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Surface Structure Effects of Sn electrodeposits on the Sn Whisker Growth

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May 31, 2005

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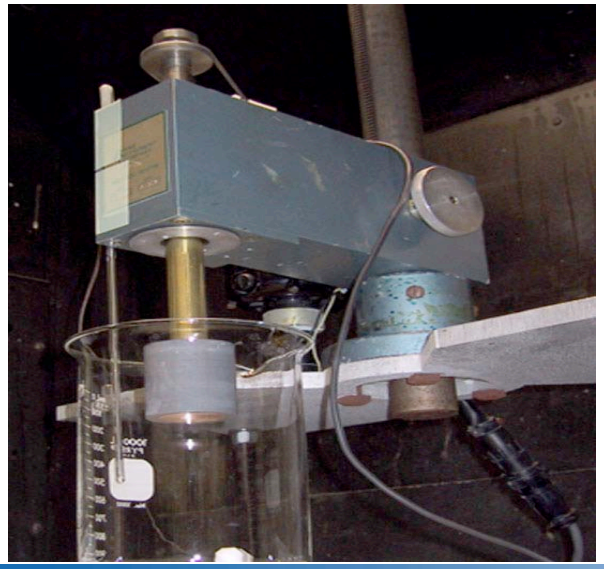
- **Crystallographic orientation of Sn electrodeposits & hillocks - EBSD**
- **Examination of the effect of Sn oxide on whisker growth - Auger and SEM analyses**

Experiments: EBSD and Auger

- **Objectives**
  - Preferred orientation of Sn deposit (EBSD)
  - Growth direction of hillocks on Sn deposit (EBSD)
  - Sn surface oxide film effect on whisker growth (Auger & SEM)
- **Samples**
  - EBSD: Sn on phosphor bronze cantilever beam (16 µm thick)
  - Auger: Sn-3wt%Cu on pyrophosphate copper coupon (15 µm thick)

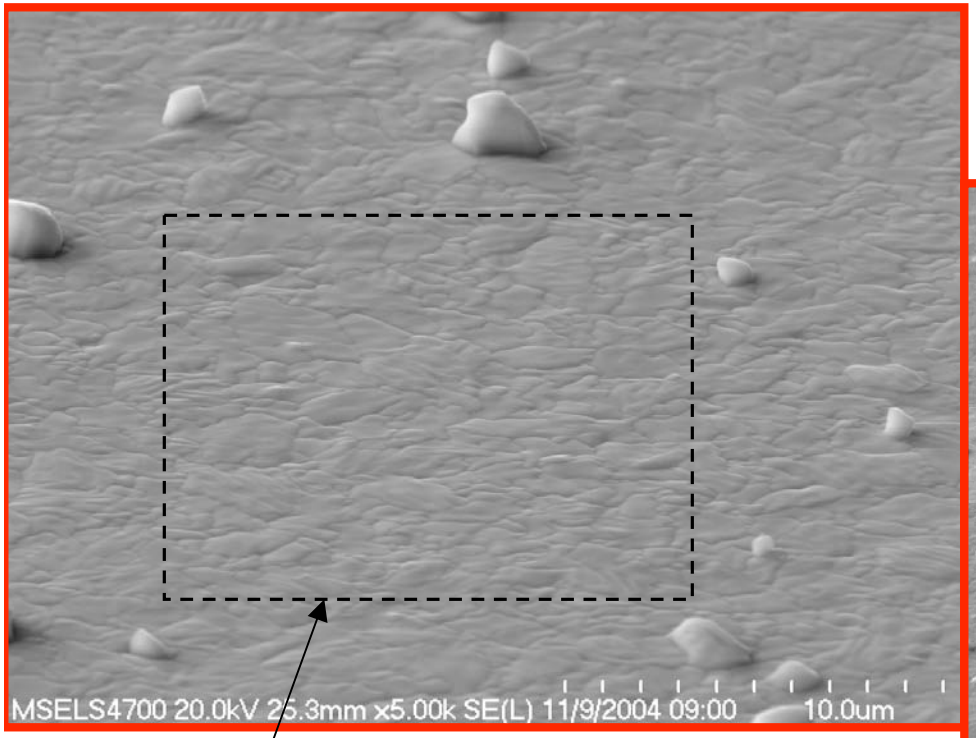


- **Plating Conditions**
  - Commercial bright methanesulfonate (MSA) with D/I water (18.3 MΩ-cm)
  - For Sn-Cu alloy, 953 mg/L of Cu^{+2} methanesulfonate added
  - Current density 60 mA/cm^2 @ 25 ºC
  - 100 rpm rotating cathode
  - 99.999% Sn sheet anode

