Electric Field Gradient Reference Material for Scanning Probe Microscopy

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MOTIVATION

Electrical scanning probe microscopes (eSPMs), such as the scanning Kelvin force microscope (SKFM) or scanning capacitance microscope (SCM), are sensitive to the electric field between the sample and tip. Interpretation of measurements with these techniques can be confounded due to unknown tip shape and volume of interaction with the sample. We have designed an electric field gradient reference sample to provide an unambiguous known reference sample of transitions in electric field over small distances. Since all dimensions and materials of the reference sample are known, the electric field at the surface can be calculated precisely. This will allow the sources of error in the measured signal to be determined as a function of tip shape and measurement conditions. The reference also functions as a method of calibrating SKFM to improve its accuracy and to make calibrated measurements on unknowns.

REMOTE BIAS INDUCED ELECTROSTATIC FORCE MICROSCOPY

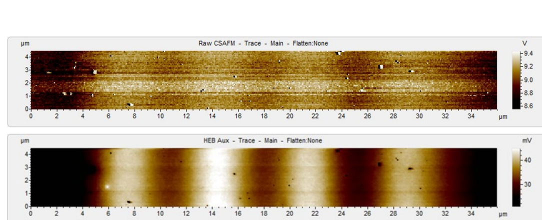
Traditional electrostatic force microscopy (EFM) uses an ac voltage applied between the tip and sample to induce a oscillation in the cantilevered tip. The phase of the oscillation relative to the drive is strongly influenced by the electrostatic force between the tip and sample due to applied and native potentials. We have found that by applying the ac voltage to a buried structure instead of the tip, we can induce additional contrast by off-setting the phase between adjacent lines. For small signals, the induced tip oscillation amplitude, A, is proportional to the force times a transfer function, G(ω), which is a function of frequency.

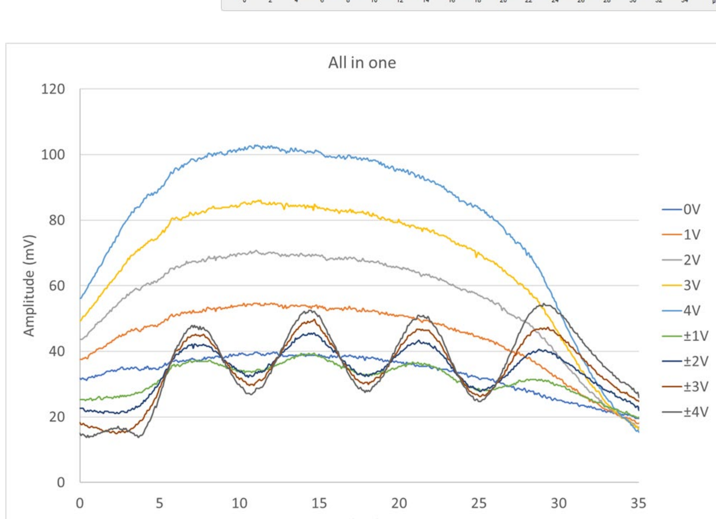
$$A = F * G(\omega) = -\frac{dC}{dz}G(\omega)[(V_{DC} - V_{CPD})V_{AC}] + A_o$$

