Scanning Kelvin Probe Microscopy (SKPM)

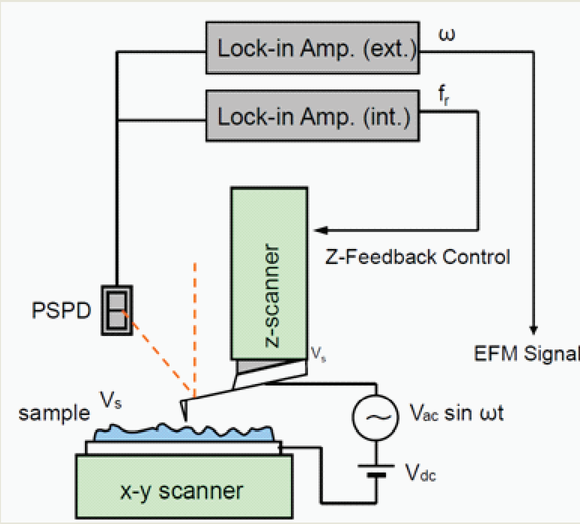
High Resolution and High Sensitivity Imaging of Surface Potential

Enhanced EFM

Three extra EFM modes are supported by the enhanced EFM option of the XE-series. They are DC-EFM (DC-EFM is patented by Park Systems US Patent 6,185,991), Piezoelectric Force Microscopy (PFM, same as DC-EFM), and Scanning Kelvin Probe Microscopy (SKPM), also known as Surface Potential Microscopy.

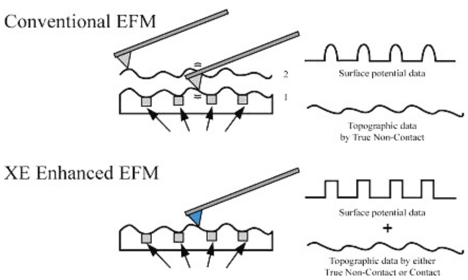
In the enhanced EFM of the XE-series whose schematic diagram is shown in Figure 1, an external lock-in amplifier is connected to the XE-series AFM for two purposes. One purpose is to apply AC bias of frequency ω, in addition to the DC bas applied by the XE controller, to the tip. The other purpose is to separate the frequency ω component from the output signal. This unique capability offered by the XE-series enhanced EFM is what excels in performance when compared to the Standard EFM.

Figure 1. Schematic diagram of the enhanced EFM of the XE-series.



Why XE Enhanced EFM?

Conventional EFM is operated by unnecessary and inefficient double-pass scan, prohibitively limiting the spatial resolution of surface potential map. The Enhanced EFM by the XE-series is designed to provide efficient one-pass scan to measure both topography and surface potential simultaneously without losing spatial resolution. Moreover, this allows the two key innovations of the Enhanced EFM: High frequency EFM signal measurement in,



- Surface charge distribution and potential imaging
- Failure analysis in micro electronics circuitry
- Mechanical hardness measurement (DC-EFM)
- Charge densitometry for ferroelectric domain
- Voltage drop on micro resistors
- Work function of a semiconductor

SKPM

Principle of SKPM is similar to Enhanced EFM with DC bias feedback (Figure 2). DC bias is controlled by feedback loop to zero the ω term. The DC bias that zeros the force is a measure of the surface potential. The difference is in the way the signal obtained from the Lock-in Amplifier is processed. As presented in previous section, the ω signal from Lock-in Amplifier can be expressed as following equation.

$$2 \times (C/d) \times (V_{\mathrm{DC}} - V_{\mathrm{S}}) \times V_{\mathrm{AC}} \sin \omega t$$

The ω signal can be used on its own to measure the surface potential. The amplitude of the ω signal is zero when $V_{DC} = V_s$, or when the DC offset bias matches the surface potential of the sample. A feedback loop can be added to the system and vary the DC offset bias such that the output of the Lock-in Amplifier that measures the ω signal is zero. This value of the DC offset bias that zeroes the ω signal is then a measure of the surface potential. An image created from this variation in the DC offset bias is given as an image representing the absolute value of the surface potential (Figure 3).

Figure 2. V_{DC} is controlled to make the amplitude of ω component to be 0, which sets V_{DC} equal to the surface potencial

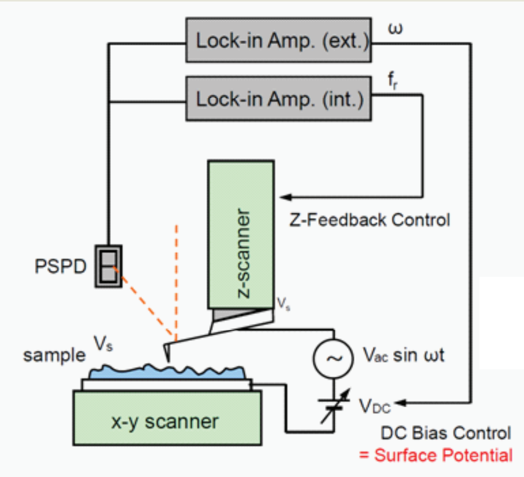


Figure 3. Surface Potential distribution on an ASIC