beam) evaporation is a type of physical vapor deposition in which the target material is evaporated by electron bombardment. The beam of electrons is generated in a charged tungsten filament and subsequently directed onto the target in the magnetic field of deflection coils or a set of permanent

Deposition method	Impurity level	Film density	Cost
Thermal evaporation	High	Low	Low
E-beam evaporation	Low	Low	Medium
Sputtering	Medium	High	Medium
PECVD	Very Low	High	High

magnets, providing sufficient energy iput to produce a directional flux of evaporated material from a molten target.

In this section, a comparison of e-beam evaporation technique with other popular thin film deposition methods is provided and shown in Table 2.1 (partially referred to Ref. [Ohring2001]). Thee-beam evaporation has higher deposition rates and lower impurity levels in comparison with thermal evaporation. The higher source temperature of the e-beam evaporation yields higher deposition rates. In thermal evaporation systems, the crucible itself heats up and may let impurities to diffuse into the deposited thin film.

5.1.1 PVD Al growth characteristics

homogenous structure temperature of substrate might lead to growth hillocks deposition rate pinholes

specifications:

procedure: eg substrate prep

5.1.2 Electron beam evaporator

(INSERT SCHEMATIC)
caption: Schematic of the electron beam evaporator: An electron beam directed at a glass substrate provides a diect flux of Al, which etc

During the deposition process, the XX material XX crucible holding the aluminium material is heated by XXX

Adjusting parameters controls XX, for example the deposition rate defines XX therefor XX. pinholes mainly affected by ??

Substrate Preparation Cleaning is a simple but critical step for a good material output. Glass substrates used in this study were cleaned using a series of washing and chemical processes

Film Thickness A predicted film thickness between 80-120 nm is required to hit a sufficient optical density of 5.

Deposition Rate Given the low thickness requirement for the Aluminium film, a low deposition rate is chosen. The rate can be varied from X-X.

The rate of deposition has effects in the crystallisation process.

e-beam current

Main specifications	
Filament type	Schottky-TFE
Laserstage travel range	50 x 50 x 25 mm
Beam size (resolution)	$\leq$ 2.5 nm
Minimum feature size	$\leq$ 20 nm
Field stitching	$\leq$ 50 nm
Overlay accuracy (alignment)	$\leq$ 50
Beam current drift	$\leq$ 0.5
Writing speed	2.5 MHz

5.2 Native oxide

native oxide or deposit oxide, is native thickness good enough for protecting aluminium

5.2.1 Oxygen Plasma

5.3 Characterisation techniques

5.3.1 Profilometer

5.3.2 Scanning Electron Microscope

Electron microscopy is a high-resolution imaging technique based on the interaction of an incident beam of coherent electrons with the irradiated specimen.

Scanning electron microscopy (SEM) utilizes a coherent beam of electrons to scan the sample surface. The detection of the secondary electrons of an energy of several eV which are emitted in inelastic scatter interactions within a few nanometers from the sam- ple surface permit an analysis of the surface topography of a specimen.

In this study SEM is used to image growth hillocks on the surface of the aluminium sample. In a conventional SEM system, the energetic electrons are created by an electron gun which can be a field emission or tungsten gun. The electron beam is accelerated by a high voltage on the order of kV to reach the desired energy and passes through a system of apertures and elextromagnetic lenses before reaching the sample. The beam is scanned on the surface of the sample, and, secondary electrons emitted from the sample surface are collected by a detector for imaging purposes.

INSERT SCHEMATIC

5.3.3 Digital Microscope

5.3.4 Supercontinuum Laser

5.3.5 Ellipsometer

non destructive non contact

uses lineary polarised light source that when reflected from the sample it becomes elliptically polarised. polarised light is light that consists of light that is travelling in one plane, the polarisation change is measured and film thickness is determined based on given information such as the incident and reflected angles, and the index of refraction. The laser light passes through a polariser and compensated. before striking the film, the light is refracted, as it enters the film reflected off the substrate and then refracted again, as it leaves the film it then passes through an analyser microscope and finally coated detecting. This unit contains a laser polariser and compensating on the right the unit contains the analyser microscope and photo detectors, down below is our stage which will hold our sample.

(Jung J, Bork) measures a relative change in polarisation and is therefore not dependent on absolute intensity

Place sample on centre of stage, open the laser shutter to allow the laser to shine through

polarsation state of light beam is defined by electric field beam state = linear at beginning waves can be added together to make new polarisation states if the two waves have different amplitudes or arbitray phases - elliptically polarised ight is generated

Ellipsometry does not inately measure thickness or index of refraction itself. Made up of a laser, a polariser, a sample stage, and an analyser. The laser emits linearly polarised light, which hits the sample and becomes elliptically polarised, linearly polarised light consists of light that travels in one plane. circularly polarised light is made of two waves in phase. elliptically polarised light is two waves with different phases. the light enters the analyser and measures the relative change from when it left the laser. with models, the thickness can be determined.

Three Phase Optical System With a three phase optical system, there are multiple layers of differing materials so a different model is needed to determine the thickness.

material 1 : aluminium oxide

material 2 : aluminium

material 3 : glass

glass and aluminium thicknesses are known, aluminium oxide is to be determined.

Using Rakic model, psi and X?? are calculated and the thickness calculated using the following formula:

5.3.6 Nanoindentor

The nanoindention technique is performed under the applied force from micro to millinewton range, with the penetration depth at the scale of nanometre to micrometre. Generally, a relativly hard tip is used to probe the specimen.

Figure (?) shows a typical force displace (P-h) curve for nanoindentation experiment on metal.

Imaging is not necessary because the machine calculates values of elastic modulus and hardness based on the area of contact.

