LAB REPORT VII

CV characteristics of Metal-Semiconductor (MS) contacts

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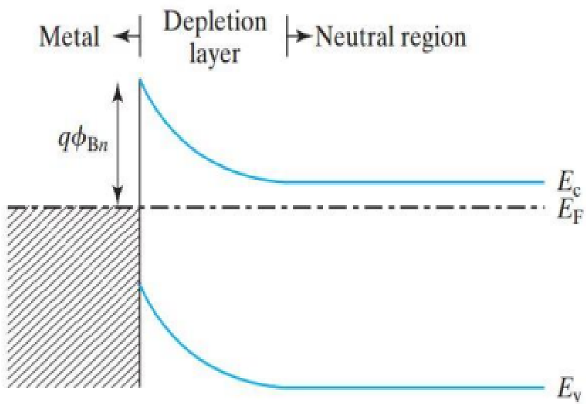
Objective: observing CV characteristics of Metal-Semiconductor (MS) contacts

Theory :

A silicon wafer is a material essential for manufacturing semiconductors, which are found in all kinds of electronic devices that enrich our lives.Few of us have a chance to encounter an actual silicon wafer in daily life. This ultra-flat disk is polished to a mirror-like surface, and made as free as possible of tiny surface irregularities, making it the flattest object in the world. It is also ultra-clean, virtually free of microparticles and other impurities. These qualities are necessary so it can be used as the substrate material of today's state-of-the-art semiconductors. You can find high purity wafers from Czochralski (CZ) and Float Zone (FZ) growth method.

Schottky barrier

One of the important parameters of M-S contacts is Schottky barrier. It is the potential energy barrier of the electron when a contact is formed between metal and semiconductor. As shown in Figure 2a, at the right end of the junction, the energy band diagram is like that of n-type silicon. At the left side of the junction, it is the energy band diagram of a metal (The Fermi level, E_F, is the energy level when no voltage is applied across the junction).



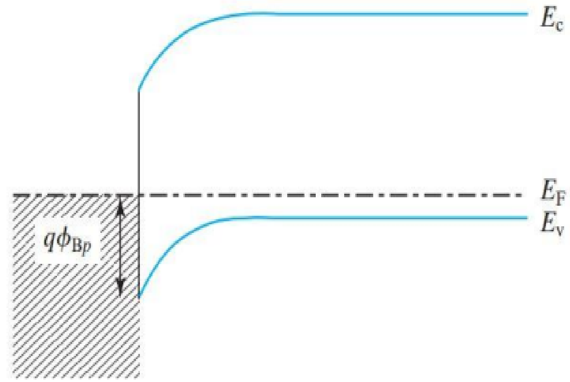


Fig.2a:Band diagram of a metal and an n-type s/c   Fig.2b:band diagram of a metal and an p-type s/c

According to Schottky and Mott (1938), the barrier height between the metal and n-type semiconductor is given by:

$$q\phi_{Bn} = (\phi_M - \chi_S)$$

where, ϕ_{Bn} is the barrier against electron flow between the metal and n-type semiconductor, ϕ_M is the work function of the metal, χ_S is the electron affinity of the semiconductor. Above equation shows the Schottky-Mott rule of the M-S contact. The bandgap energy is given by:

$$q(\phi_{Bn} + \phi_{Bp}) = Eg$$

Eg is the bandgap energy in the semiconductor, ϕBp is the barrier against hole flow between the metal and p-type semiconductor.

C-V Measurements

Figure 3 gives the schematic of the depletion layer at the Schottky junction. There are two different conditions due to the voltage being applied to the metal or not.The depletion-layer thickness is:

$$W_{dep} = \sqrt{\frac{2\varepsilon_s(\phi_{bi} + V)}{qN_d}}$$

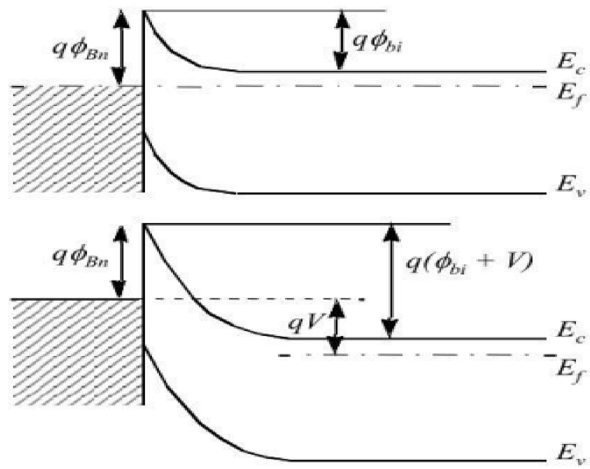


Fig.3: Potential across the depletion layer at the SCwhere, ϕbi is the built-in potential across the depletion layer, εs is the relative permittivity of the metal, d is the donor concentration on the n-side. For the capacitance, the function for calculation is given by:

