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Shock, Vibration, and Wind Tunnel Tests of Electronic Components with Sn Whiskers

Zequn Mei, Sue Teng, Mudasir Ahmad
Cisco Systems, Inc, San Jose, California, USA

Acknowledgement: Dr. P. Oberndorff
Philips Centre for Industrial Technology, 5600 MD Eindhoven, the Netherlands

Motivation

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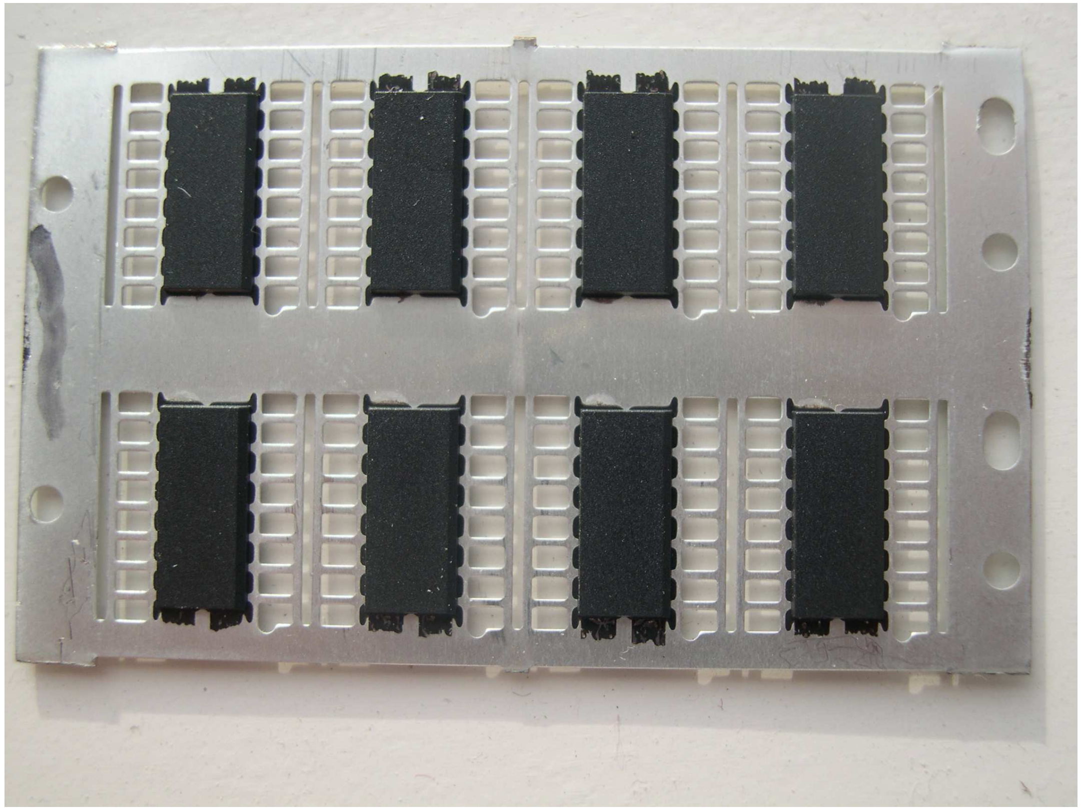
- In a typical electronic assembly, the lead spacing of most components is large. The risk of a tin whisker to short two adjacent leads is minimal.
- However, if whiskers break off and move freely they may short the components with small lead spacing.
- Most people assume whisker would break off, but there has been little test data.
- Whiskers might not break off under normal service condition.
- Sn Whiskers of single crystal might be stronger than polycrystalline Sn because of few crystal defects.

Test Samples

- 8 TSOPs in leadframe, before being cut into individual parts. Cu lead frame, coated with 3 μm thick matte Sn. No post-plate bake. 30°C/60%RH for 8 weeks. Numerous whiskers, their max length is about 200 μm.

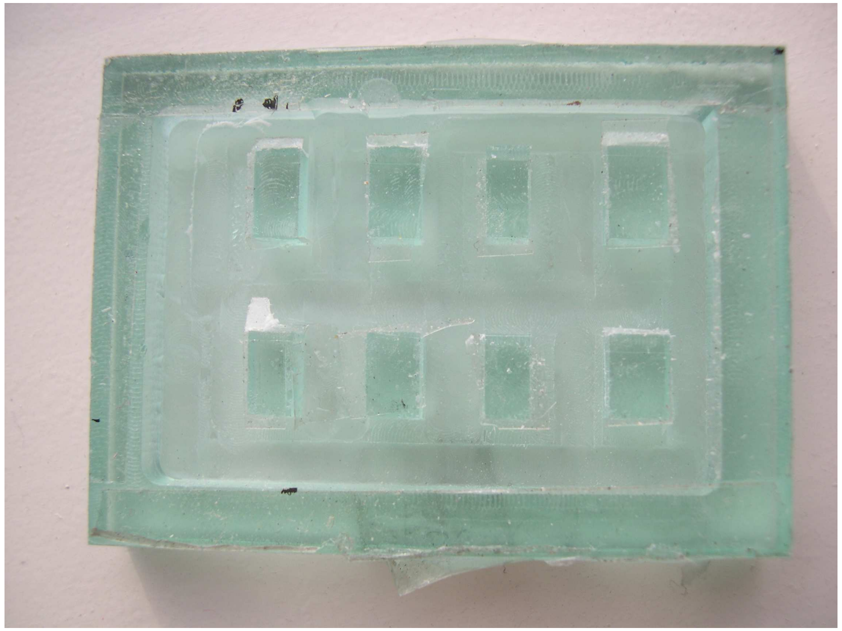


Test Procedure

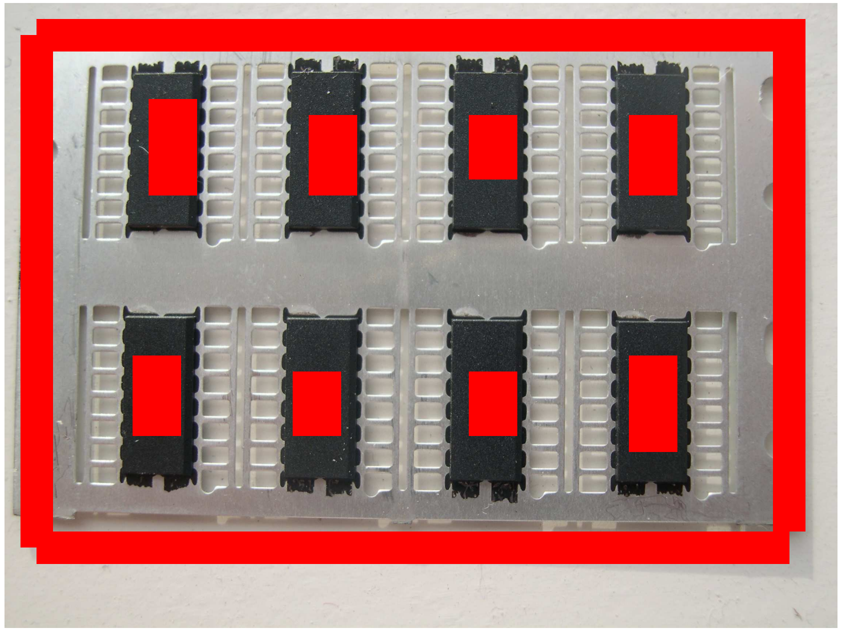
- Photographed whiskers under SEM.
- Mechanically Shocked TSOPs three time at 1500G, Mil-std-883F, Method 2002.4, condition B.
- Photographed the same whiskers.
- Vibrated the same TSOPs, 30 min, Mil-std-883F, Method 2007.3, condition A, peak g level = 20 g, 20 to 2000 hz, random frequency.
- Photographed the same whiskers.
- Blew wind over the same TSOPs, 400 feet/min, 30 min.
- Photographed the same whiskers.

Fixture for Shock and Vibration Tests

- Two carved plastic plates, so to hold QFPs at their plastic mold, and the outside frame. No touch on the leads.