Crystallographic Orientation of Sn deposits & Hillocks

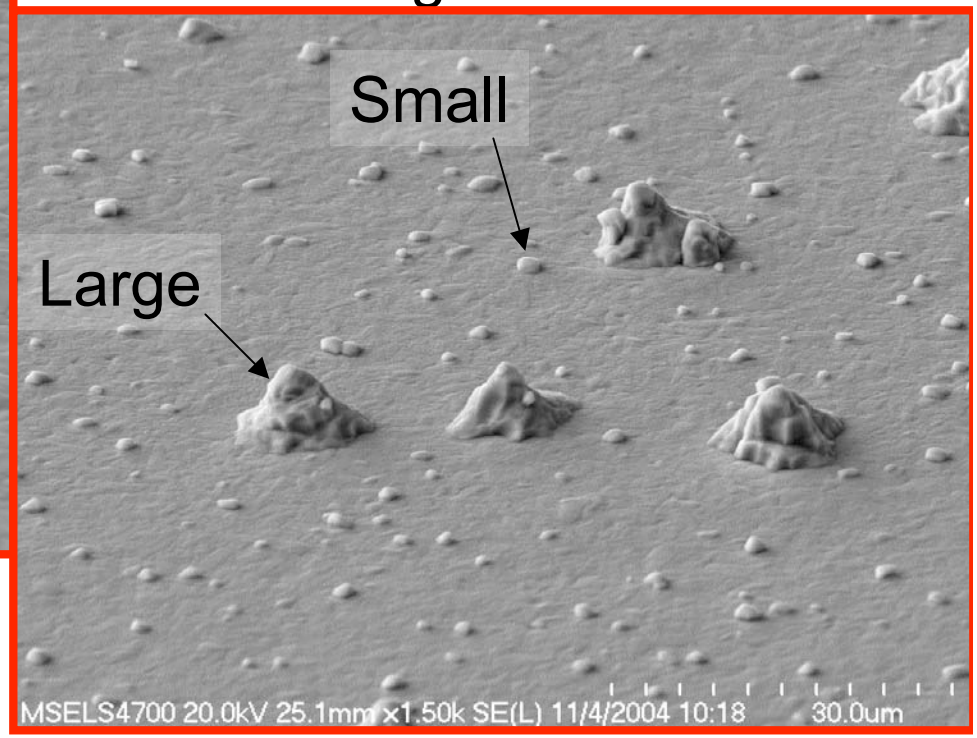
Crystallographic Orientation

16 µm pure Sn on phosphor bronze cantilever beam

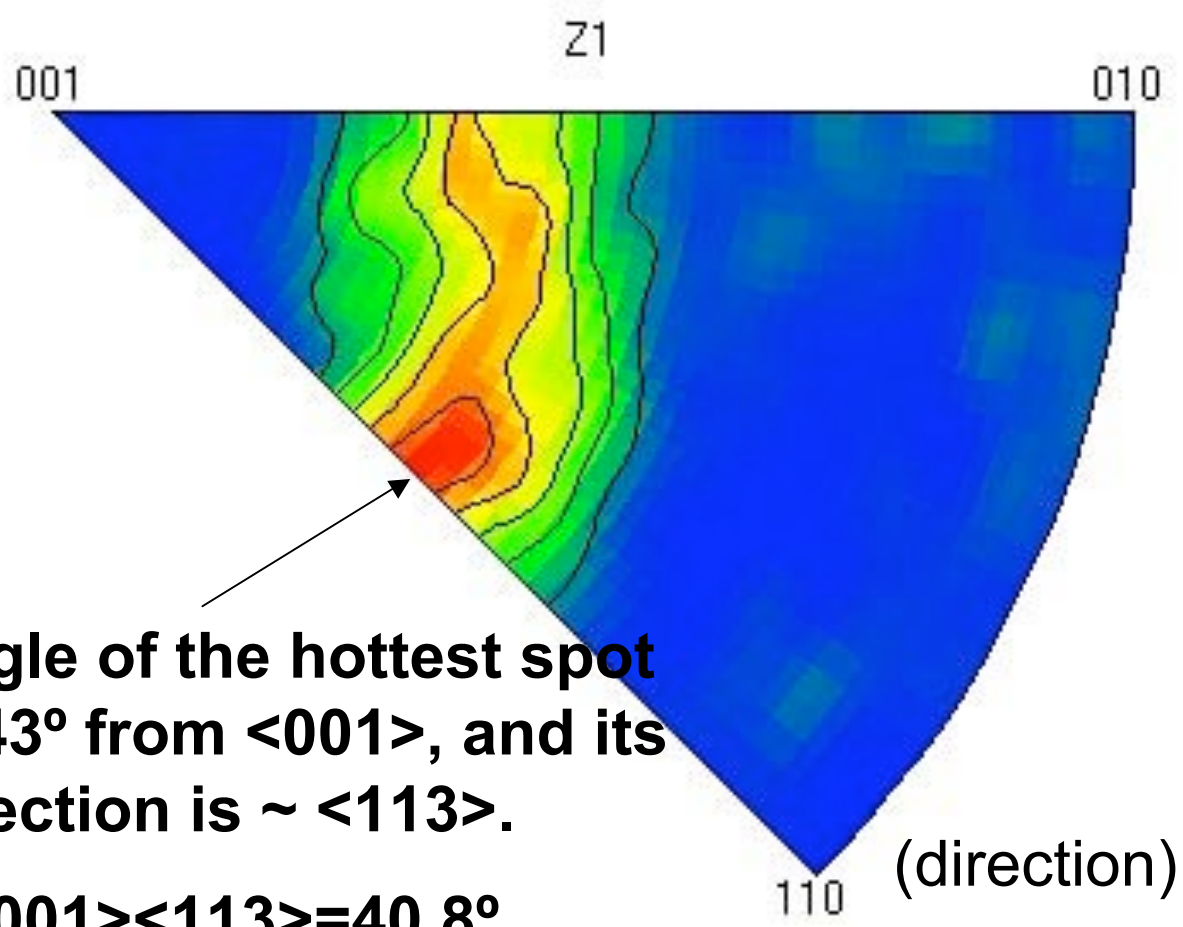


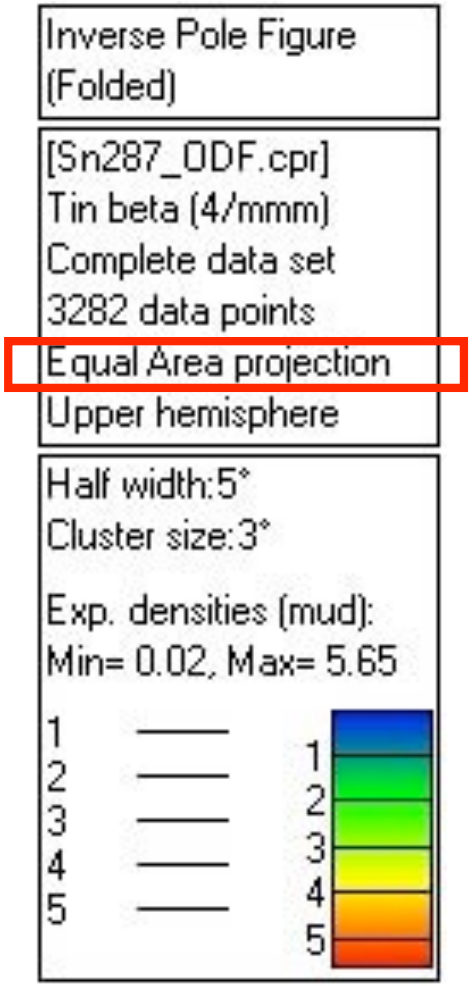
A measured area for grain orientations: 3 places

