Advancements In Performance Buckling Beam Probes

Introduction:

The following presentation is a collaborative effort between Probe Technology Corporation and Intel Corporation to investigate the enhancement of Vertical Buckling Beam Probes.

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Historical Consideration:
The Semi-Conductor Industry has continually extended its demands on the wafer level test electrical & mechanical performance. The demand for increased current has recently grown at an accelerated pace.

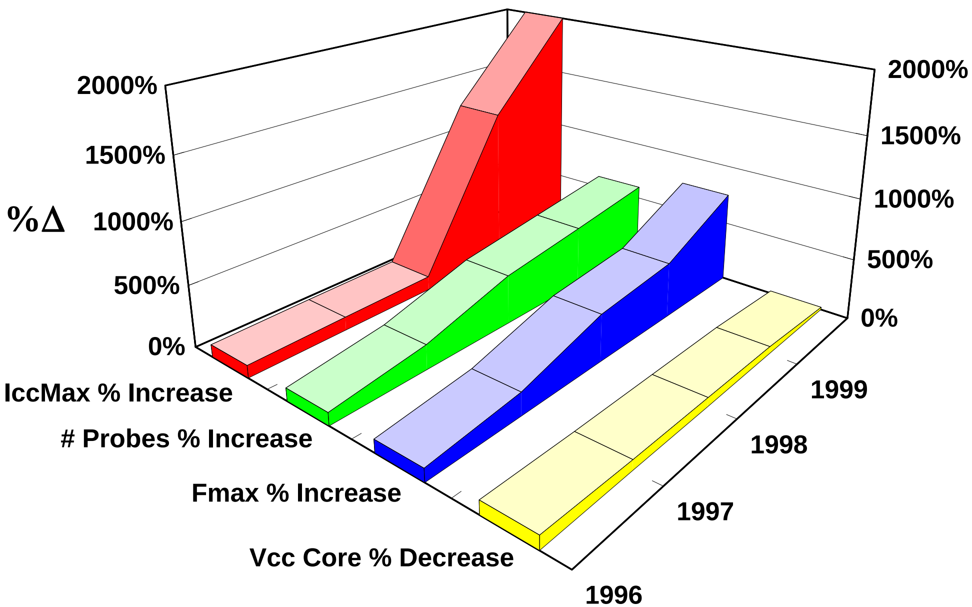


Figure 1 - Performance % change from 1996 to 2000.

Upcoming Generations:
From the graph, we can see a significant increase in the required current per die. The SIU must be able to handle higher currents on a per probe basis with the scaling of each new generation. To scale proportionally with the DUT power requirements, the DC current carrying capability of the probes is expected to increase by more than 1500%.

Meeting This Demand:
Vertical Buckling Beam current carrying limits and robustness must be scaleable to meet/exceed the Sort Next-Generation performance. These aggressive requirements have resulted in the incorporation of advanced metallurgy techniques and enhanced probe geometry's.

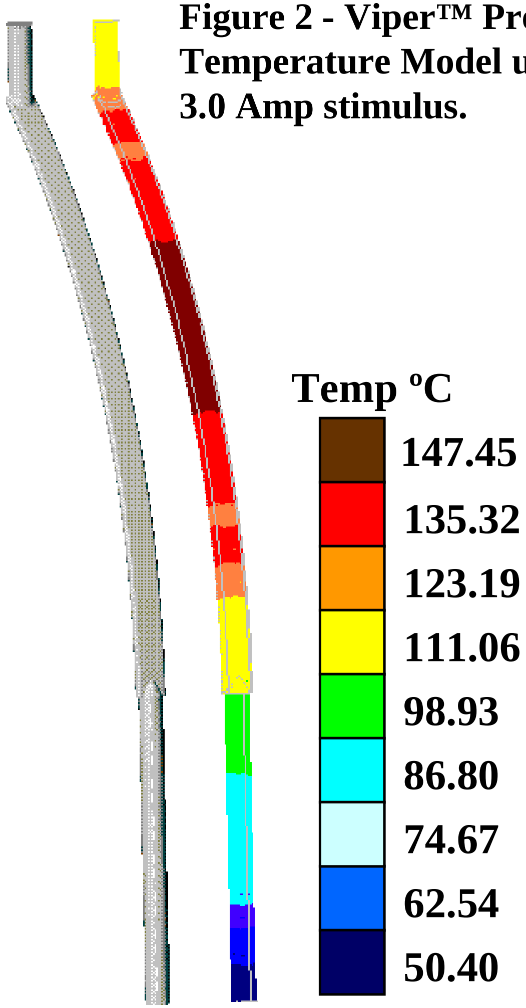


Figure 2 - Viper™ Probe Temperature Model under a 3.0 Amp stimulus.