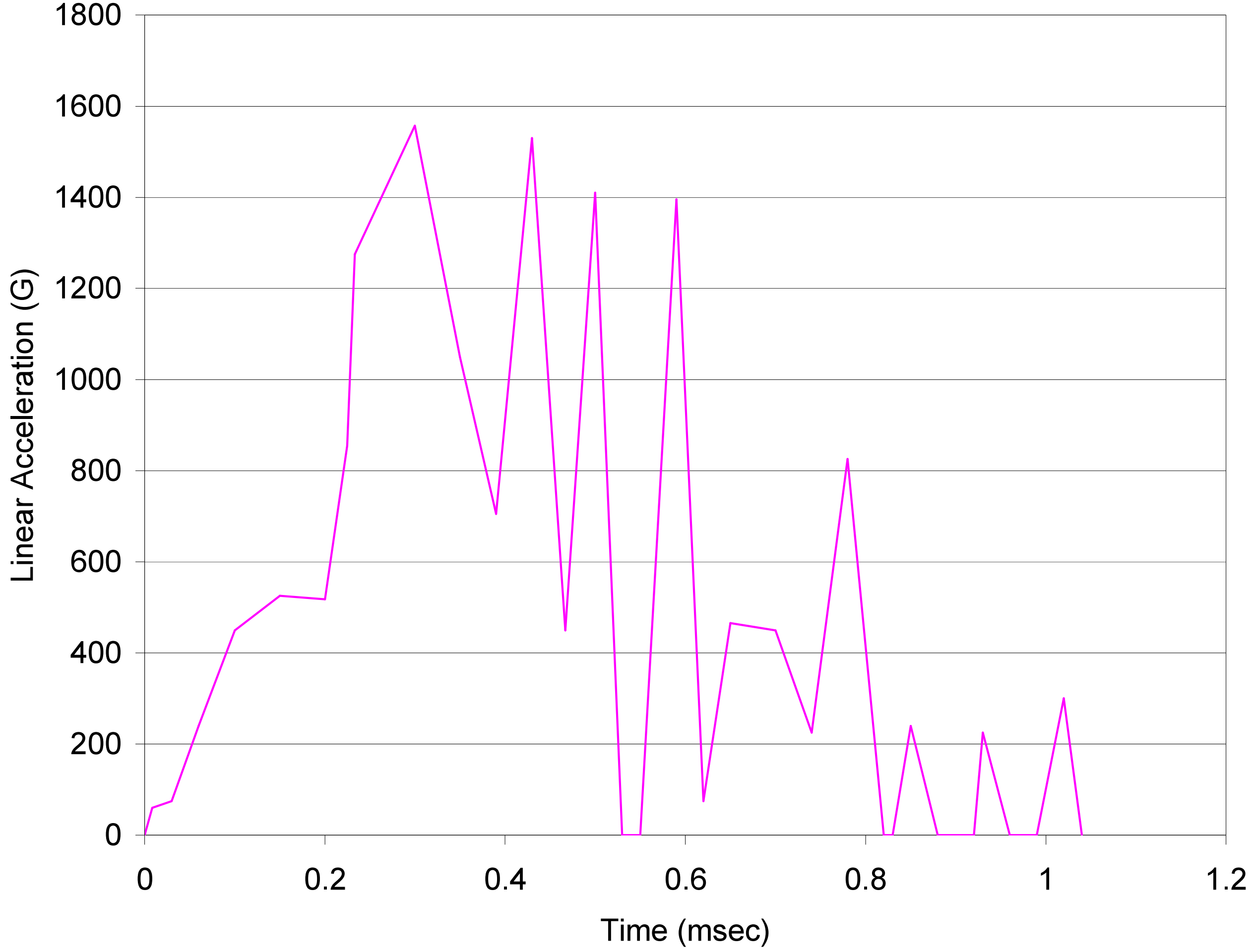


One of the two fixture plates



Hold the area in red color

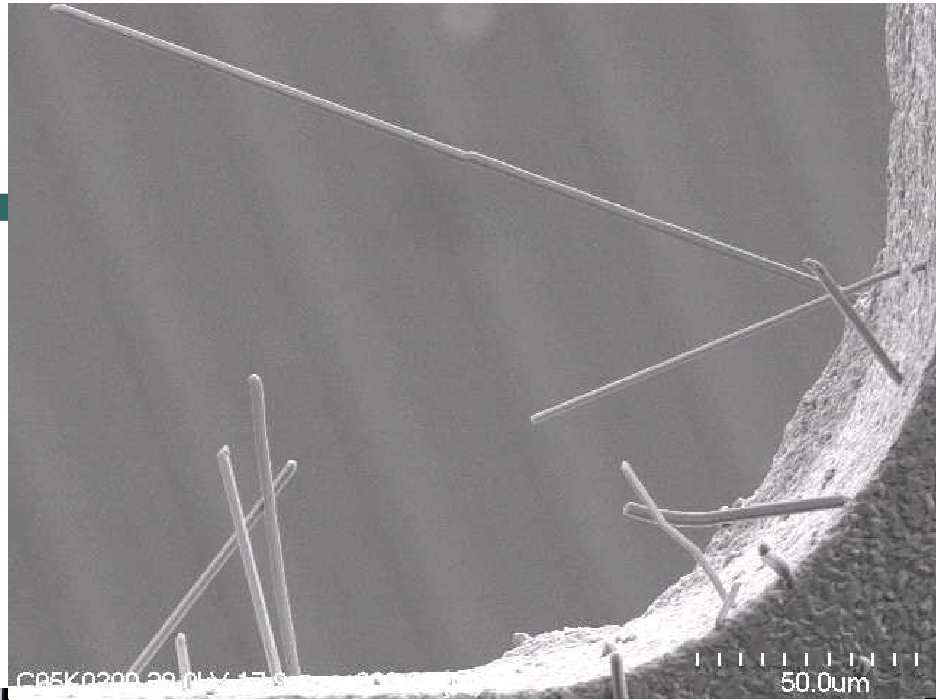
Shock three times > 1500 G

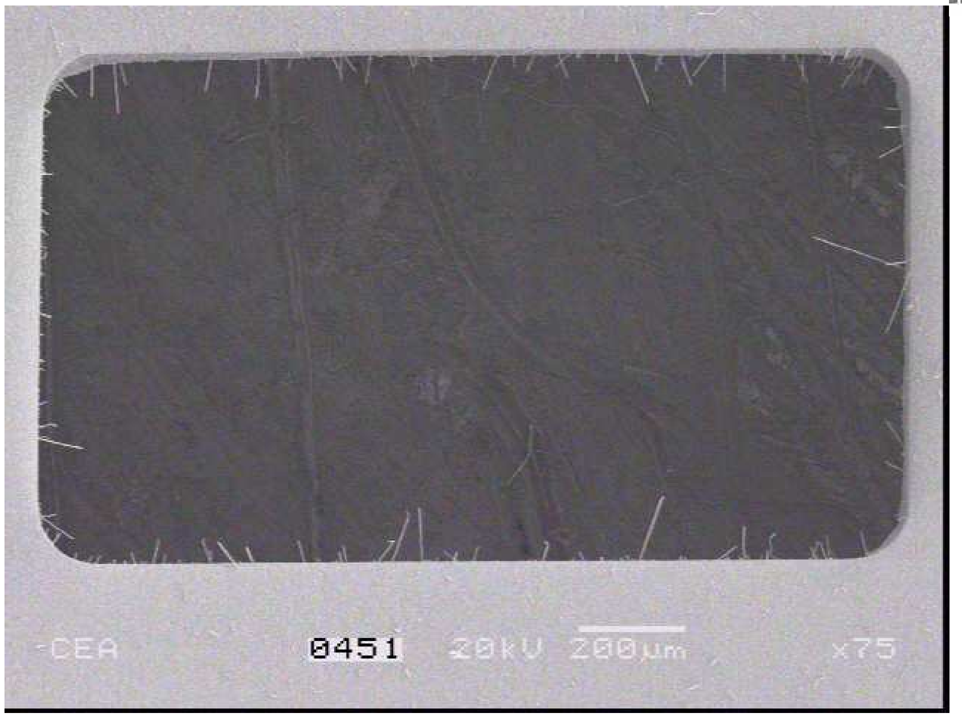


A typical G vs time plot in shock tests

Whiskers

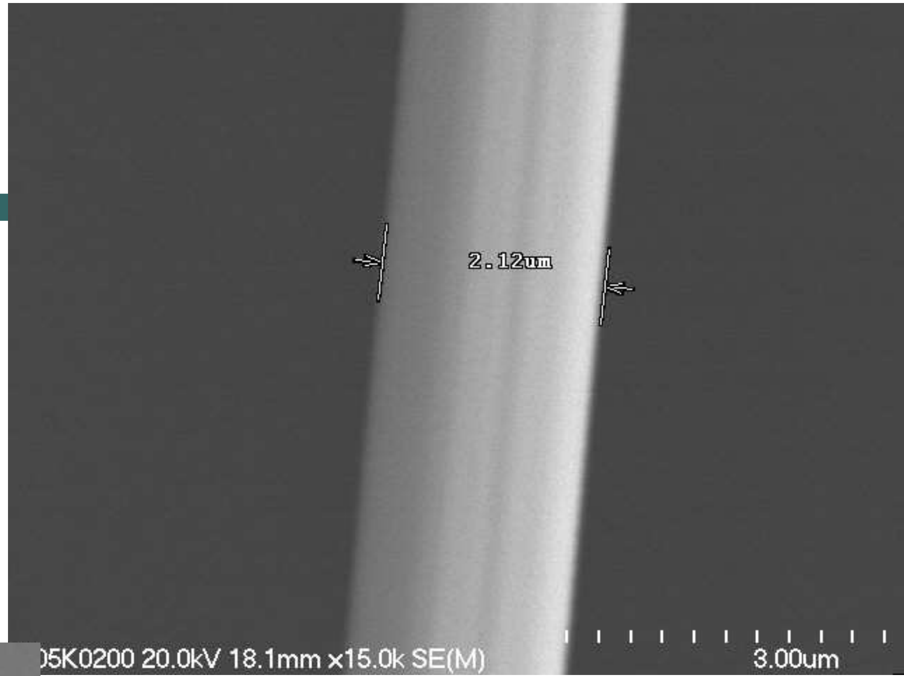
- Pictured ~ 200 whiskers of length 100-200 µm, before tests. Some examples are shown here.