Bimodal distribution of Hillocks: growth direction of small & large measured



Preferred orientation growth direction <hkl>



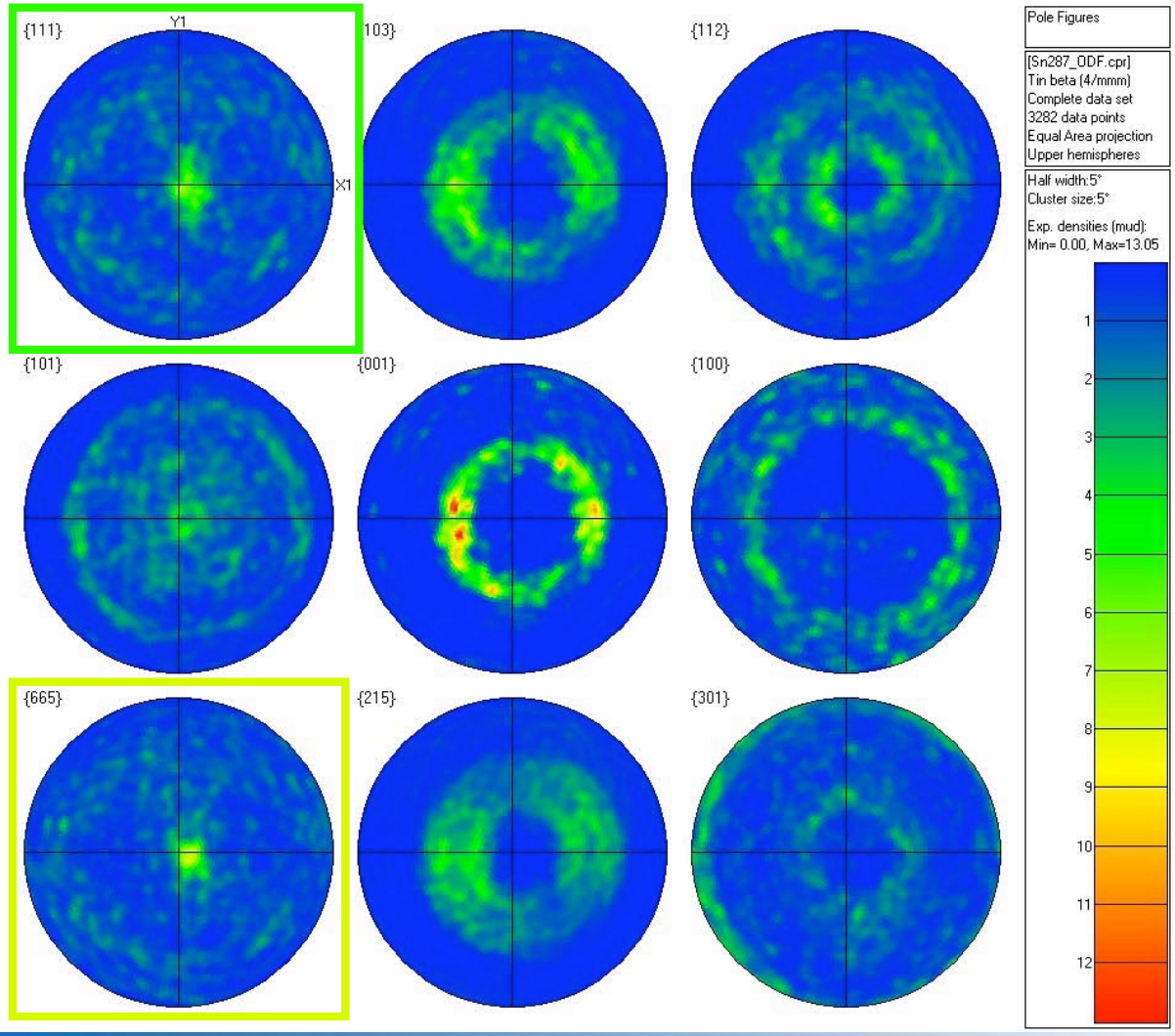


Angle of the hottest spot is 43º from <001>, and its direction is ~ <113>.

∠<001><113>=40.8º

Z1: normal direction to the sample surface

Preferred orientation plane (hkl)



Sn(665) and Sn(111) planes show the most preferred orientation.