Finite Elements:
Sophisticated Finite Element Models were constructed to accurately predict the probe feature's Electromechanical behavior, ensuring a correct by design structure.

Thermal Modeling Details:

- Vertical Buckling Beam Probe- BeCu material.
- FEM (Finite Element Model).
- Temperature map due to I^2*R heating.
- Heat transfer boundaries include conduction to the space transformer, the wafer, as well as convection to the environment.
- Steady-State condition considered.

Observations:
Note the off-center location of maximum temperature.

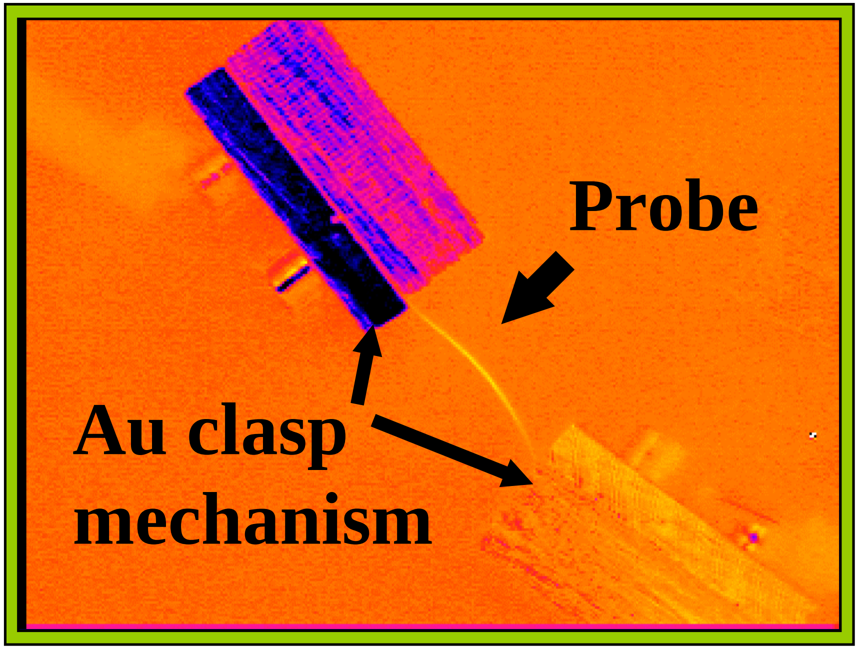
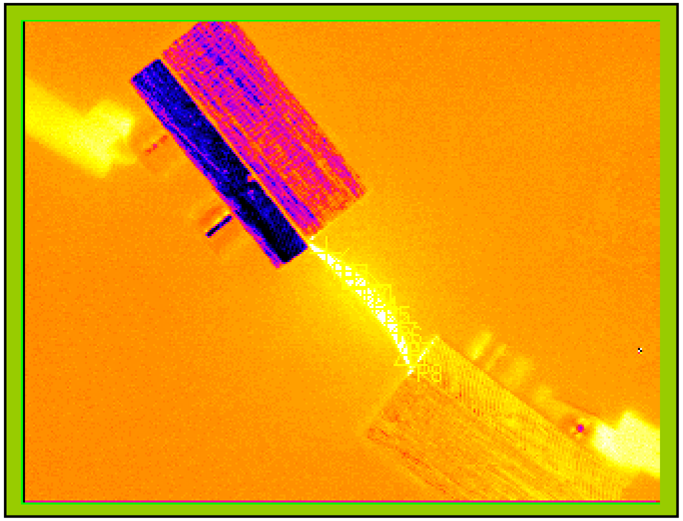


Figure 2 - Mounted Buckling Beam Probe.

Temperature Profile:
Under current strain, several discrete points were observed for thermal emission along the Viper™ probe. The Direct Current was gradually increased while monitoring the impact on Electrical and Mechanical properties.

Model Validation/Calibration:
A Viper™ Buckling Beam probe was harnessed to a precision Current Supply via gold clasp mechanisms. An Infrared Microscope system was used to characterize the temperature profile of the probe while being exposed to Direct Current. A worst case scenario was considered as the probe was continually powered.

Figure 3 - Probe illuminated with current.