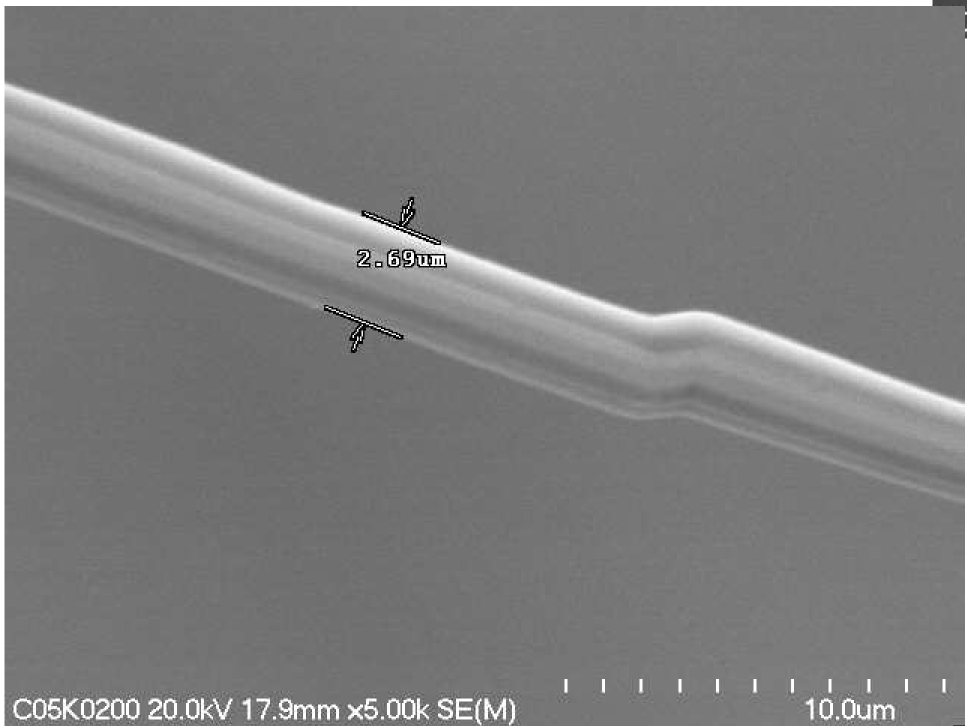


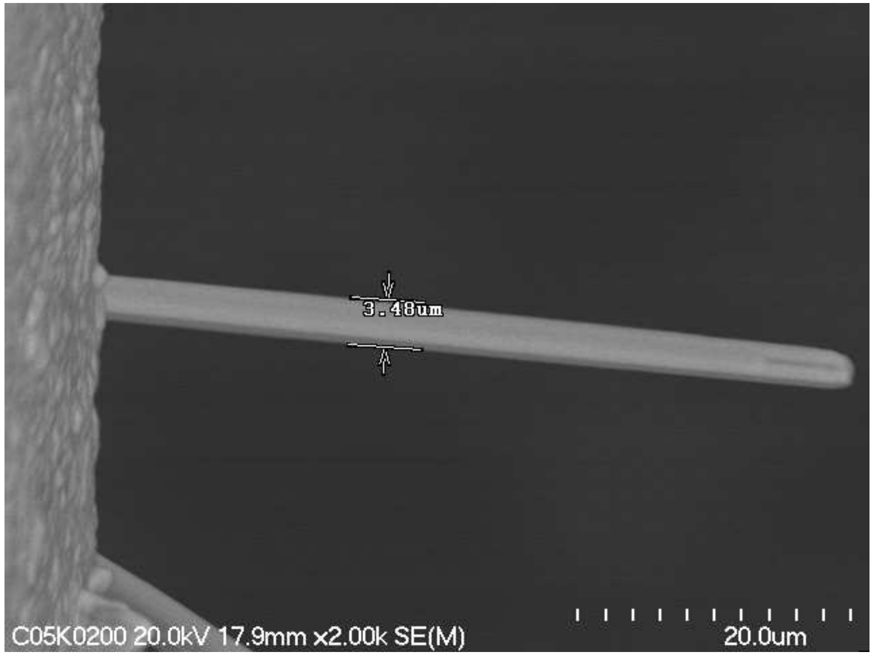


Whiskers

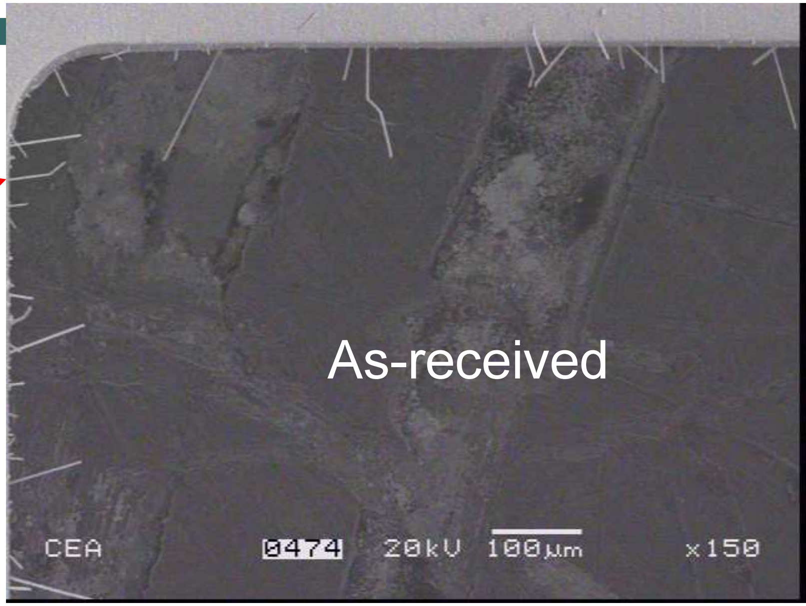
- The whisker diameter varies between 2 and 5 microns.