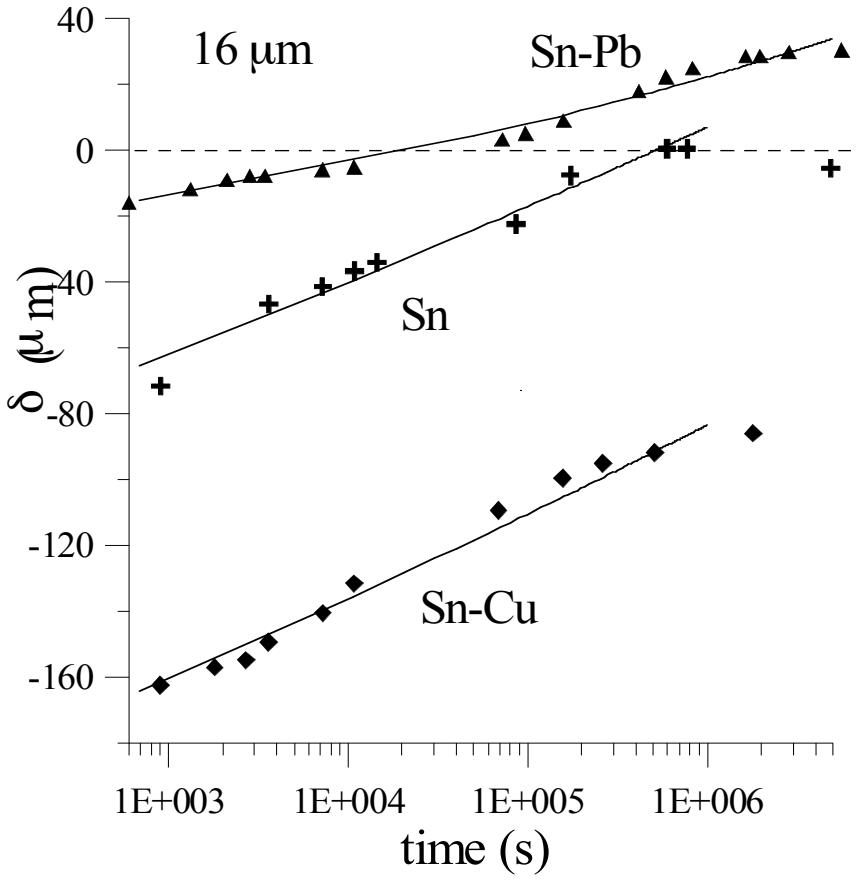
∠(665)(001)=42.8º

∠(111)(001)=37.7º

*** (665)⊥<113>**

Crystallographic Orientation of Sn Deposit

16 µm thick Sn and Sn alloy cantilever beam tests



Bright Sn and Sn alloy electrodeposits show instantly compressive stress after deposition, and they release their stresses as a function of time by localized Nabarro-Herring-Coble creep.

i.e., compressed during deposition

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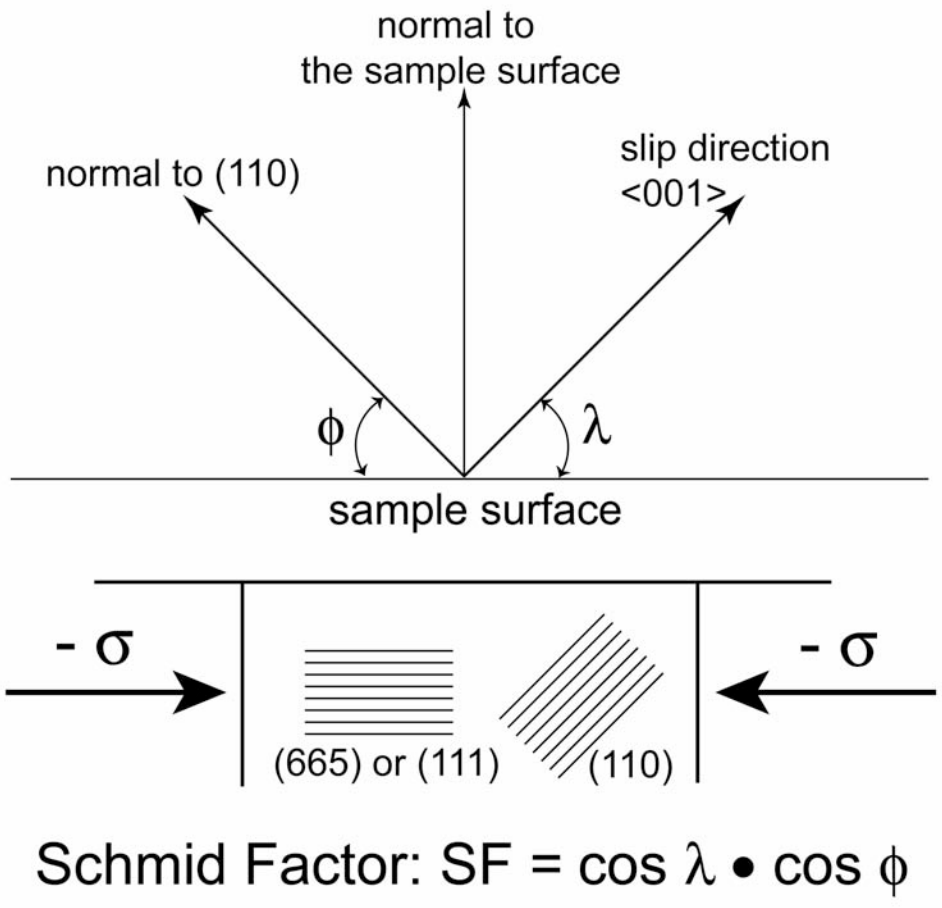
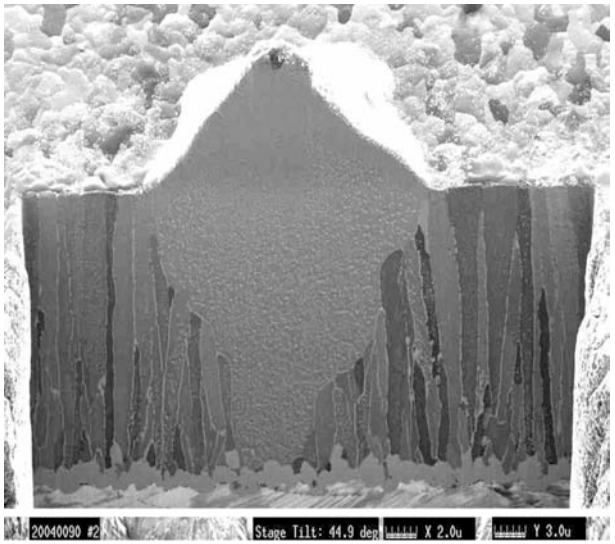
Crystallographic Orientation of Sn Deposit

Bright Sn deposits may grow as a texture in order to reduce strain energy by slip from a high stress level of bright Sn deposition at 25 ºC that is 0.59 T/Tm of Sn.