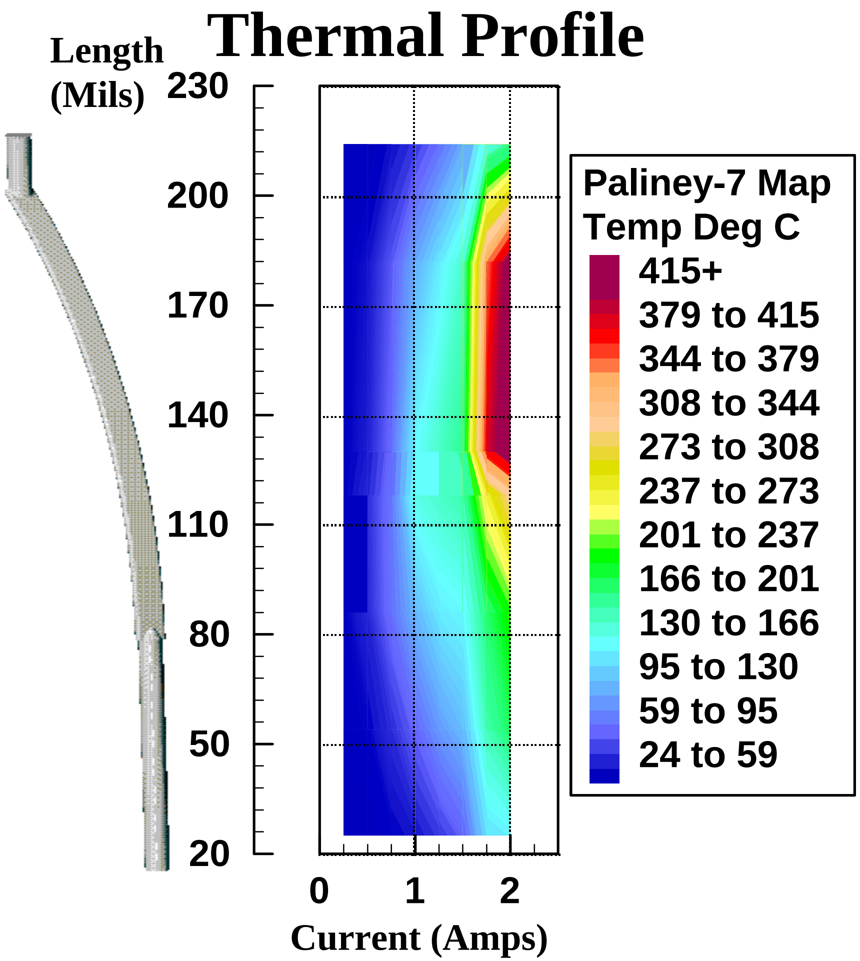
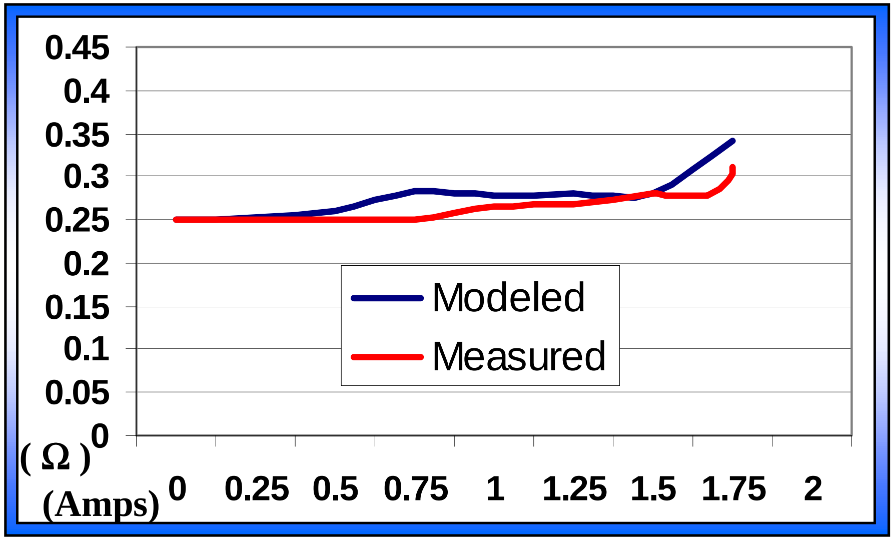


Figure 4 - Distributed Temp versus Current.

Results:

The Buckling Beam sustained the continuous and increasing current up to the 1.75A mark.

Figure 5 - P7 0.225" BB Bulk Resistance vs. Current.



Observations:

The softening voltage, with which relaxation of the probe structure occurs, is apparent with increasing resistance (occurring after the 0.75A mark) and consistent with historical data for both the annealed & age hardened Paliney®-7 conductors (softening potential 0.220V).

Model Validation/Calibration:
Succeeding the Paliney®-7 measurements, a Viper™ BeCu Buckling Beam probe was characterized.

The image to the right was taken moments before the thermal yield strength of the Buckling Beam probe was achieved.

The probe under test was shielded from air flow to minimize Thermal Convection Effects.