$$C = A\frac{\varepsilon_s}{W_{dep}}$$

where, A is the area of the contact area between metal and semiconductor and the relationship between C and V is given by:

$$\frac{1}{C^2} = \frac{2(\phi_{bi} + V)}{qN_d\varepsilon_s A^2}$$

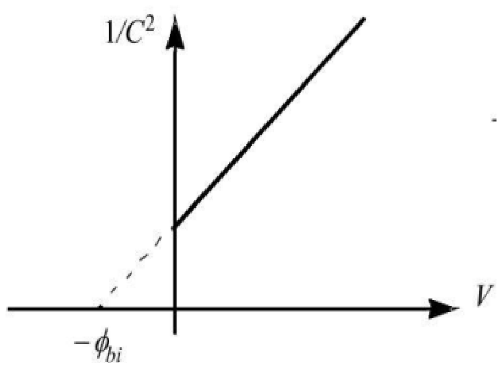


Fig.4:The plot of 1 C2 versus V on the metal-semiconductor contacts

Keithley 4200

The 4200A-SCS Parameter Analyzer reduces the time from setup to running characterization tests by up to 50%, allowing uncompromised measurement and analysis capability. Plus, embedded measurement expertise provides unparalleled test guidance and gives supreme confidence in the resulting measurements.Advanced measurement hardware for DC I-V, C-V, and pulsed I-V measurement types.

Fig.5: Keithley 4200

Begin testing immediately with hundreds of user-modifiable application tests included in theClariussoftware.Automated real-time parameter extraction, data graphing, analysis functions.

BNC cable

The BNC connector features two bayonet lugs on the female connector; mating is fully achieved with a quarter turn of the coupling nut. It uses an outer conductor with slots and some plastic dielectric on each gender connector. This dielectric causes increasing losses at higher frequencies. Above 4 GHz, the slots may radiate signals, so the connector is usable, but not necessarily stable up to about 11 GHz. BNC connectors are made to match the characteristic impedance of cable at either 50 ohms or 75 ohms. They are usually applied for frequencies below 4 GHzand voltages below 500 volts.

Fig.6: BNC cable

Mercury probe

MDC MERCURY PROBES are precision instruments that enable rapid, convenient, and non-destructive measurements of semiconductor samples by probing wafers with mercury to form contacts of well-defined area.MDC MERCURY PROBES may be connected to C-V plotters, computerized semiconductor measurement systems, curve tracers, or doping profilers for a variety of measurements. MERCURY PROBES eliminate time consuming metalisation and their convenience make them ideal tools for production process monitoring applications. Their accuracy and reproducibility make them attractive for R&D applications.

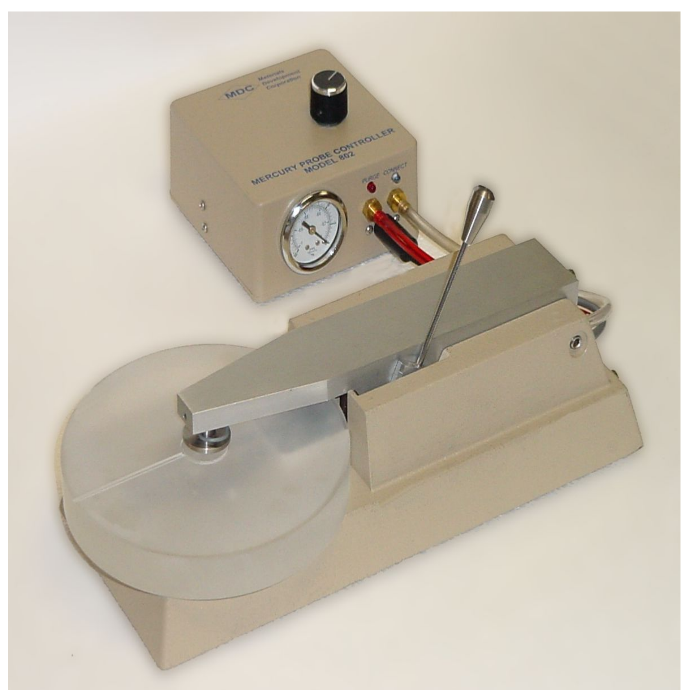
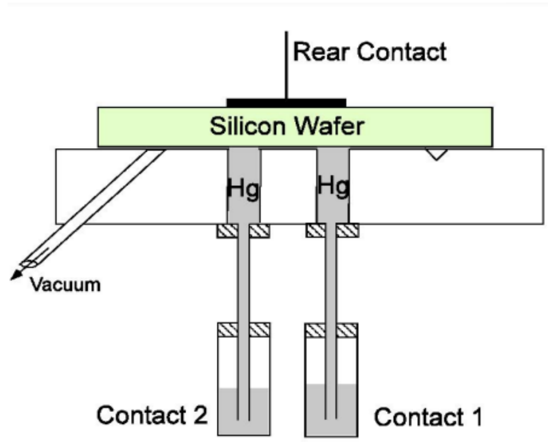