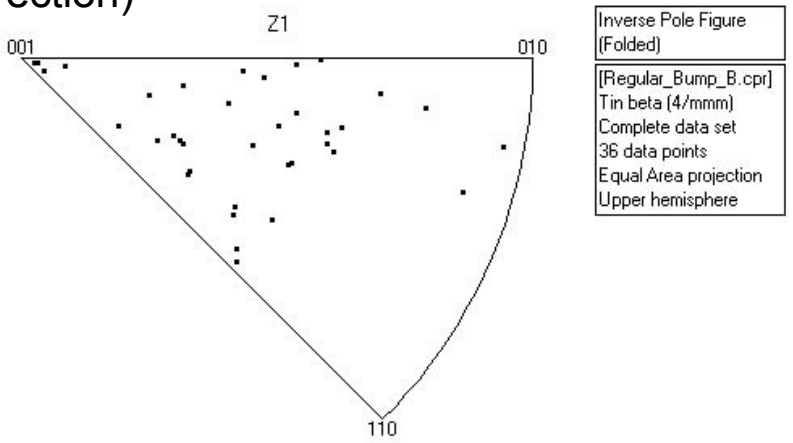


- **Primary slip system of Sn: (110)<001> @ R.T.** (E.Schimid and W.Boas, *Plasticity of Crystals*, Chapman and Hall LTD., London, (1968))
- **Observed orientation has very easy slip since these preferred orientations have a high number of the Schmid factor. (SF_{max} = 0.5)**
- **For example,**
  - **For Sn(665), ϕ= 42.8º; λ = 47.2º; and SF = 0.49**
  - **For Sn(111), ϕ= 37.7º; λ = 52.3º; and SF = 0.48**

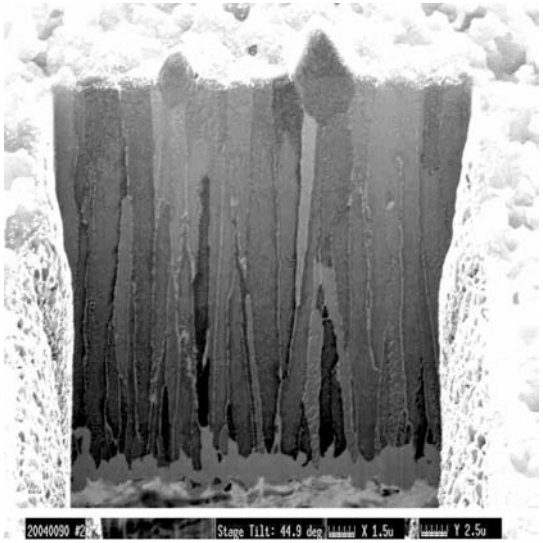
Hillock Orientation of Sn Deposit



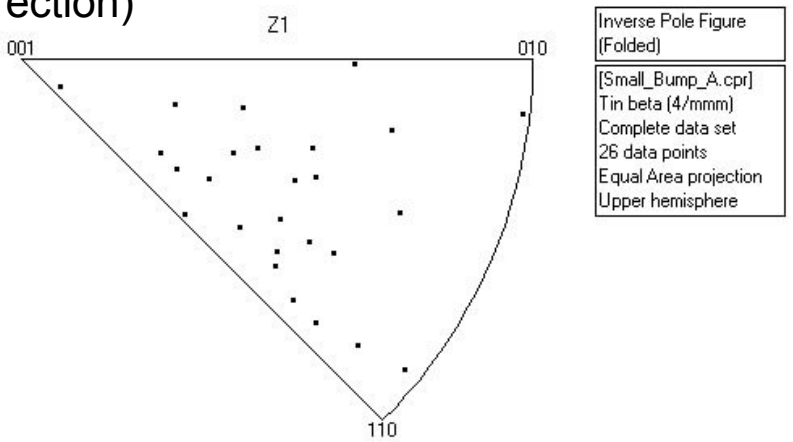
(direction)



Large hillock: ~ 15 µm



(direction)