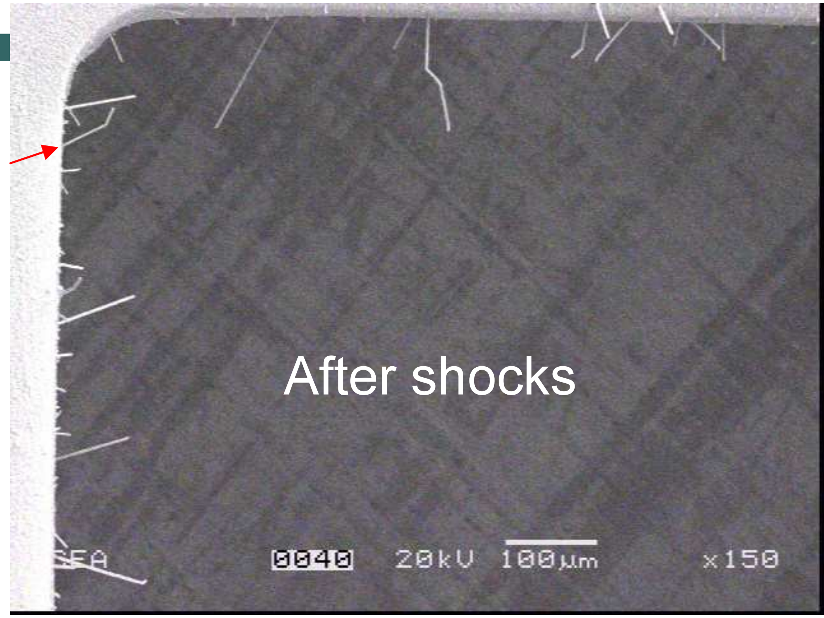


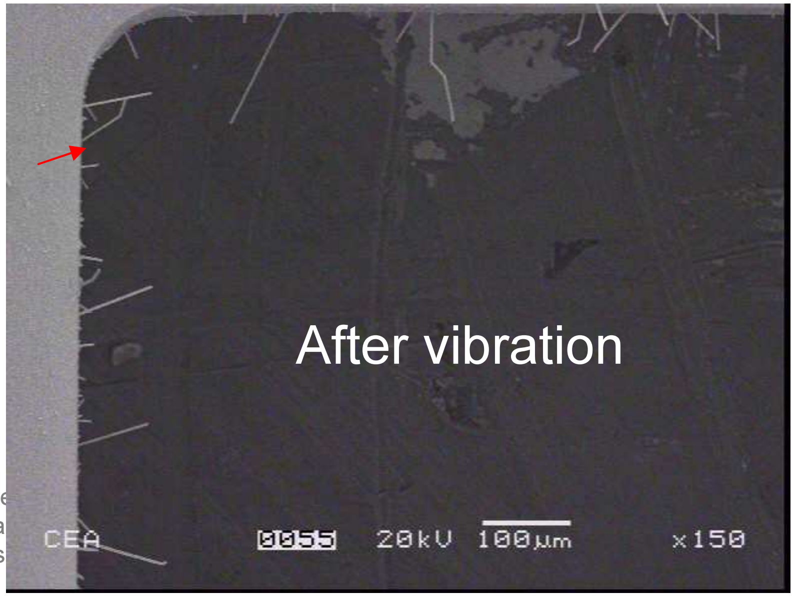


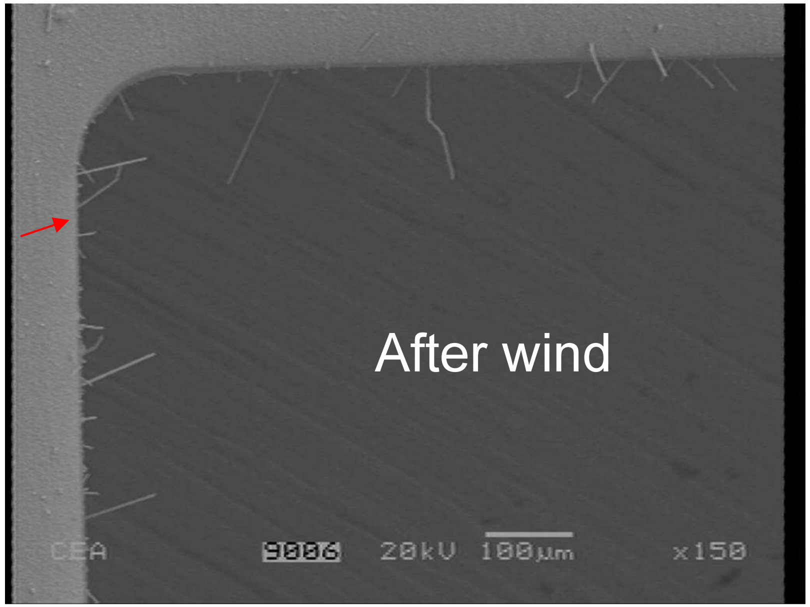


Whiskers before and after tests: one bent after shock

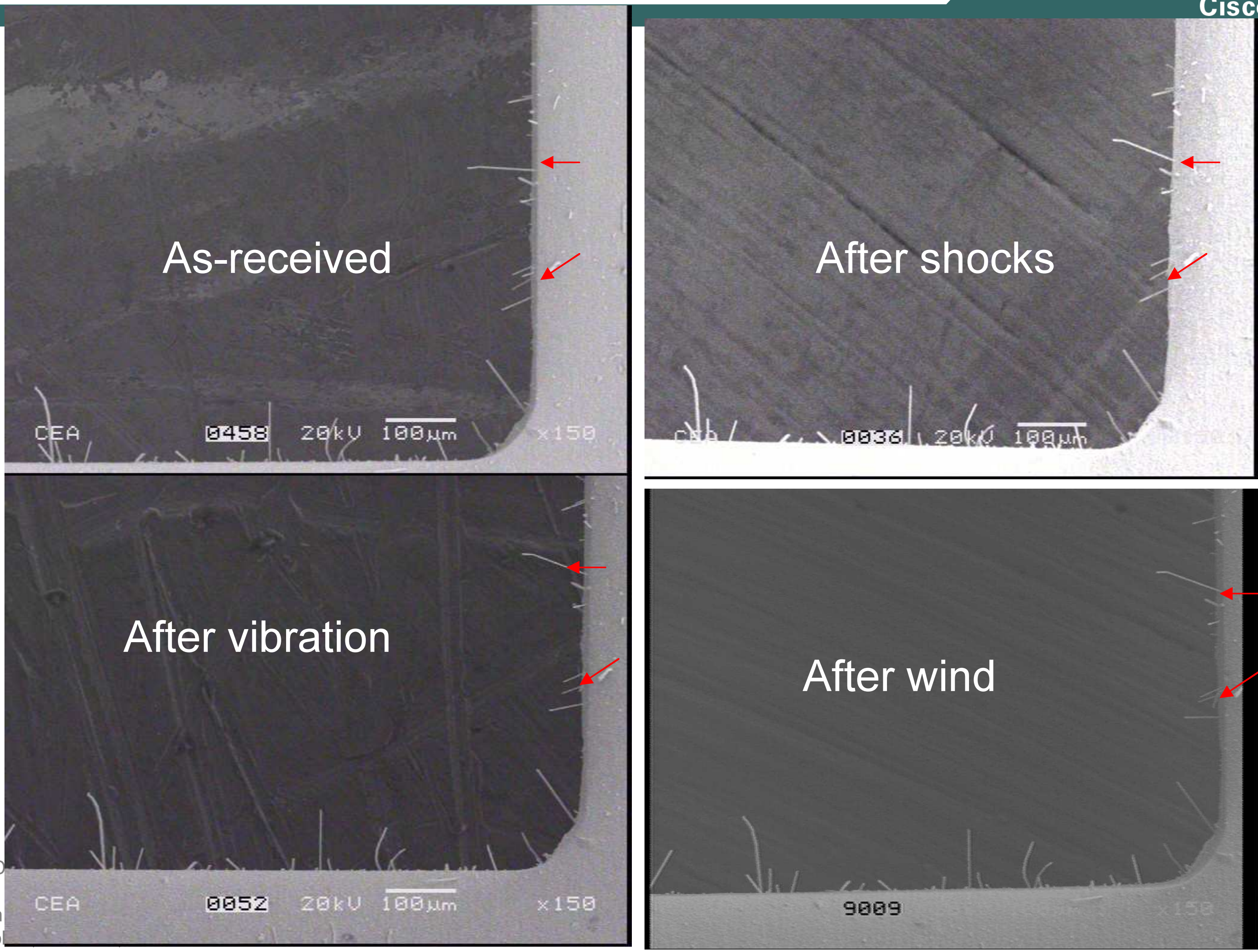




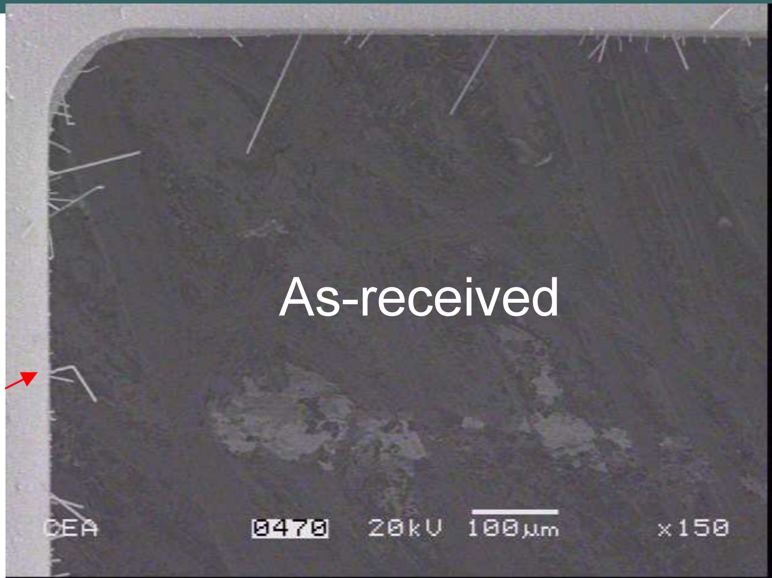


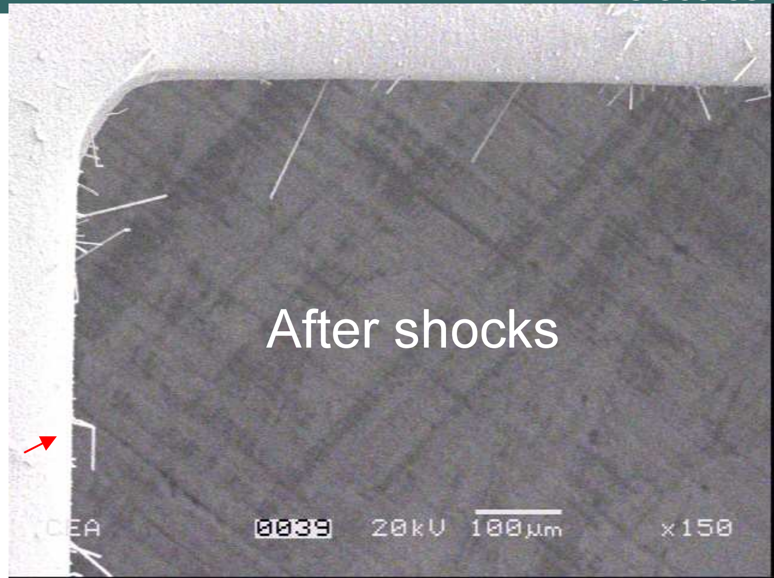


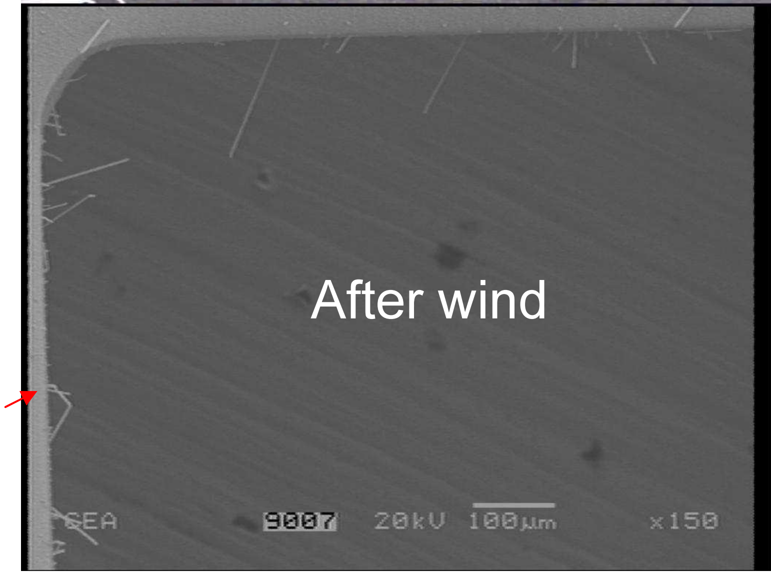
Whiskers before and after tests: one missing, one bent