Fig.7: Mercury probe

Possible applications include:

- Doping Profiles of bulk or epitaxial layers
- MOS characterization
- Permittivity of Dielectrics
- Detection of residual films on conducting substrates
- Current-Voltage testing of Photovoltaic devices



The mercury probe has three contacts. Two front contacts that are made by liquid mercury, and a back contact that is made by pushing a stainless-steel cylinder against the wafer. The two front contacts are an inner dot (diameter =775 µm) and an outer almost closed ring situated around the dot. A vacuum pump is used to push the mercury against the wafer. For a particular vacuum range the size of the dot contact is very well defined. The vacuum is made by a small pump (white). At the top of the pump you find a black pressure adjuster that can be used to change the vacuum pressure. Please DO not change the setting of this adjuster. If the vacuum becomes too large, mercury will be sucked into the vacuum pump, and if the vacuum is too small, the size of the mercury contacts will no longer be very well defined.

Precautions during mercury use

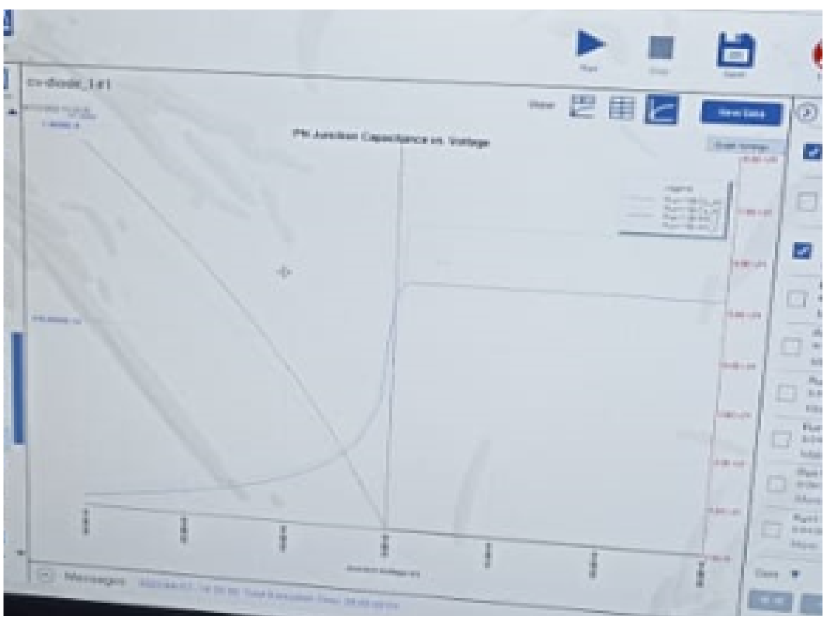
- Before loading your sample in the probe clean it and remove all silicon debris.
- Make sure that if you cleaned the sample by acetone that it is totally dry before it is loaded in the mercury probe.
- The material the mercury probe is made off does not like acetone or most of the other solvents.
- The wafer needs to be flipped so that the polished part of the wafer will make contact with the frosted glass substrate holder of the probe.
- After loading the wafer in the probe move the arm slowly from the off to the on position. This will push the mercury up against the wafer. This motion should not take more than 2.5 seconds.

Procedures

The following steps generally we use during experiment while measuring CV characteristics-

1. Take the Si sample and place it on the chuck of mercury probe properly.
2. Here, two cylinders filled with Hg are below side.
3. We place the sample in such a way so that it covers complete chuck.
4. It is MS contact so generally we deal with frequency more than 30KHz. Here, we apply 1MHz frequency and -30 v to 30 v from keithley4200 display.

Results



1. Following graph shows C V Characteristics of p - type si sample


cv-diode_1#1
PN Junction Capacitance vs. Voltage
Save Data
Run History
Terminal Settings
Help
Run1201
Run1200
Run1199
Run1198
Run1197
Run1196
Run1195
Run1194
Run1193
Messages