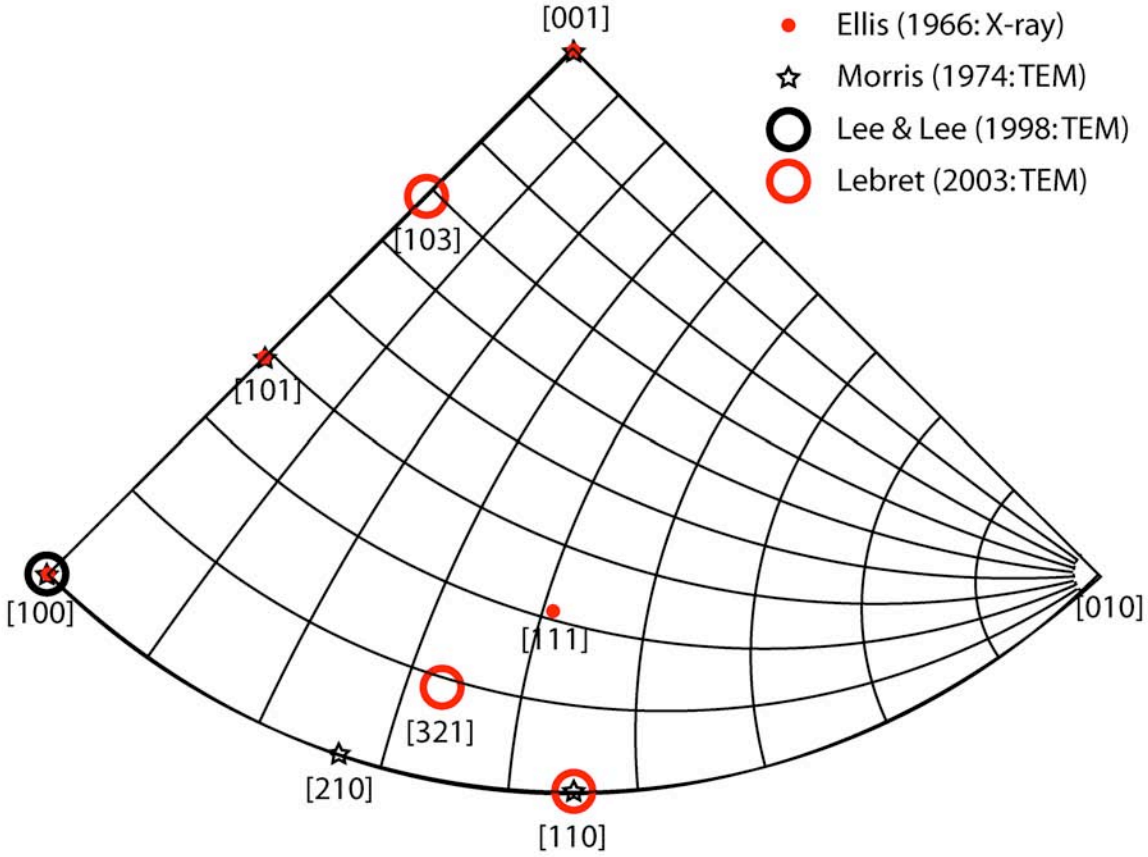


Small hillock: ~ 2 µm

Courtesy: G. Galyon and L. Palmer, IBM

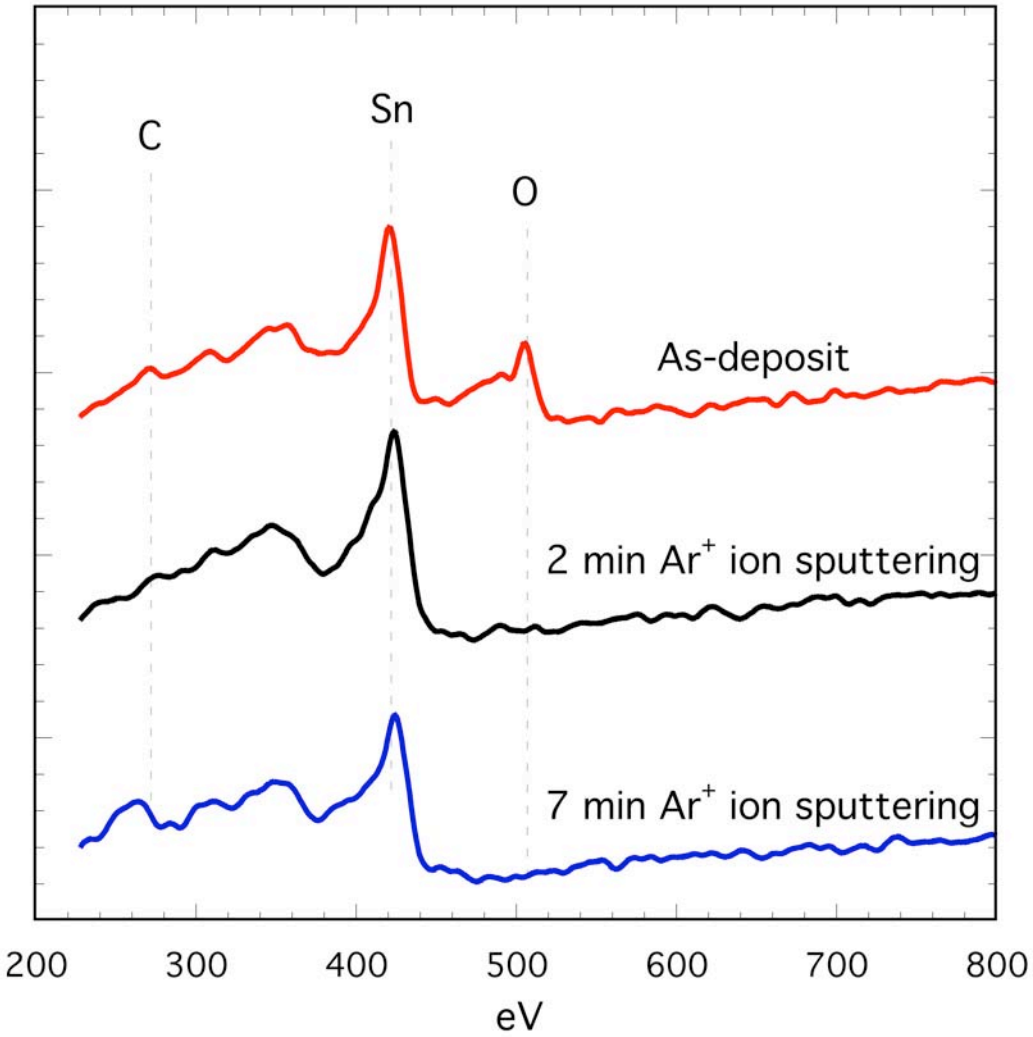
Hillock Orientation of Sn Deposit

Sn deposits show a strong texture; nevertheless, hillock growth direction is scattered, which agrees with widely varied reports of whisker growth direction.