Whiskers before and after tests: one bent







Whiskers before and after tests: one twisted

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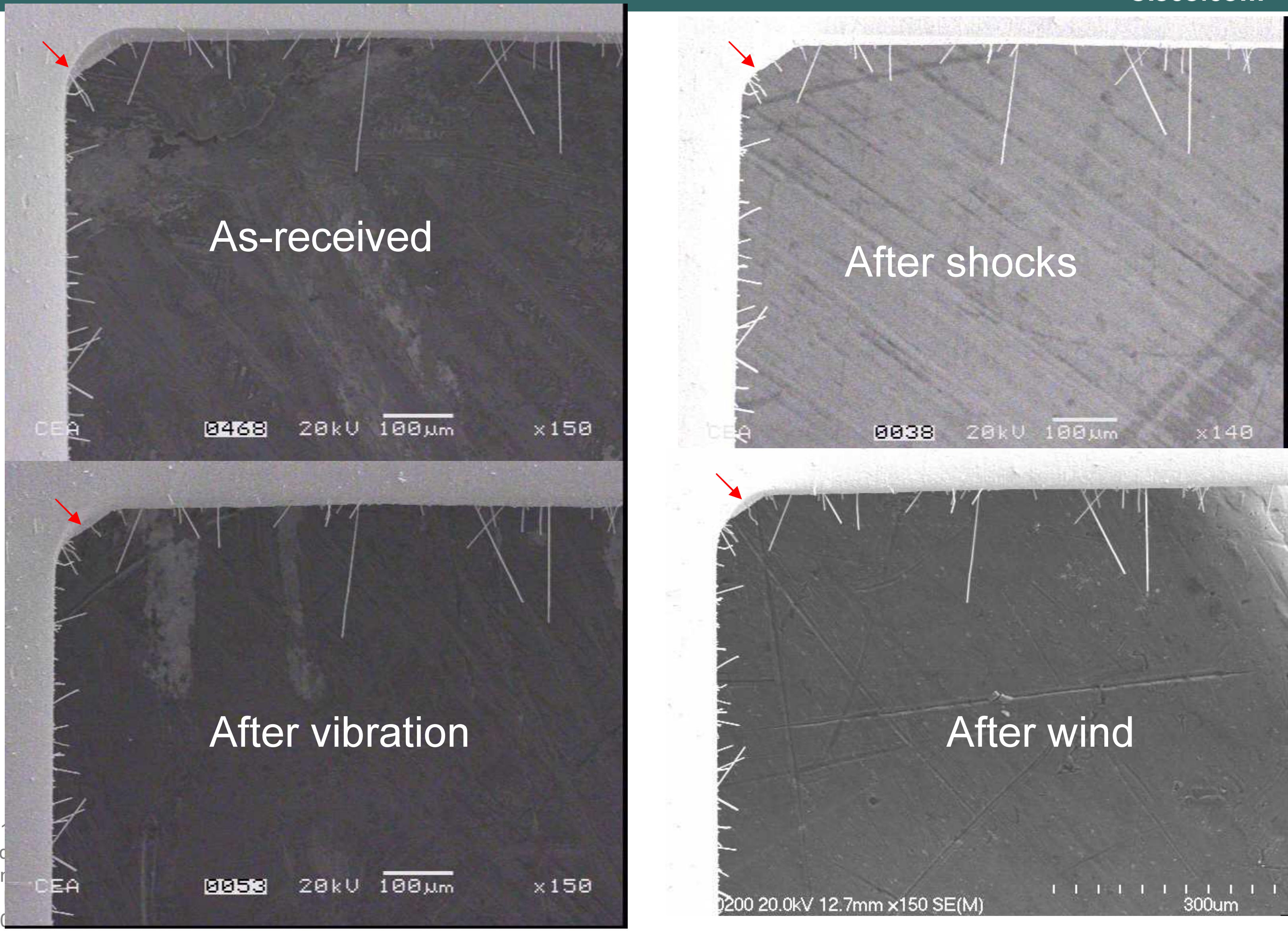
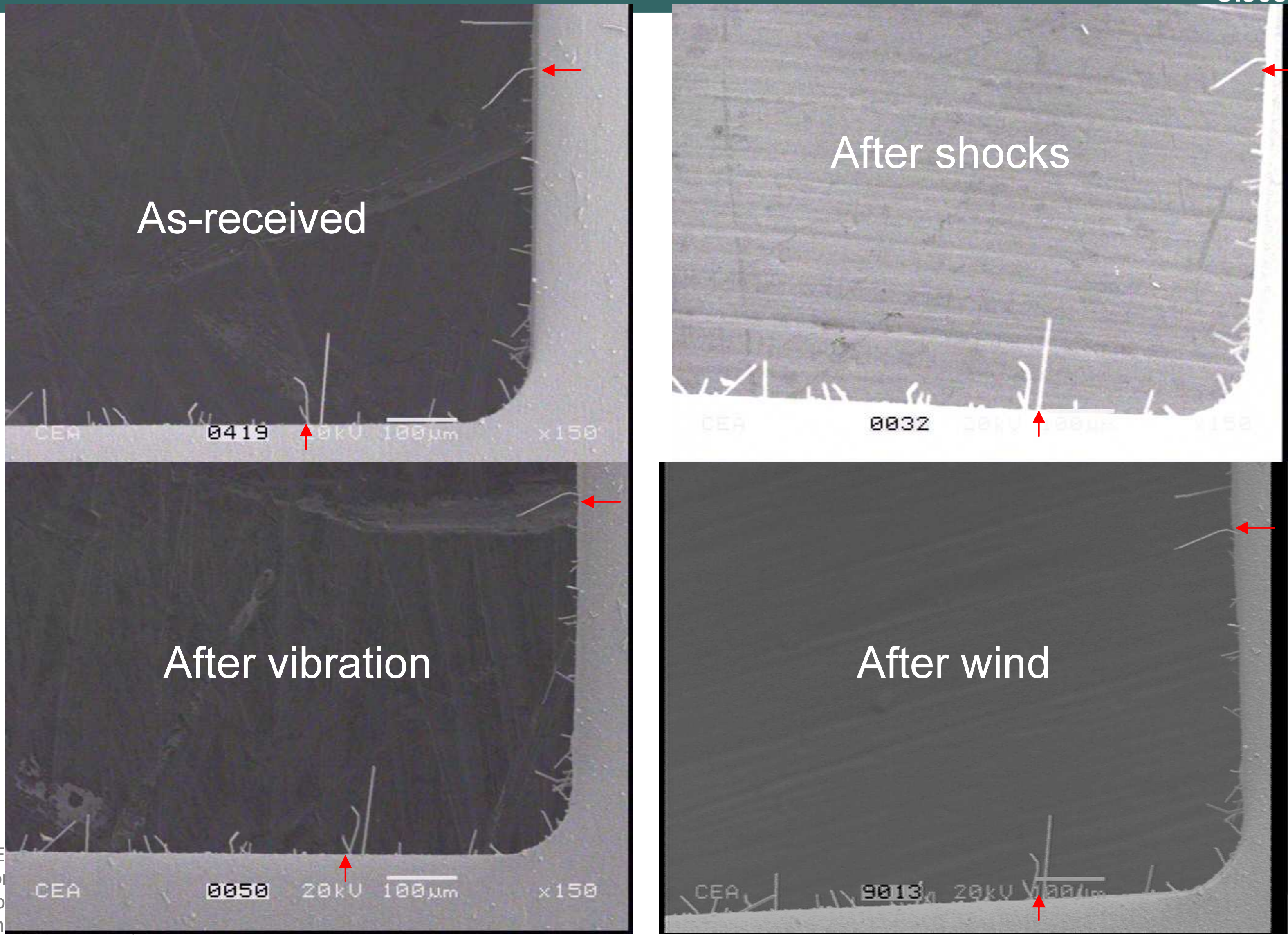
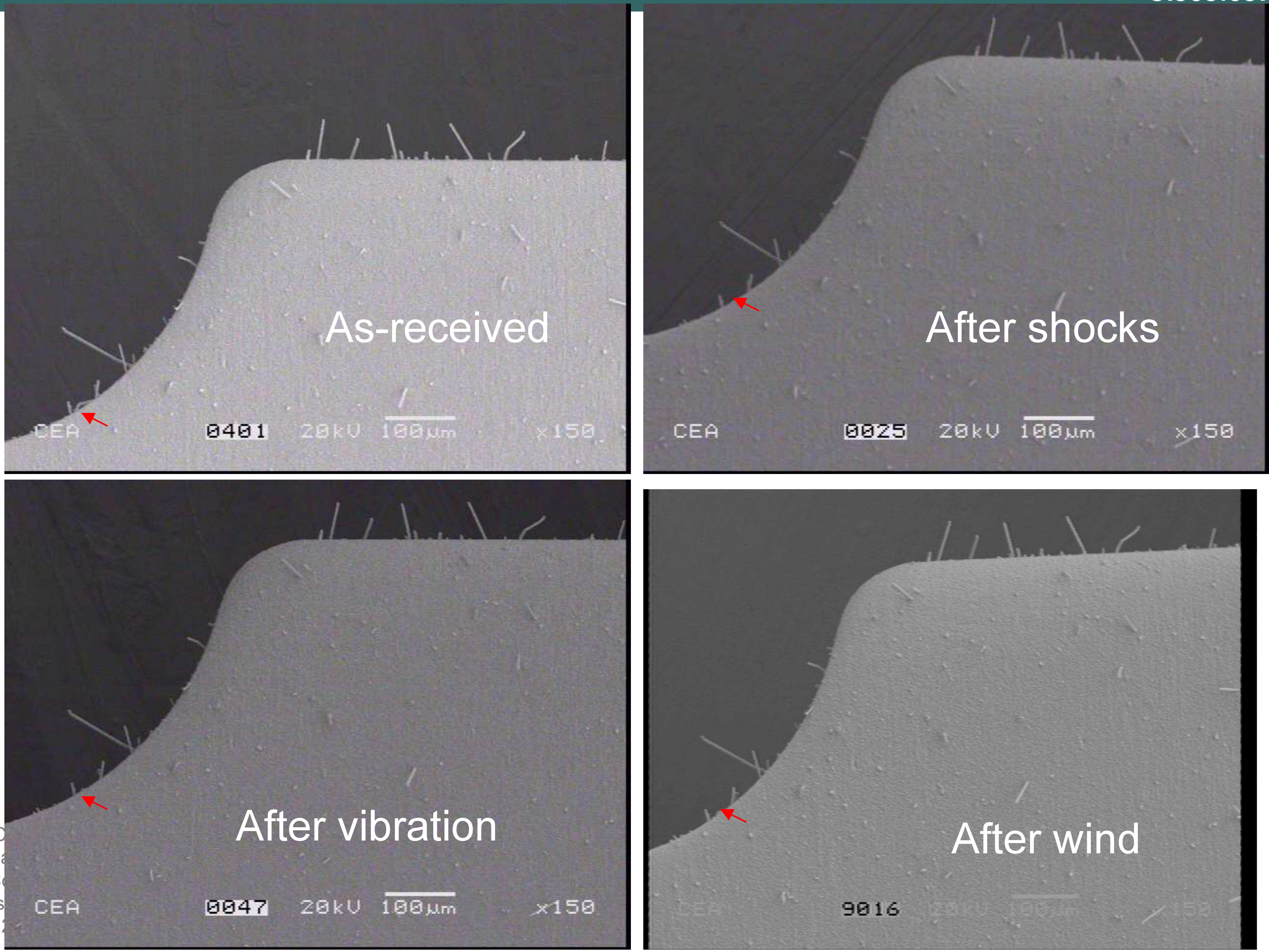


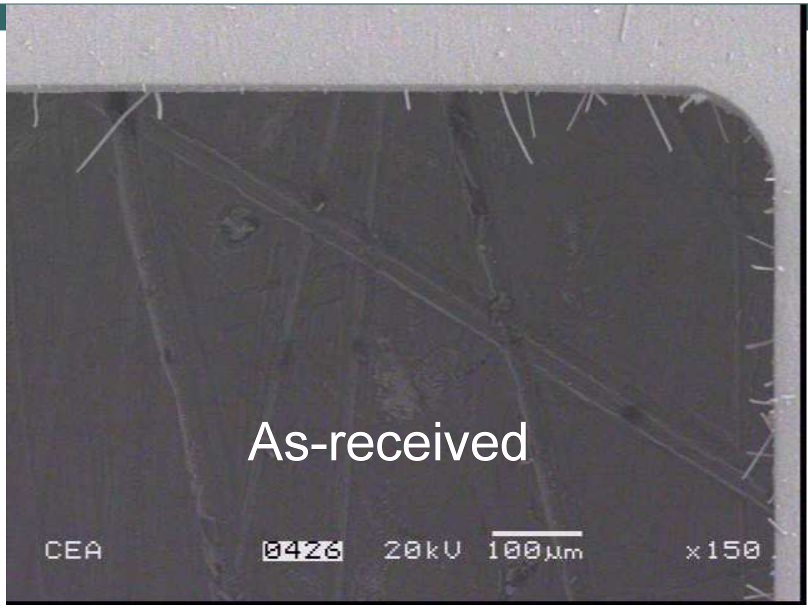
Whiskers before and after tests: two bent

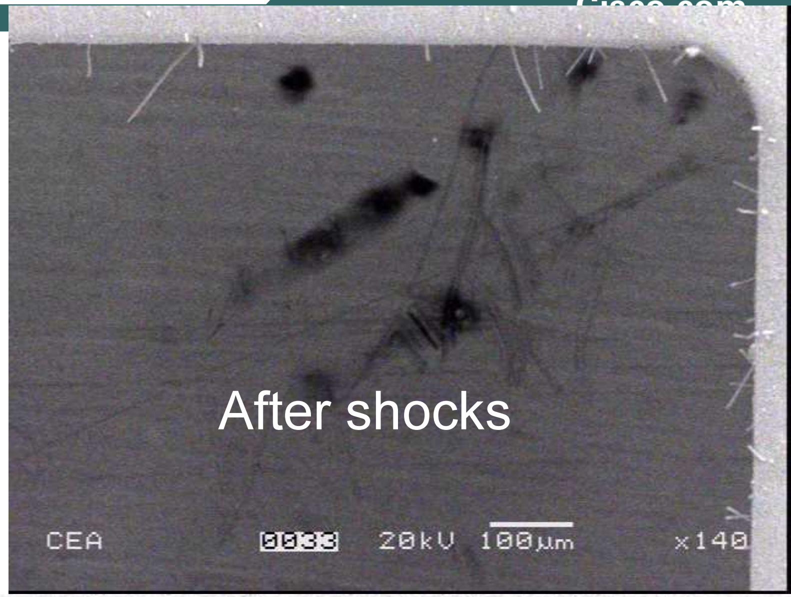


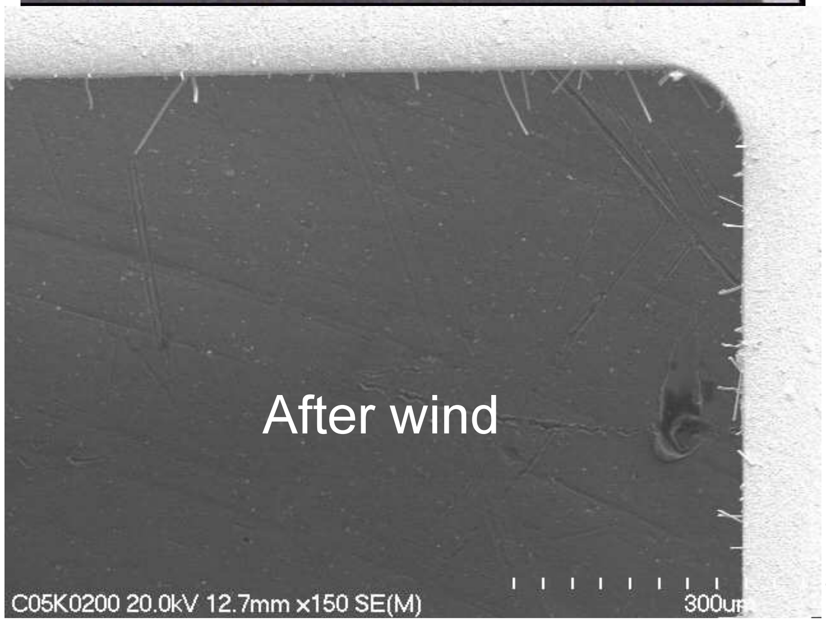
Whiskers before and after tests: one missing