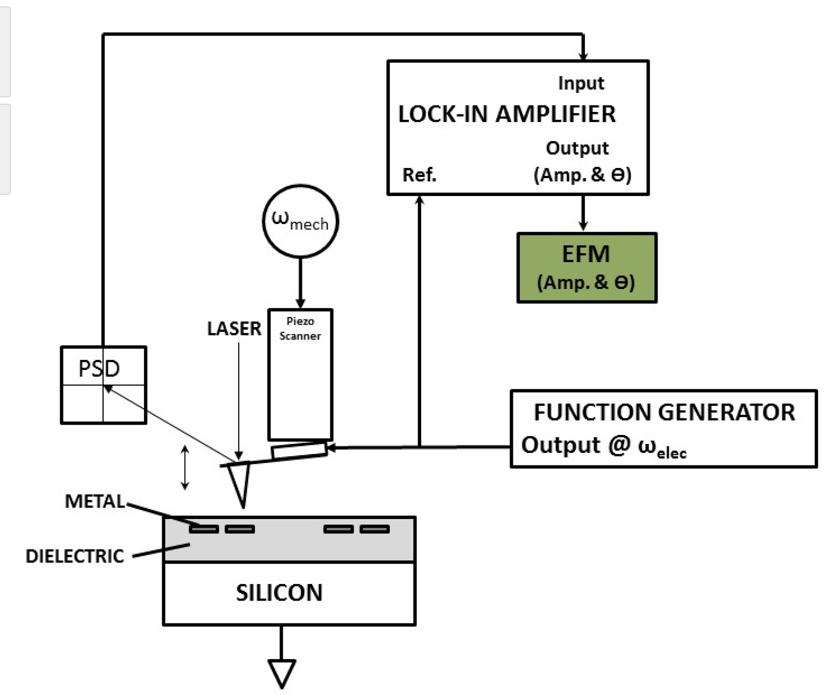
Traditional EFM

phase

amplitude



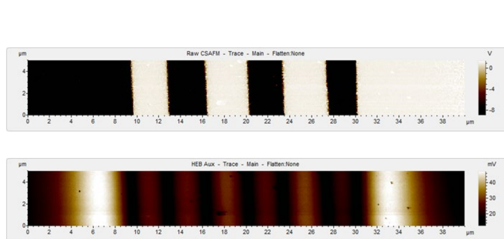


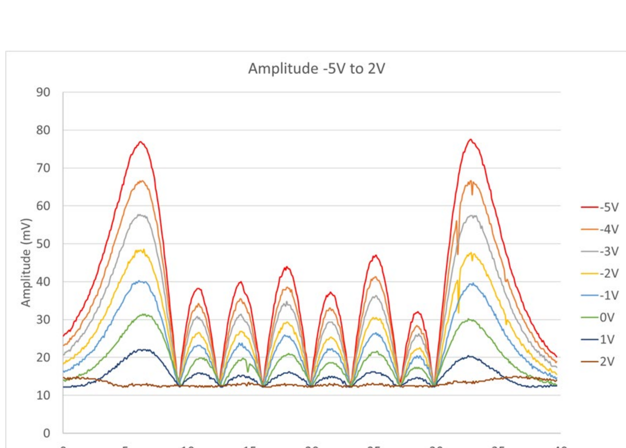


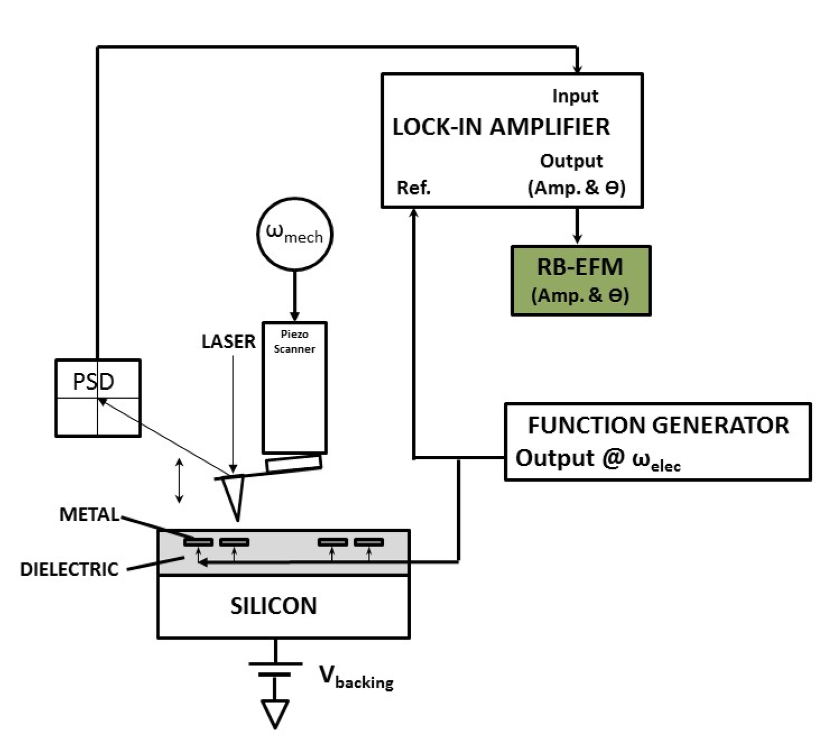
REMOTE BIAS INDUCED EFM

phase

amplitude

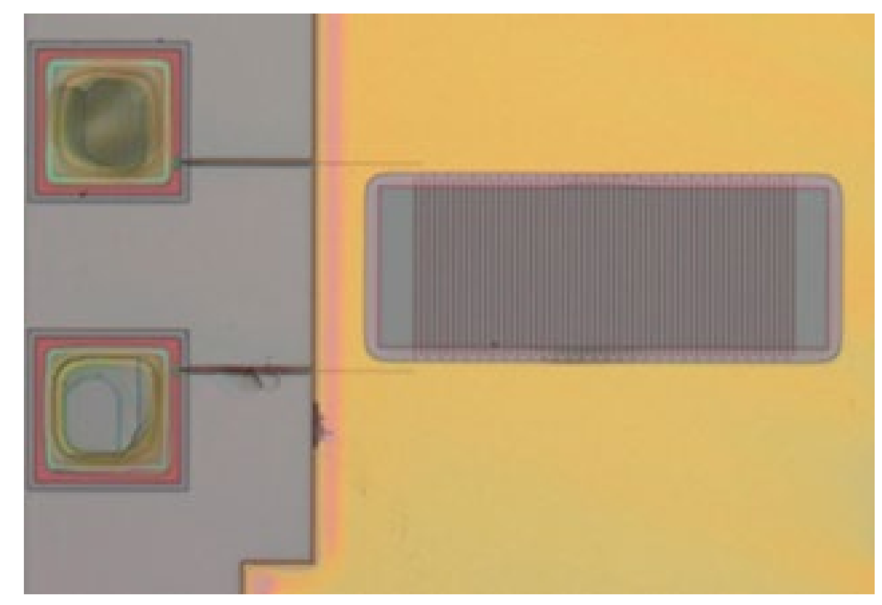






Alternating lines are biased 180º out of phase with each other, creating a self