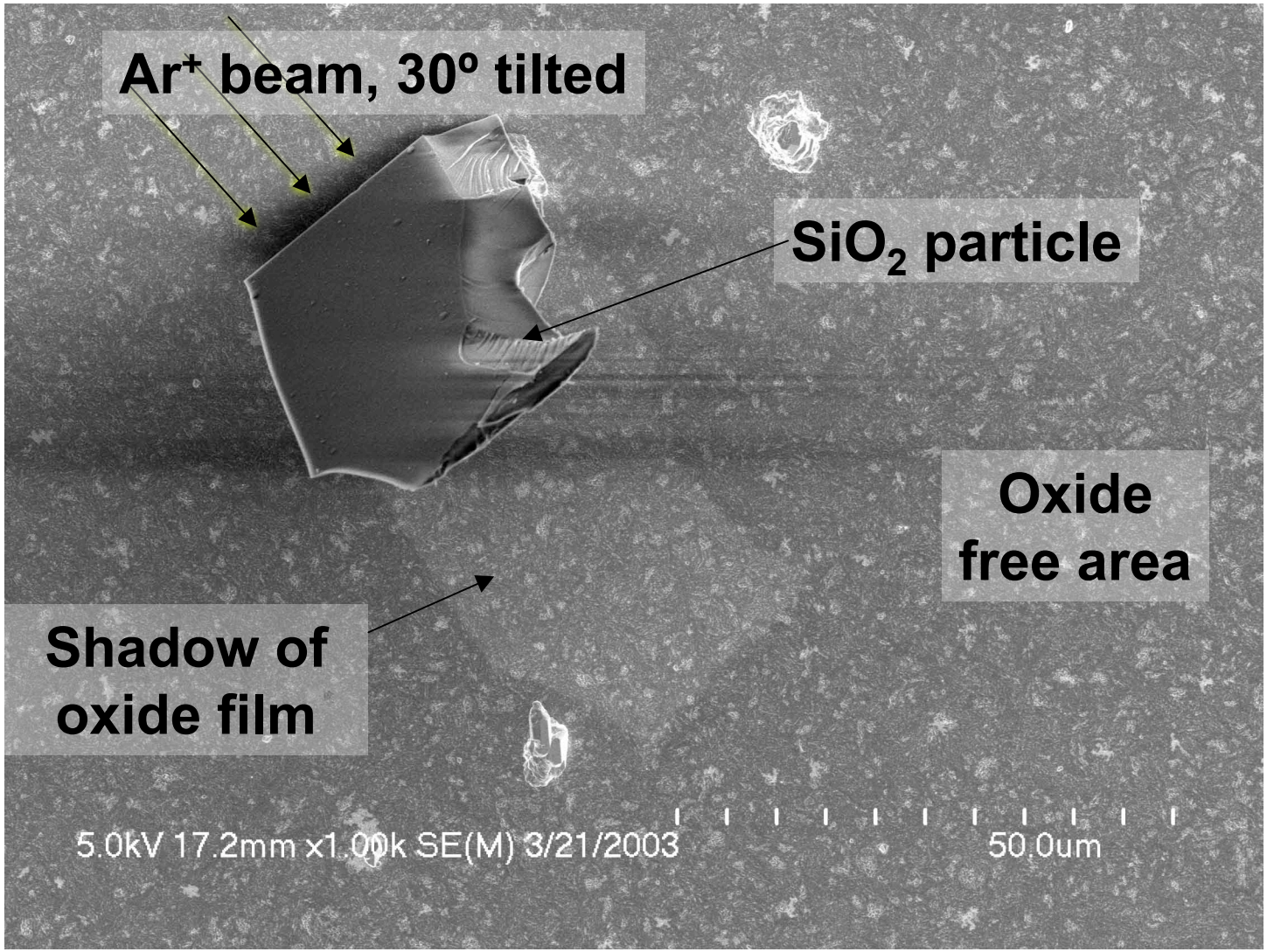
Effect of the Surface Oxide Film on Whisker Growth: Sn-3wt%Cu Deposit