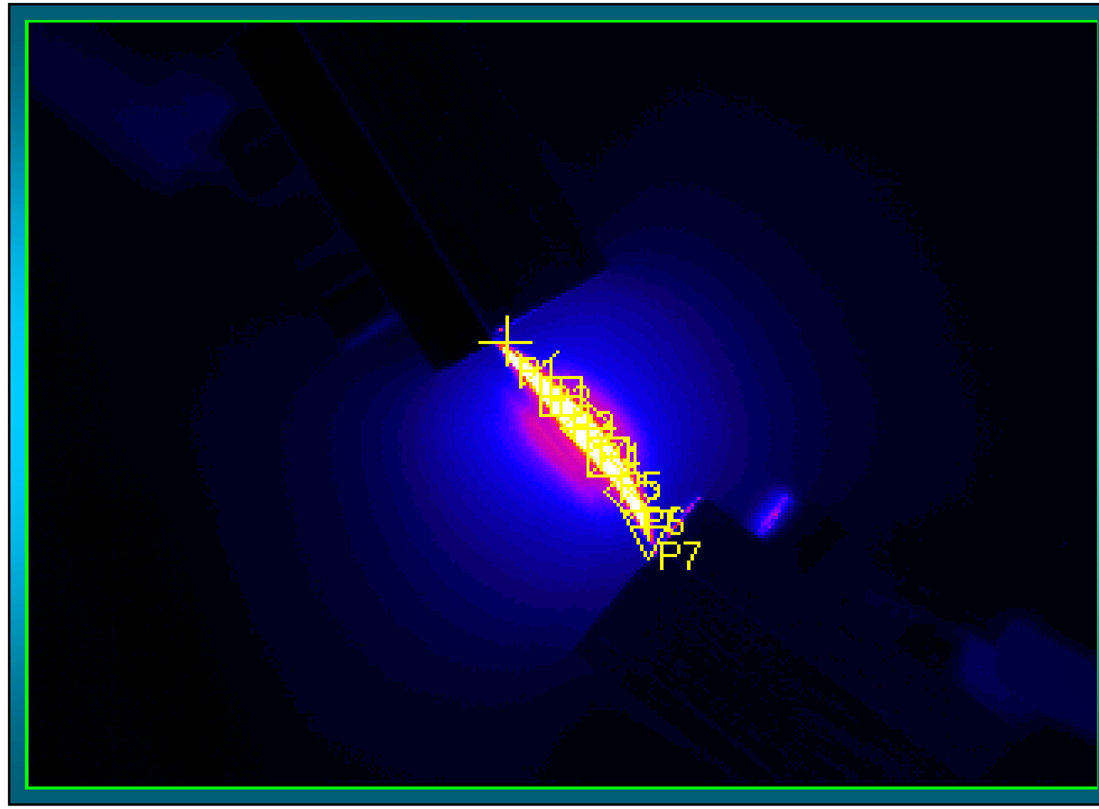
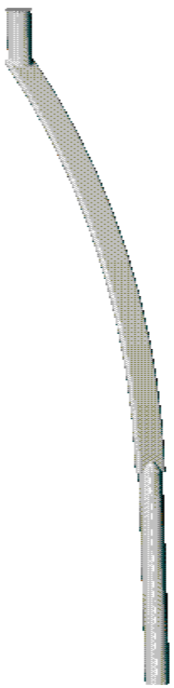