Whiskers before and after tests: no change







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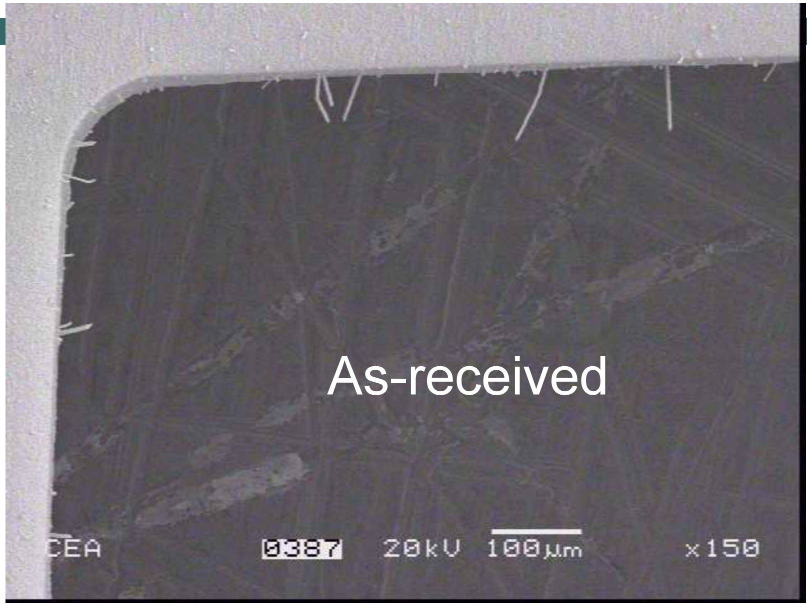
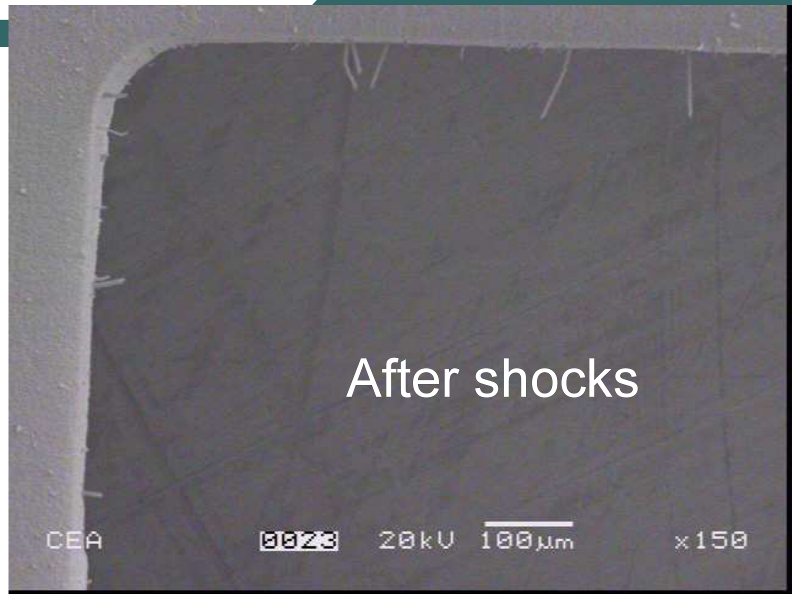
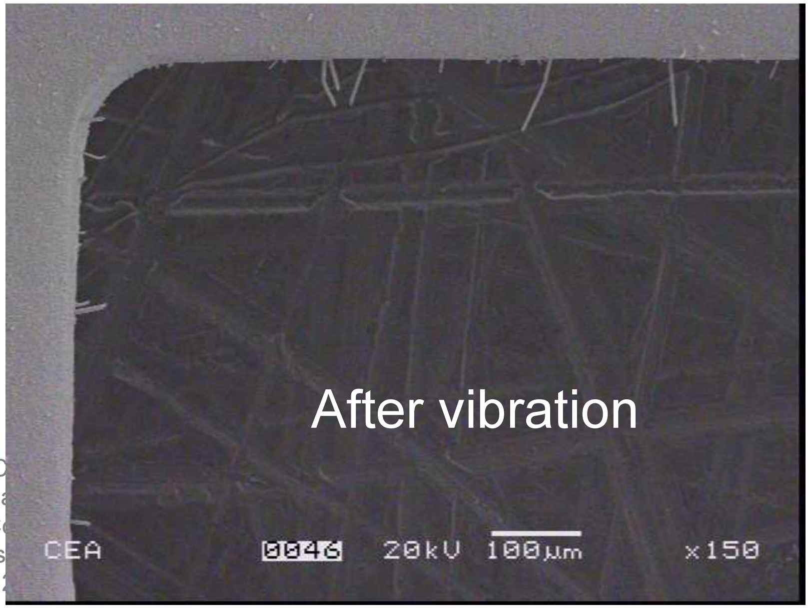
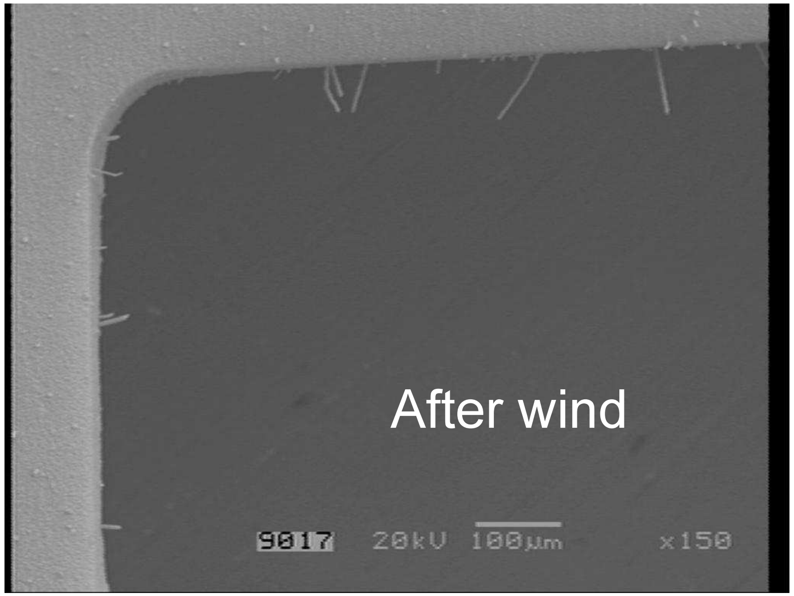
Whiskers before and after tests: no change