shielding effect and enhancing our ability to resolved buried lines with EFM.

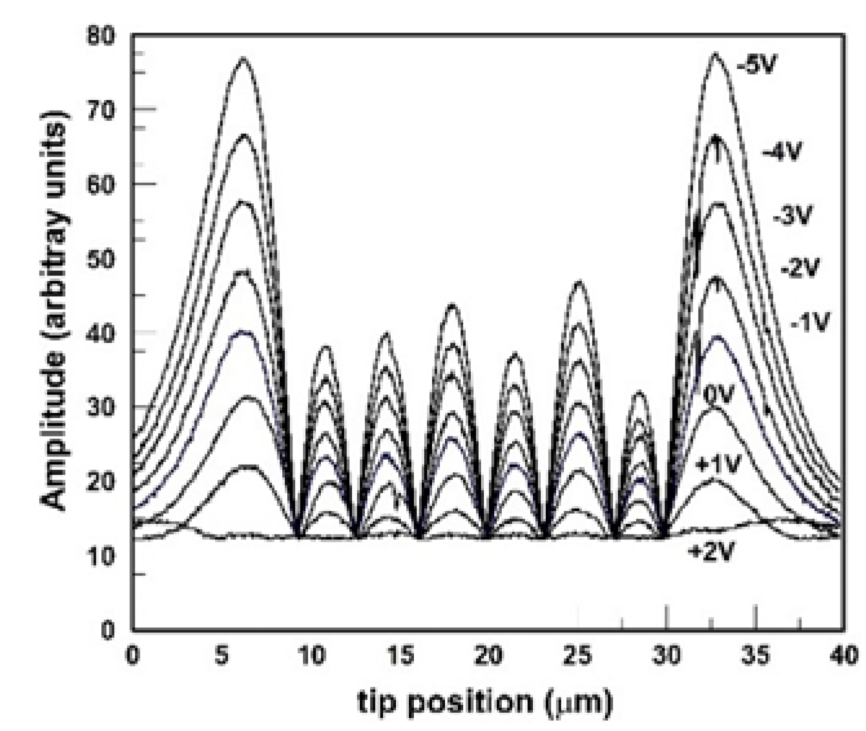
ELECTRIC FIELD GRADIENT REFERENCE



Each set of three lines is connected to a polysilicon voltage divider that reduces the potential by a factor of 0.382 per stage (not visible beneath shielding). There are 10 stages, stepping down from 10 V to 0.66 mV.