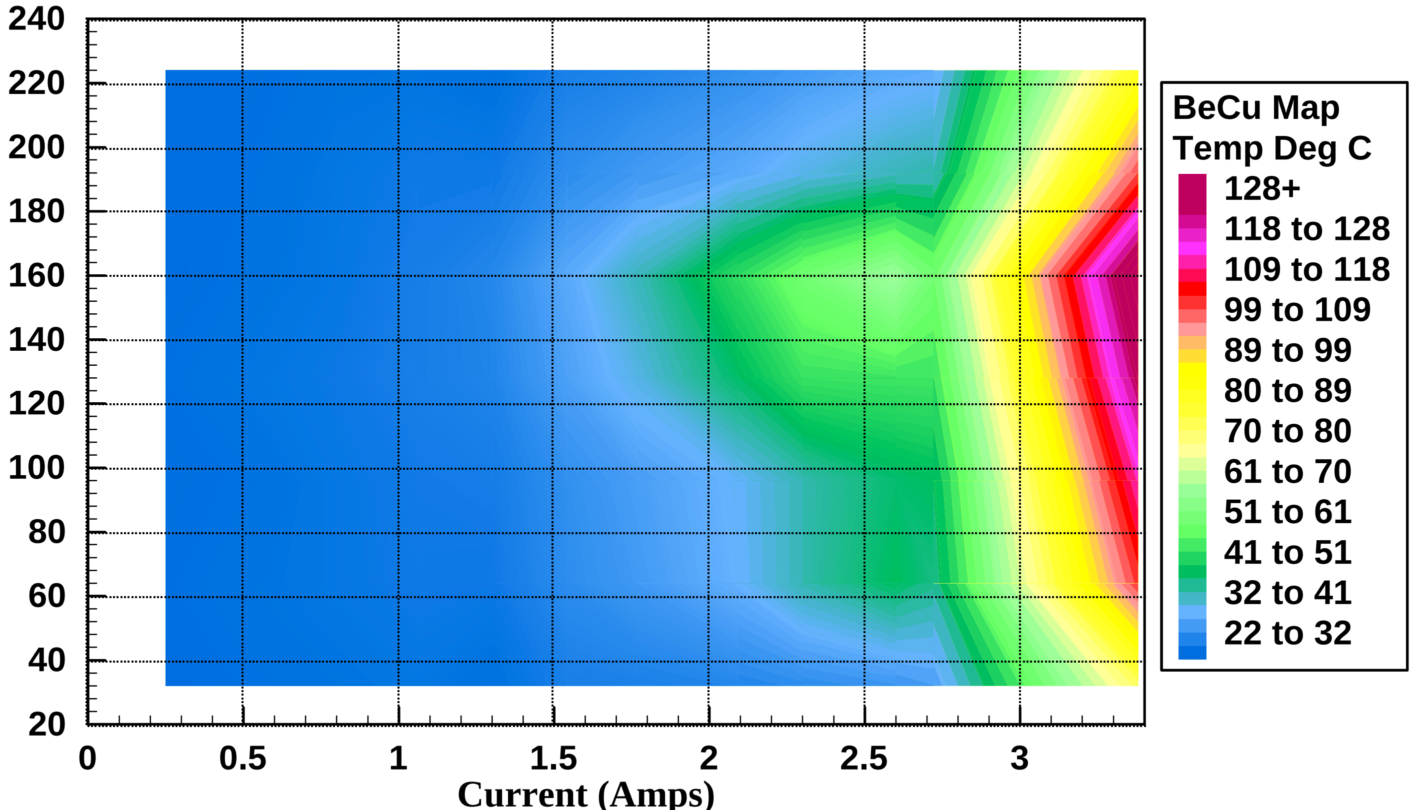
Figure 6 - BeCu Probe illuminated with current.

Observations:
The bulk of the heat dissipation occurred at the center of the probe throughout the experiment. Moreover, cooling occurred at the contiguous probe ends due to the thermal conductivity of the Au mounting fixtures.

Thermal Profile

Figure 7 -BeCu Temp Distribution.

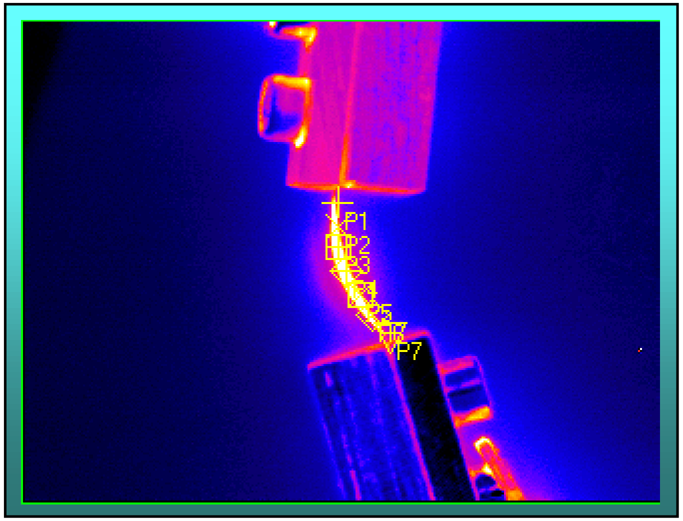




Observations:

The BeCu Viper™ probe yielded during the transition from 3.5-4.0 Amps. From the graph we recognize the melting potential - occurring roughly at 3.7 Amps.

Figure 8 - BeCu Probe Under Test



As the current is increased through the constriction, or probe ribbon, it will soon follow the I^2R heating until the formed region softens relieving the energy.