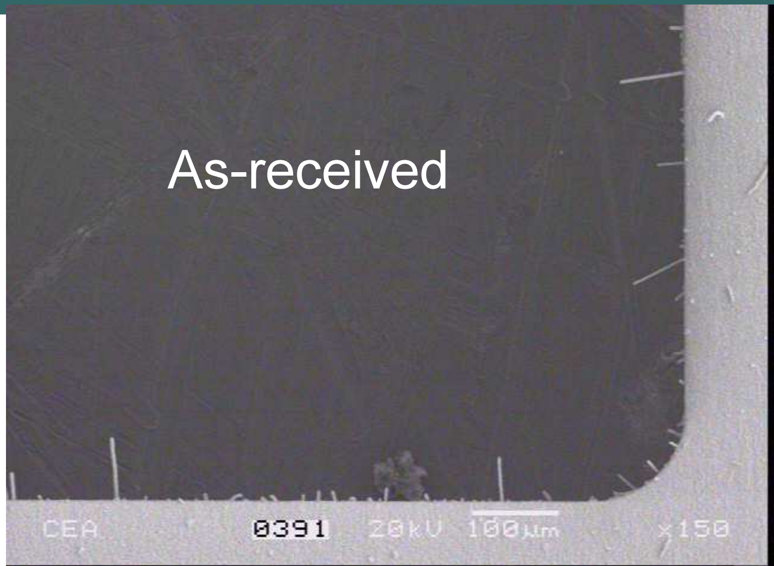


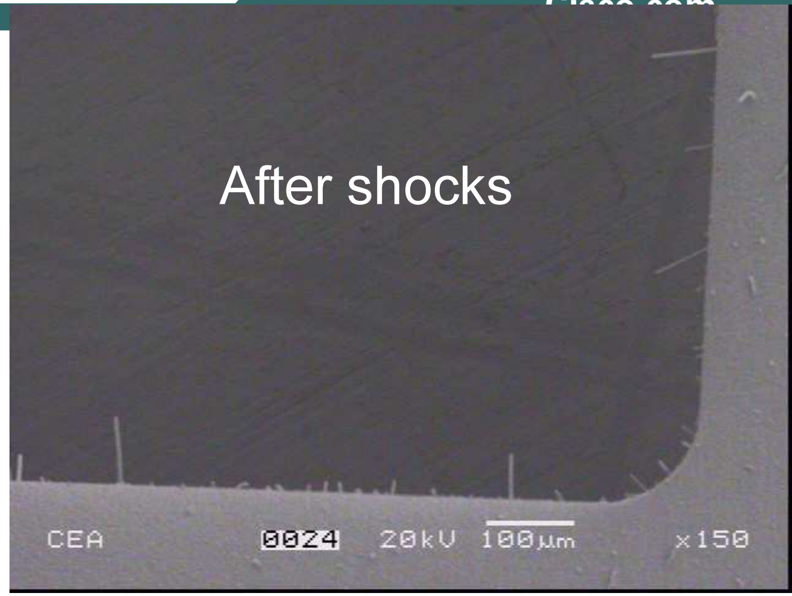


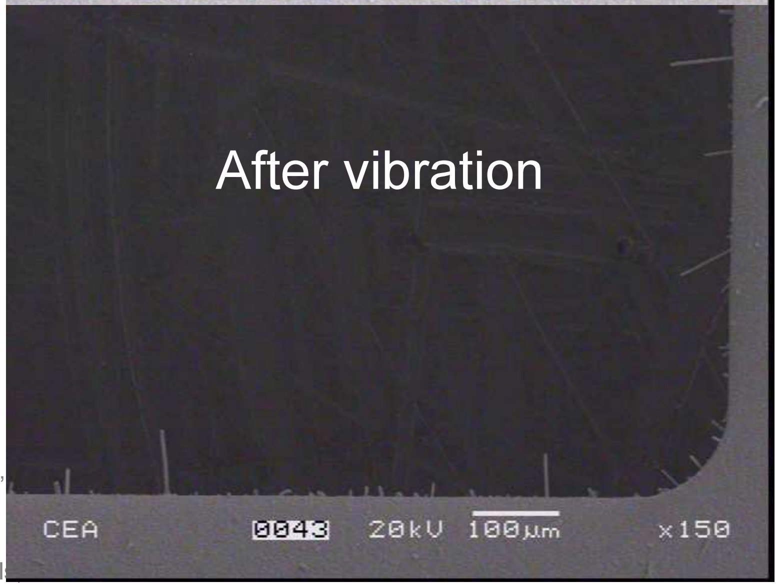


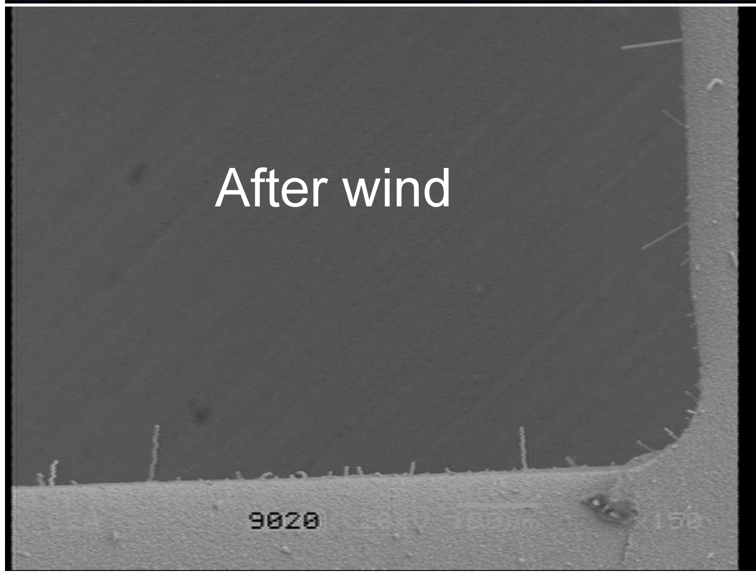


Whiskers before and after tests: no change

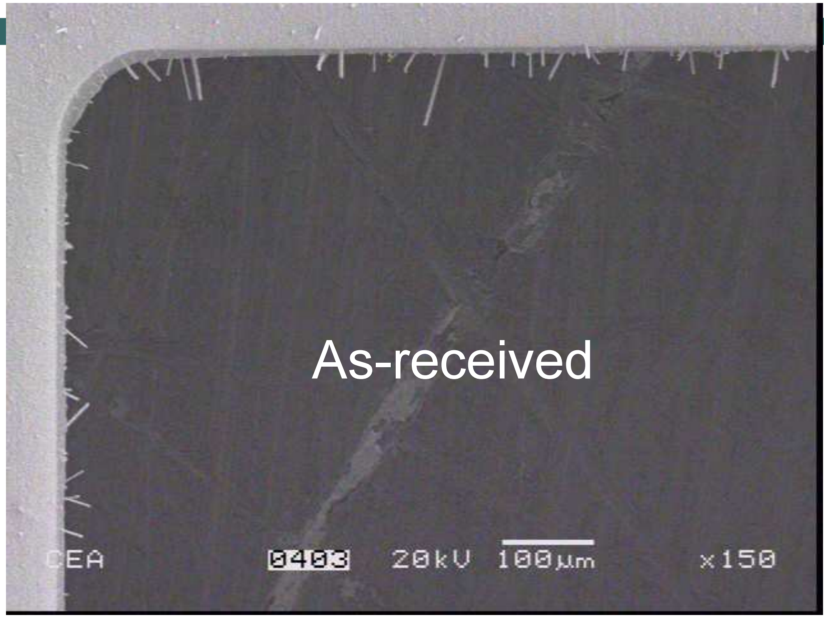


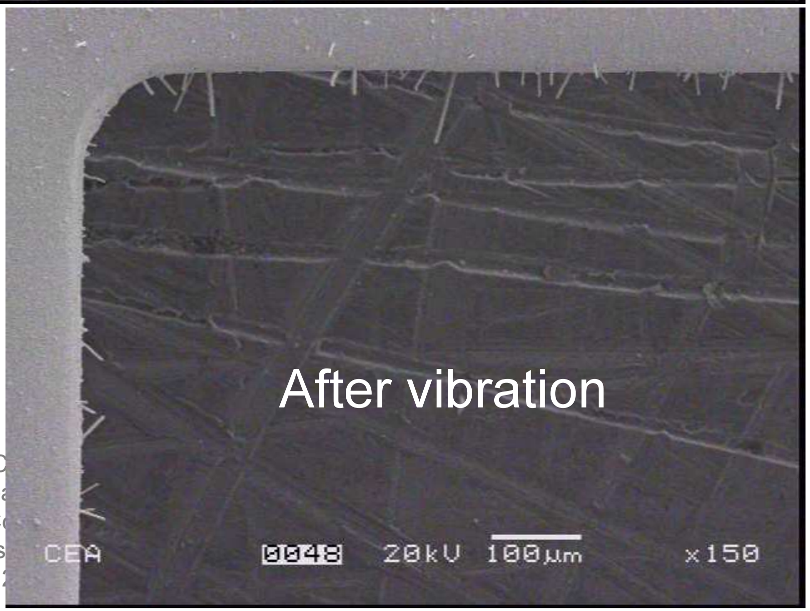


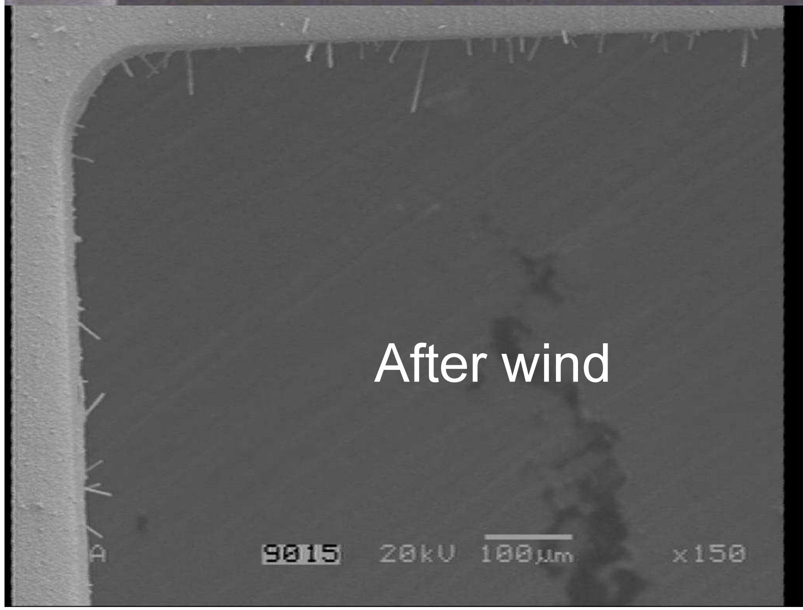




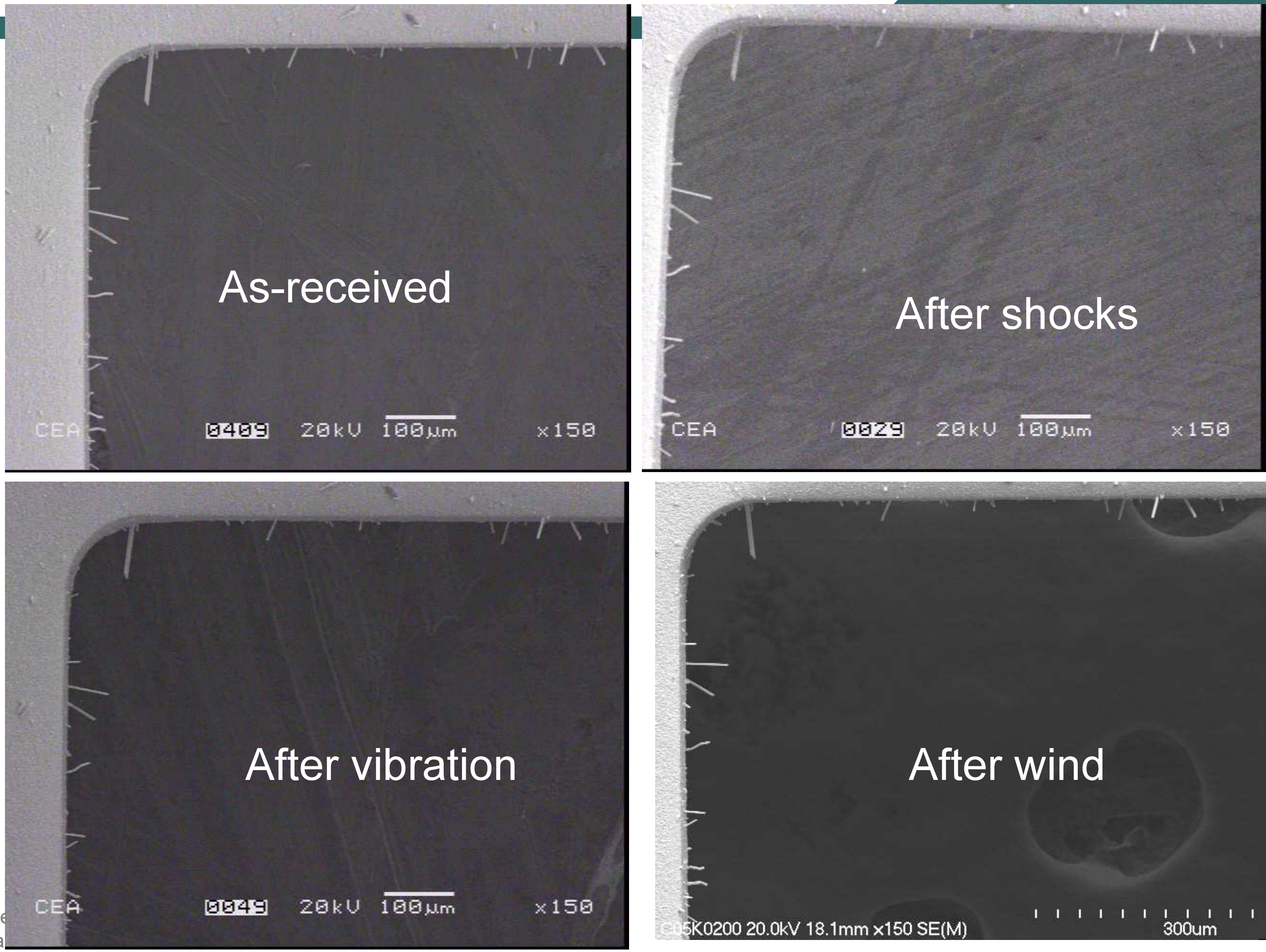
Whiskers before and after tests: no change