ELECTRIC FIELD MEASUREMENTS

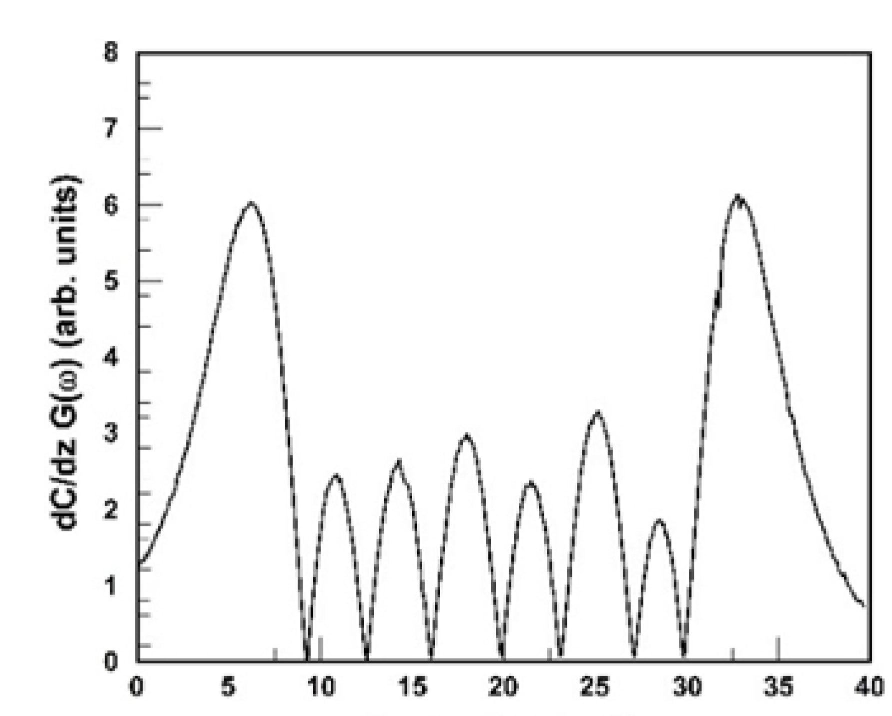
RB-EFM amplitude measured for a single set of interdigitated lines with dc bias voltages increasing from -5 V to +2 V in 1 V steps. Lines are 1.2 µm wide with 2.4 µm separation between them and covered by 2300 nm of TEOS.



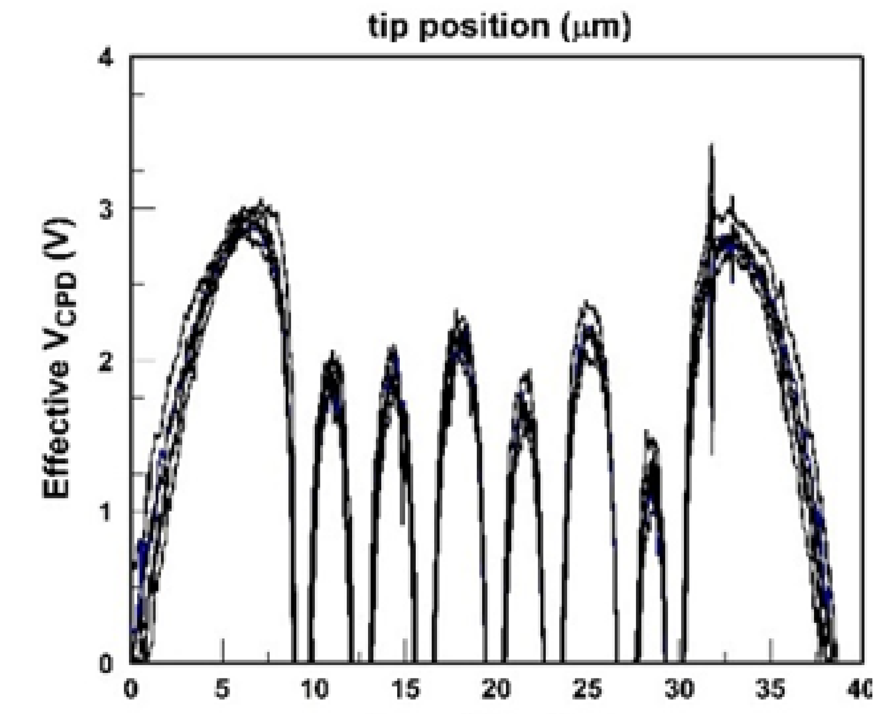
By controlling the bias on the lines we can also separate the effects of the capacitance gradient from the applied surface potential on the EFM tip response.

$$V_{CPD,eff} = \frac{A}{\left[-\frac{dC}{dz}V_{ac}G(\omega)\right]} + V_{dc}$$

The geometrical component of the response (dC/dz), which depends on the tip to metal line capacitance only. Data is calculated by taking the slope of amplitude versus dc bias voltage at each tip position point from the previous figure.



Effective contact potential difference at the test structure insulator surface due to the buried metal lines. Eight curves from each dc bias are plotted, approximately the same effective CPD is seen regardless of the dc bias.



CONCLUSIONS

Will these reference materials be useful to you? We are seeking beta testers. We want to hear your ideas about what kind of Electric Field and Magnetic Field reference materials will help you make more accurate and precise measurements.

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