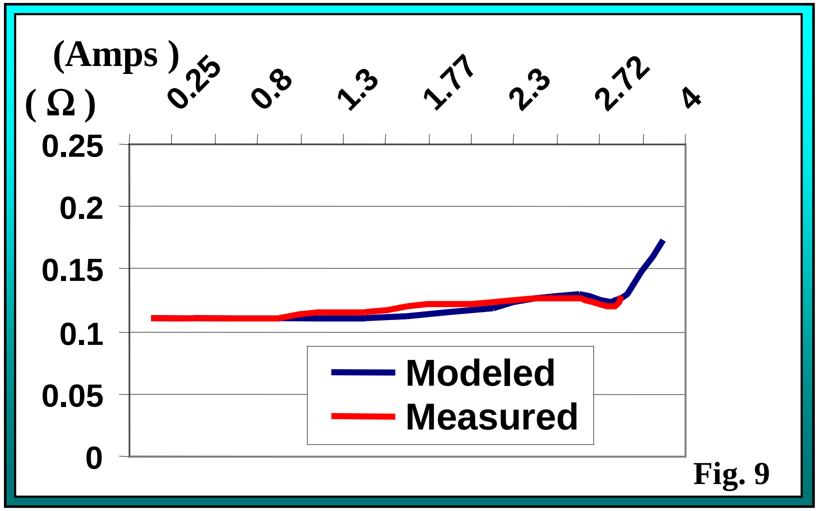
The mechanical integrity of the probe should then be considered to validate the useable current region for the structure.

Analysis:

The softening voltage appears to begin beyond the 1.5 Amp mark (softening potential 0.174V).

Relating the BeCu Thermal Profile, Figure 7, we observe a gradual increase in temperature at the probe ribbon, corresponding to the inflection point of Figure 9.

Figure 9 - Bulk Resistance vs. Current BeCu 0.225" BB. Analytical and empirical trend shown.



Electromechanical Considerations:
A Viper™ Buckling Beam probe was harnessed to a precision current supply via gold clasp mechanisms. Under load, the micro-contacts were powered and exercised monitoring the load cell force measurements.

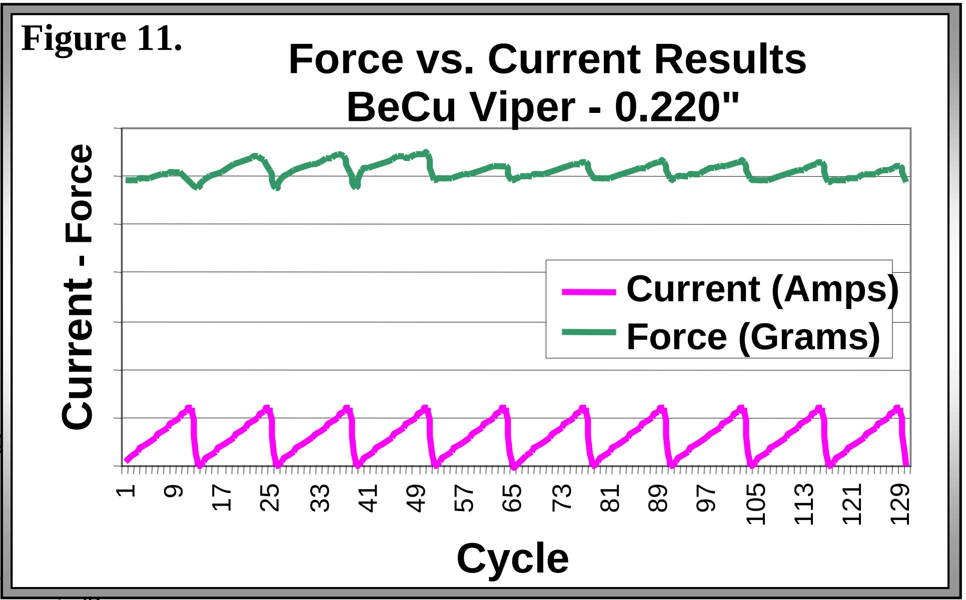


Figure 11.