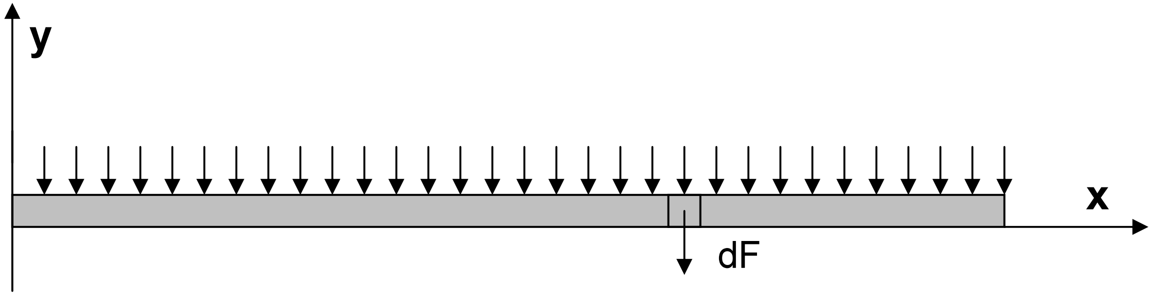




Whiskers before and after tests: no change



Estimation of the stress in shock test



The stress in a whisker during shock is modeled as bending of a rod. An uniformly distributed force, dF, is applied on the whisker, dF = dm* G, where dm is the differential mass, and G is the acceleration measured during shock test.

Estimation of the stress in shock test (continue)

$$d\varepsilon_x = \frac{y\,dM}{EI_y}$$

$$d\varepsilon_x(y = R) = \frac{R\,dM}{EI_y}$$

$$dM = \int x\,dF = \int_0^L xG\rho\pi R^2\,dx$$

$$\varepsilon_x = \frac{R^3 G\rho\pi L^2}{2EI_y}$$

$$I_y = \frac{\pi R^4}{4}$$

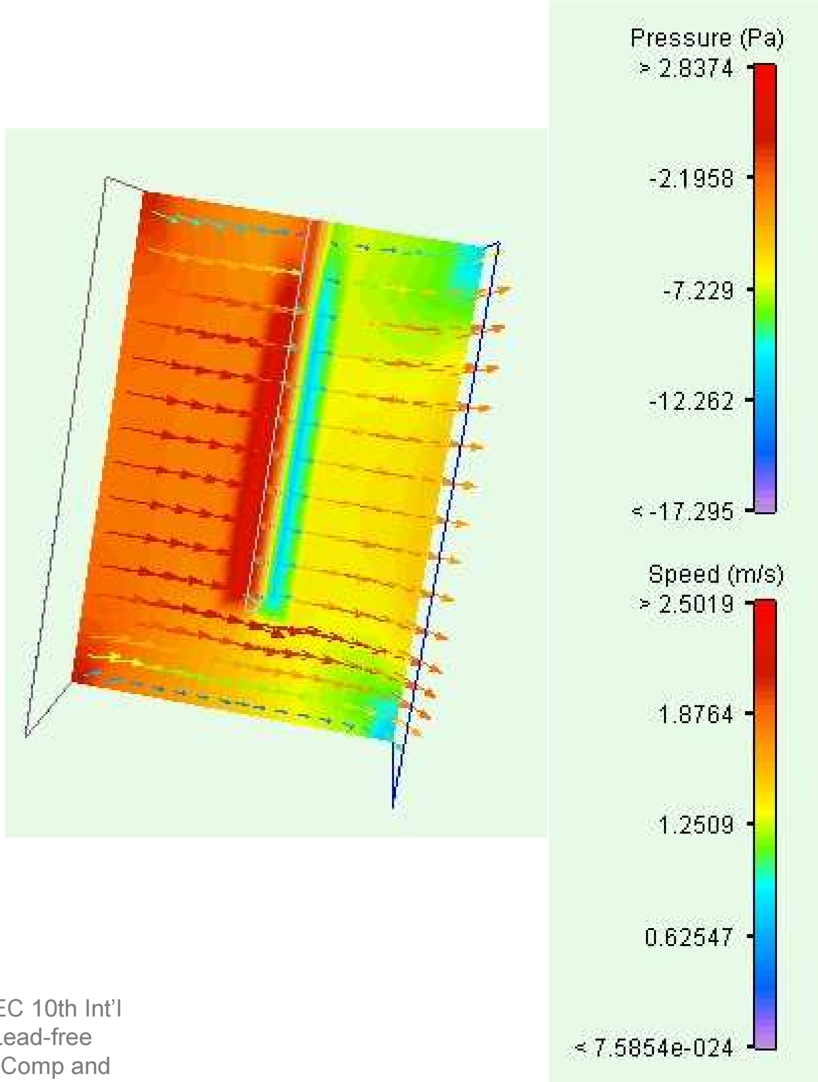
$$\sigma_x = E\varepsilon_x = \frac{2G\rho L^2}{R}$$

G is the acceleration, ρ density, L the whisker length, and R the radius. The stress is proportional to L^2, and inversely to R.

Assume:
G=1500 g, g=9.8 m/sec^2
ρ= 7300 kg/m^3
L = 200 μm, R = 1 μm

Then: σ_x= 8.6 MPa
Less than the yield stress of polycrystalline Sn of 20 MPa. The yield stress of a single crystalline Sn is not known to us.

Estimation of the stress in wind tunnel test

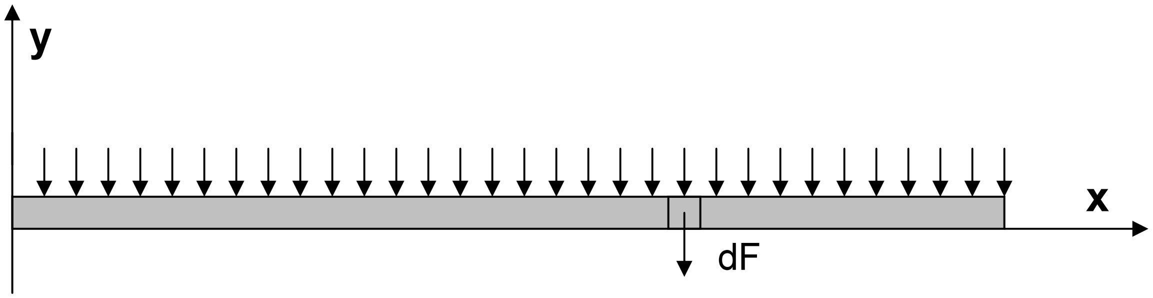


- Used Navier Stokes/CFD to compute the pressure drop across the whisker.

-The pressure drop is practically uniform across the length of the whisker (picture on the left).

-The average pressure drop for air flow of 400 ft/m is 21.7 Pa, assuming whisker length of 150 µm and diameter of 5 µm.

Estimation of the stress in wind tunnel test (continue)



The amount of force applied on the whisker due to the airflow is estimated by cantilever beam with uniform pressure.

Assume, P=21.7 Pa, L=150 µm, R = 2.5µm, σ_x = 0.1 MPa. Much less than the yield stress of polycrystalline Sn of 20 MPa.

We didn't do the calculation for L=200 µm, R = 1 µm. But this result shouldn't change our conclusion since the stress is so low for L=150 µm R = 2.5 µm.

$$d\varepsilon_x = \frac{ydM}{EI_y}$$

$$d\varepsilon_x(y = R) = \frac{RdM}{EI_y}$$

$$dM = \int xdF = \int_0^L xP2Rdx$$

$$\varepsilon_x = \frac{R^2PL^2}{EI_y}$$

$$I_y = \frac{\pi R^4}{4}$$

$$\sigma_x = E\varepsilon_x = \frac{4PL^2}{\pi R^2}$$

Natural frequency during vibration

$$y = \frac{PL^3}{3EI}$$

$$K = \frac{P}{y} = \frac{3EI}{L^3}$$

$$I = \frac{\pi R^4}{4}$$

$$f(natual) = \frac{1}{2\pi}\sqrt{\frac{K}{m}}$$

$$m = \pi R^2 L \rho$$

$$f(natual) = \frac{1}{2\pi}\sqrt{\frac{3ER^2}{4L^4\rho}}$$

Assume:
E = 50 GPa, R = 1 µm, L = 200 µm
ρ = 7300 kg/m^3

f(natural)= 9022 Hz
>> 2000 Hz used in the vibration test

Summary and Conclusion

- Among ~200 whiskers of 100 – 200 µm length and 2– 5 µm diameter, only 1 or 2 whiskers were missing, and a few whiskers were bent after 3 shock tests at 1500 g.
- No missing or shape change were observed during subsequent 30 min vibration at 20 g with random frequency of 20 to 2000 hz, and 30 min wind blowing at 400 ft/min.
- Maximum stress in a 200 µm long 2 µm diameter whisker during a 1500 g shock test is estimated to be 8 MPa, less than a polycrystalline Sn yield stress of 20 MPa. The yield stress of a single crystal Sn may be higher.
- The results from this study indicate that it is unlikely that whiskers would break off in typical service conditions.