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# Contact Potential Difference and Photo Voltage

## Comparing the Kelvin Probes

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For the Cahen group

# 1 Introduction

The purpose of this manual is to outline the measurements I did to compare the three Kelvin Probes (KPs) in 618, 301 and 101. The one i 618 measures in ambient, 301 in the glovebox (=nitrogen atmosphere) and the one inside the Lakeshore in 101 (referred to as the Mc Allister) can measure in ambient, under vacuum and with temperature dependence. Next to measuring the contact potential difference (CPD), all three KPs can be used to illuminate a sample and thus measure the surface potential volage (SPV).

A standard reference with known and stable work-function, HOPG, is used to callibrate the probe, to find the workfunction of the probehead. To compare the three probes, I used Si-H as a relatively stable and well understood sample. The results of this comparison will be summarised in Section 3.

## 1.1 (Brief-)Theory

# 2 Procedure

## 2.1 Si-H Sample Preparation

n-Si-H<100> is prepared according to a slightly modified standard procedure:

- Cut, wipe with Ethyl Acetate, Rinse with Ethyl Acetate
- Sonicate for 6 min each in Ethyl Acetate, Acetone, Ethanol and Water. Rinse with new solvent before sonication.
- Blow dry with  $N_2$
- Asher for 3 min at 100W; 1l/min  $O_2$ ; 1l/min  $Ar$
- Etch in 2% HF for 1 min
- repeat Asher
- repeat Etch

During the last etch, take a stopwatch and let it run upward from zero, bring it with you to the KP and record the time between takind the sample out of the etch and the beginning of the CPS measurement.

## 2.2 Callibration

The aim of the callibration is to find the workfunction of the probe  $\varphi_{\text{Probe}}$ .

Take a piece of HOPG, put it on the sample holder. Take a piece of scoth tape and tape the HOPG down on the holder. Gently and uniformly secure the tape onto HOPG with tweezers. Rip off the tape, a smooth surface of HOPG should be left behind. Mount this onto a sample holder, measure the CPD.

In 618 and 301 the CPD is given as:

$$\text{CPD} = \varphi_{\text{Sample}} - \varphi_{\text{Probe}} , \tag{1}$$

so  $\varphi_{\text{Probe}} = \varphi_{\text{Sample}} + \text{CPD}$ , so the value for the probe is given as  $\varphi_{\text{Probe}} = 4.65 - \text{CPD}$ . For the Mc Allister, the equation depends on the way you connect the setup. Here, the equation is:

$$\text{CPD} = \varphi_{\text{Pre-Amp}} - \varphi_{\text{Other}} . \quad (2)$$

Most often, the pre-amp will be connected to the probe-head, so its workfunction will be given by  $\varphi_{\text{Probe}} = 4.65 + \text{CPD}$ .

HOPG will deteriorate in air with time. Most probably, this is due to water adsorption on the surface. It is therefore advisable to be quick with the measurement, not to wait till stabilisation and average only the first few points.

## 2.3 Si-H Measurement

Measure the CPD of Si-H for at least two minutes. Change the position of the probehead over the sample, measure again for at least two minutes, repeat. The stopwatch used to time the etch should be running continuously. In this way, the sample's exposure time to air for each individual CPD measurement is known. When analysing the data, a plot of CPD vs time should yield a (more or less) straight line. The y-intercept of that line is (close to) the actual CPD-value that would have been measured immediately after the etch, i.e. for a perfectly fresh surface.

# 3 Results

## 3.1 HOPG

As mentioned, HOPG deteriorates slowly in air. The change in CPD is  $0.9 - 1.1 \frac{\text{mV}}{\text{min}}$ , consistent in 618 and the Mc Allister so it might well happen that HOPG doesn't 'stabilise'<sup>1</sup>.

When callibrating the Mc Allister, a jump of about 20-40 mV can be observed when switching on the weak pump. This jump is not a physical value since sometimes, the CPD goes up and at other times, it goes down. The best explanation is a displacement of the probe head over the sample, since the size of the jump is within the known inhomogeneity of HOPG. A similar jump of  $\sim 10$  mV is observed when switching on the turbo pump. The CPD of HOPG is independent of temperature to within 10 mV, measured over a range of 50K to room-temperature, in steps of 50K.

## 3.2 Si-H

n-Silicon-H was prepped and measured according to the procedure outlined above. The results of that comparison are given in Fihure 1. Since all the independent Kelvin Probes give the same results

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<sup>1</sup>Our definition of 'stable' is: standard deviation  $< 0.5$ ,  $\frac{d(\text{CPD})}{dt} < 1 \frac{\text{mV}}{\text{min}}$

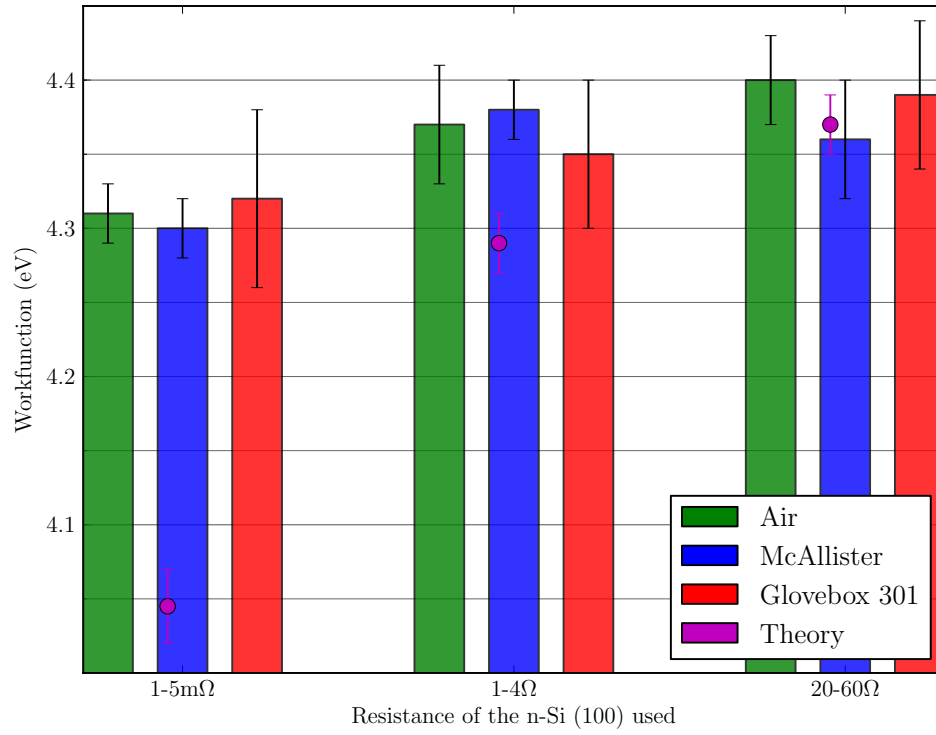


Figure 1: Summary of the measured workfunction for the n-Si-H samples used, compared to theoretically expected values. The indicated error includes deviations in the samples as well as the inaccuracy of calibration with HOPG.