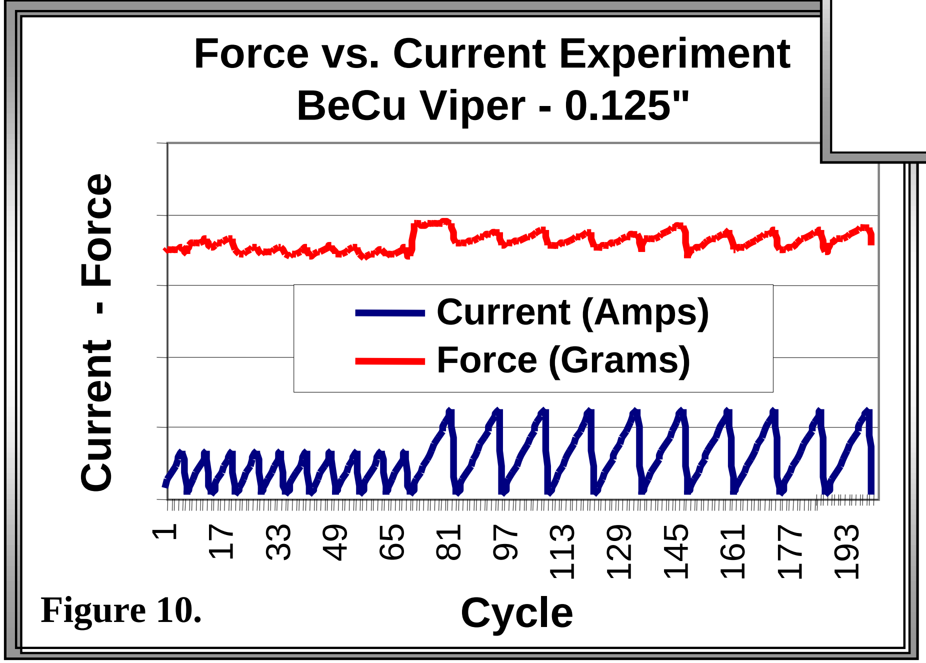


Figure 10.

Observations:
The force of the Buckling Beam modulated slightly with the continuous increase of current. The period of the continuous power cycle ranged from 60-90 seconds.

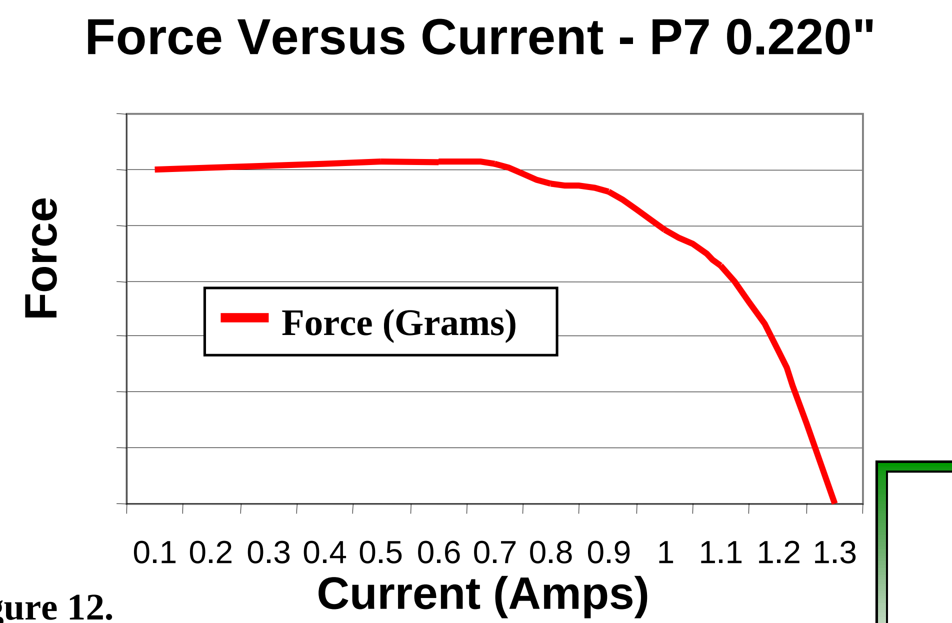


Figure 12.

Electromechanical Considerations:
The force transducer apparatus was again applied to Paliney®-7 Buckling Beams Probes. Probes of length 0.220” and 0.125” were considered.

Analysis:
The 0.220” Buckling Beam, results seen in Figure 12, started becoming compliant at the 0.75A mark. Referring back to the Thermal Profile (Figure 4) we observe a distinct correlation of this event.

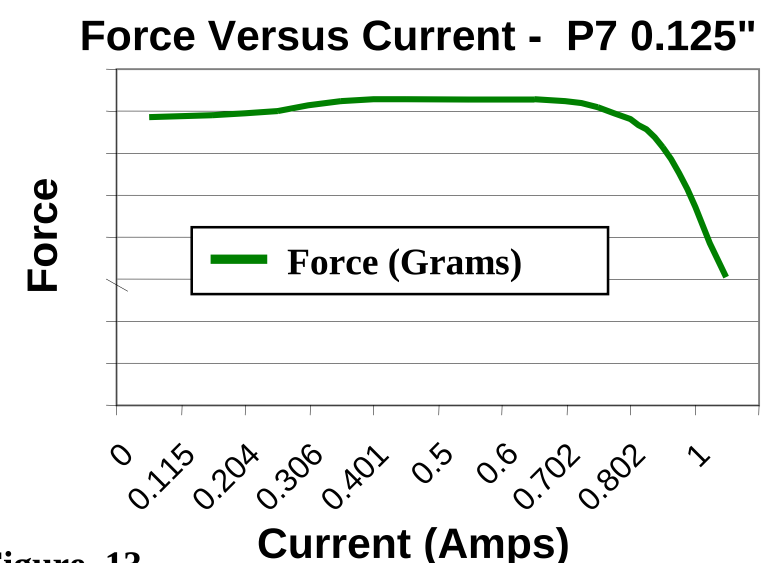


Figure. 13.