Limitation of testing only 10be measured

1. turn on pc
2. turn on X
3. no MRN, no AFM head
4. calibration of tip = check constants file is loaded
5. when calibrating, bring sample to camera, focus camera, set a boundary
6. test
7. save graph
8.

Elastic contact

5.4 Image Analysis

ImageJ Images taken from the SEM were imported into ImageJ software. Using

Hillock count

```
    OGName = getTitle();
fileName = replace(OGName, ".tif","");

run("Set Scale...", "distance=0.29113333 known=1 pixel=1 unit=nm global");
path = getDirectory("image");
run("Bandpass Filter...", "filter_large=35 filter_small=2 suppress=None tolerance=5 autosca
setAutoThreshold("Default dark");
//run("Threshold...");
run("Convert to Mask");
setThreshold(255, 255);
run("Analyze Particles...", "size=200.00-Infinity show=[Bare Outlines] display clear compos
selectWindow("Results");
saveAs("Results","/Users/sukiyau/Documents/EngD/thesis/chapter 2/imagej/hillock/csv/35 2/" 
selectWindow("Drawing of " + fileName + ".tif")
saveAs("Tiff", "/Users/sukiyau/Documents/EngD/thesis/chapter 2/imagej/hillock/tiff/35 2/" +
selectWindow(fileName + ".tif");
close();
```

Pinhole count

```
    fileName = replace(OGName, ".png","");
run("Set Scale...", "distance=151.0915667 known=1 pixel=1 unit=mm global");
path = getDirectory("image");
run("8-bit");
run("Bandpass Filter...", "filter_large=20 filter_small=3 suppress=None tolerance=5 autoscal
setAutoThreshold("Default dark");
//run("Threshold...");
run("Convert to Mask");
setThreshold(255, 255);
run("Analyze Particles...", "size=0-Infinity show=[Bare Outlines] display clear composite");
selectWindow("Results");
saveAs("Results","/Users/sukiyau/Documents/EngD/thesis/chapter 2/DinoXope/imageJ pinhole cou
selectWindow("Drawing of " + fileName + ".png")
saveAs("Tiff", "/Users/sukiyau/Documents/EngD/thesis/chapter 2/DinoXope/imageJ pinhole count
selectWindow(fileName+".png");
close();
```

MATLAB

```
%% Housekeeping
clc
clear all
close all
```

6 Conclusion

7 Future work

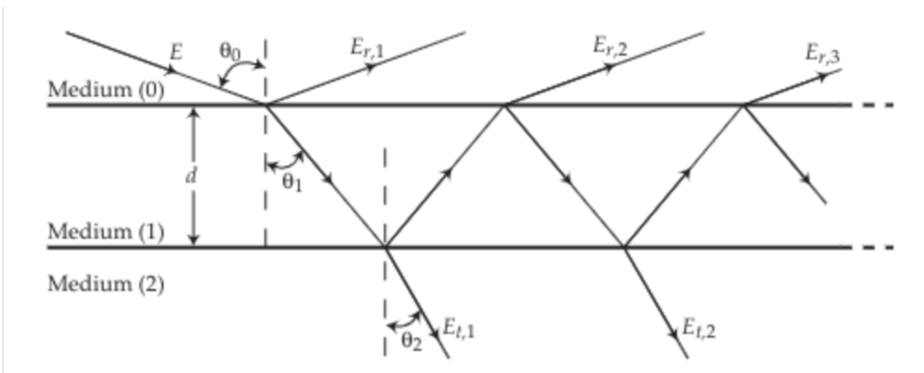
next steps = applying this recipe to the chip instead of a glass substrate
will it adhere? how can i create a mask?

Appendix A. ¡some heading here¿

Three Phrase Optical System

Assumptions:

1. The system is considered to have parallel boundaries between each phase.
2. Medium 1 has lateral dimensions much larger than its thickness d, whereas medium 0 and 2 are of infinite thickness.
3. All three media are considered homogenous and optically isotropic.
4. Medium 1 is not an amplifying medium.
5. Monochromatic plane incident wave.



test

$E_{r,1...n}$ = reflected light
$E_{t,1...n}$ = transmitted light
$E_{r,1}$ has a phase change due to the propagation from A to E $E_{r,2}$ has a phase change due to the propagation from A to C

Reflection and Transmission of an Incident Wave

In a three phase system, an incident wave propagates through medium 0, and makes contact with medium 1 at an angle of ϑ_0. The incident wave is partially reflected at the boundary and partially transmitted through medium 1 at an angle of ϑ_1. The transmitted part of the incident wave propagates through medium 1 until it makes contact with the boundary between medium 1 and medium 2. At this boundary the wave is again partially refelcted and partially transmitted through medium 2 at an angle of ϑ_2. The connection between thw angles ϑ_0, ϑ_1 and ϑ_2 are given by Snell's law

$$\tilde{n}_0 \sin(\theta_0) = \tilde{n}_1 \sin(\theta_1) = \tilde{n}_2 \sin(\theta_2) \tag{A.1}$$

Where $\tilde{n}_0$, $\tilde{n}_1$ and $\tilde{n}_2$ are the complex refractive indxes for medium 0, 1 and 2 respectively.

$$E_{r,1} = \rho_{01} \cdot E \tag{A.2a}$$

$$E_{r,2} = \tau_{01} e^{-j\beta} \rho_{12} e^{-j\beta} \tau_{10} \cdot E \tag{A.2b}$$

$$E_{r,3} = \tau_{01} e^{-j\beta} \rho_{12} e^{-j\beta} \rho_{10} e^{-j\beta} \rho_{12} e^{-j\beta} \tau_{10} \cdot E \tag{A.2c}$$