Figure 14 - Force versus Current Analysis: BeCu Viper™ - 0.220”.

Observations - Both the full length probes, and the low inductance reduced length probes, successfully demonstrated their propensity to withstand considerable and comparable amounts of current without immediate mechanical degradation.

Figure 15 - Force versus Current Analysis: BeCu Viper™ - 0.125”.

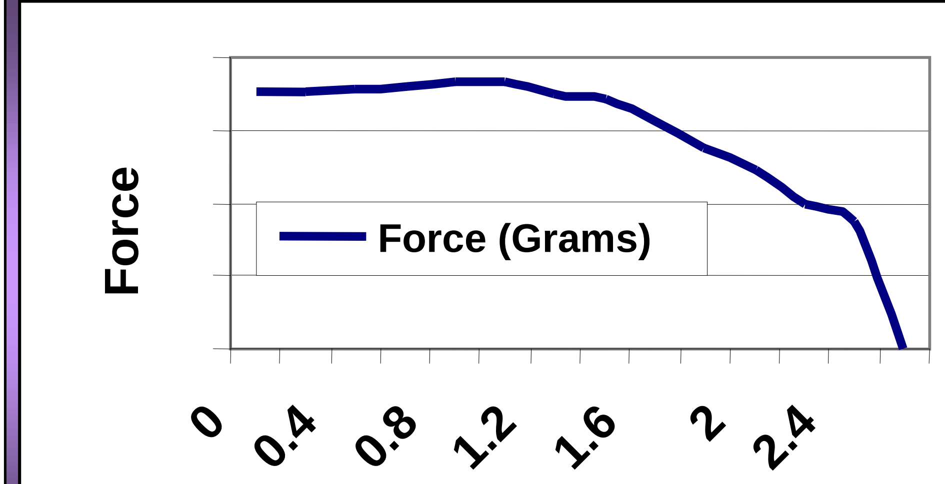


Figure 14.

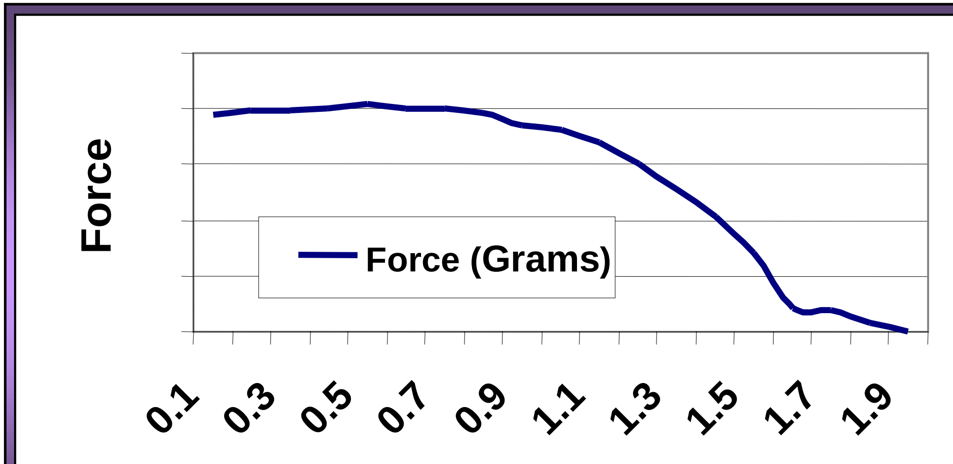


Figure 15.

Summary:
The steady-state models of the DC current response corresponded to the empirical data within 10% of error.

The novel application of IR Microscopy enabled significant insight into the electromechanical properties of Buckling Beam Probes; thereby affirming and calibrating analytical models.

Increased modeled-to-measurement accuracy is possible with further refinements to the test measurement tooling and setup.

Conclusions:
With the continued increase of device current and longer die test cycles, a detailed understanding of the critical tooling parameters and boundary conditions must exist.

The Finite Element Analysis approach to design has enabled the ability to incorporate and resolve the most crucial elements for High Volume Manufacturing Sort applications.

The experimental results confirm that the selected Buckling Beam geometry has enabled significant current carrying capability while maintaining mechanical integrity; thus asymptotically approaching the boundary conditions of the employed probe material.