Sn Oxide Film: Auger Analysis

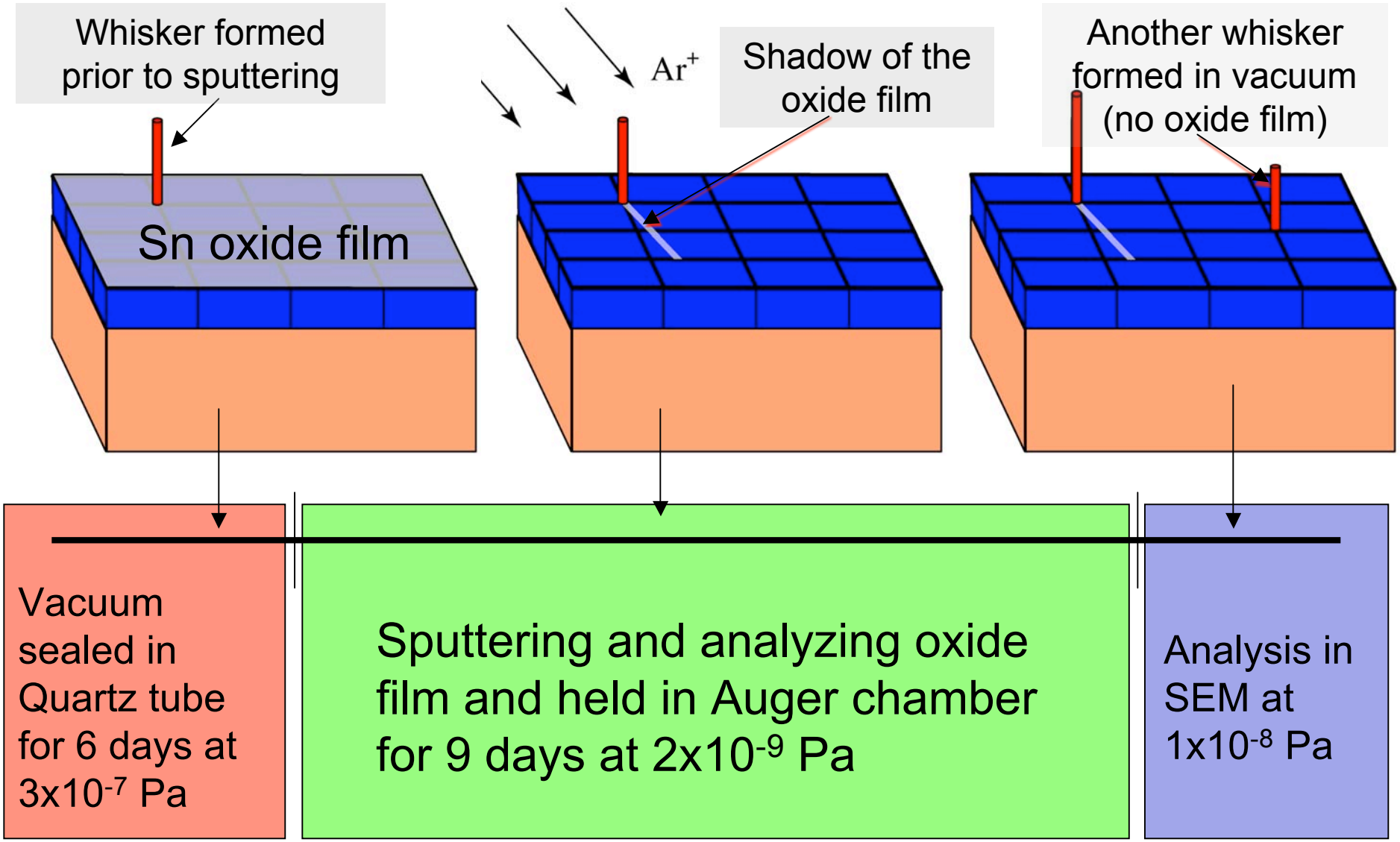


- **Plated and sealed in a quartz tube with an ultra high vacuum $3x10^{-7}$ Pa before Auger analysis.**
- **After 7 min of Ar^+ sputtering, Sn oxide surface film was eliminated successfully.**

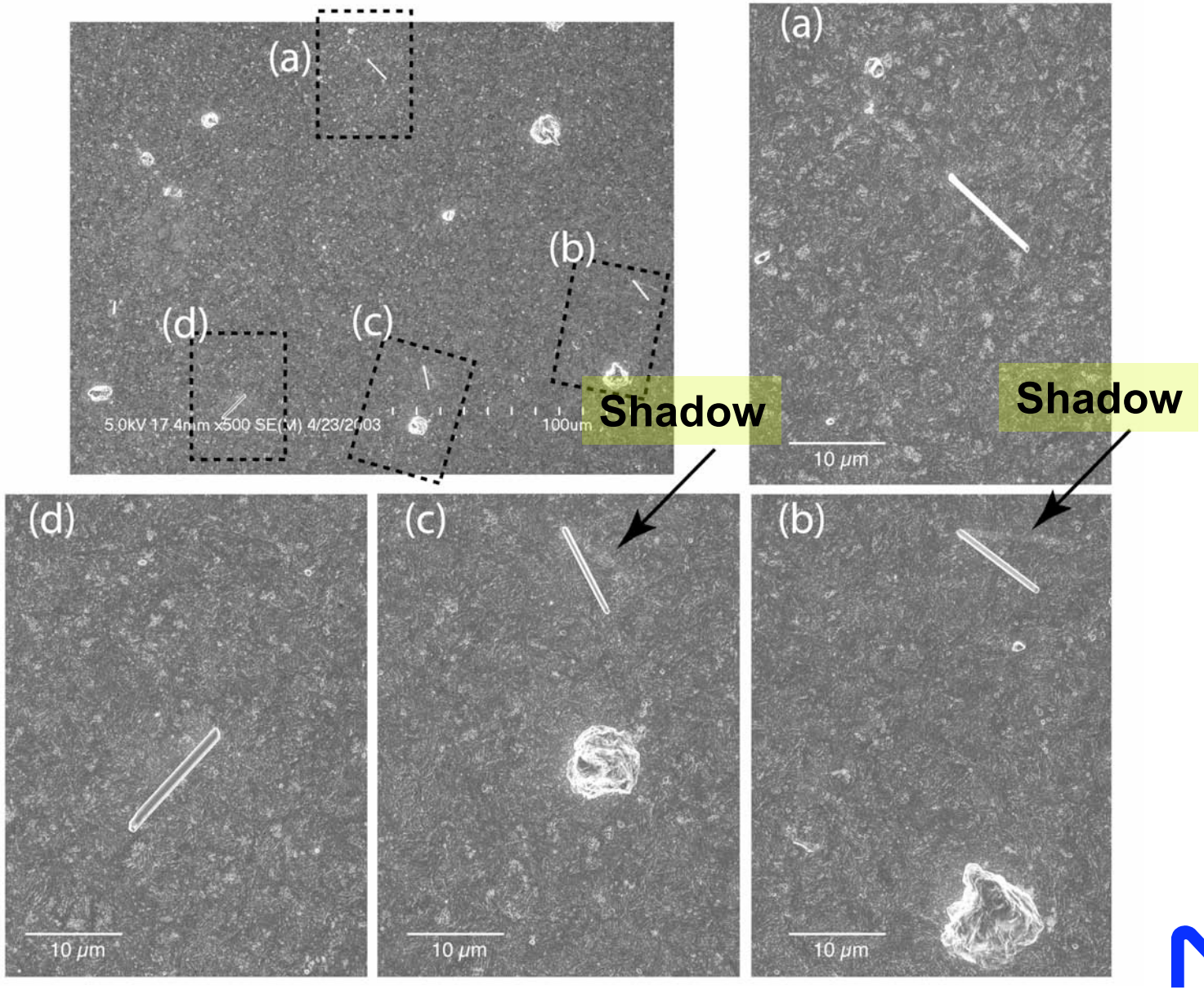
Shadow of oxide remains after sputtering



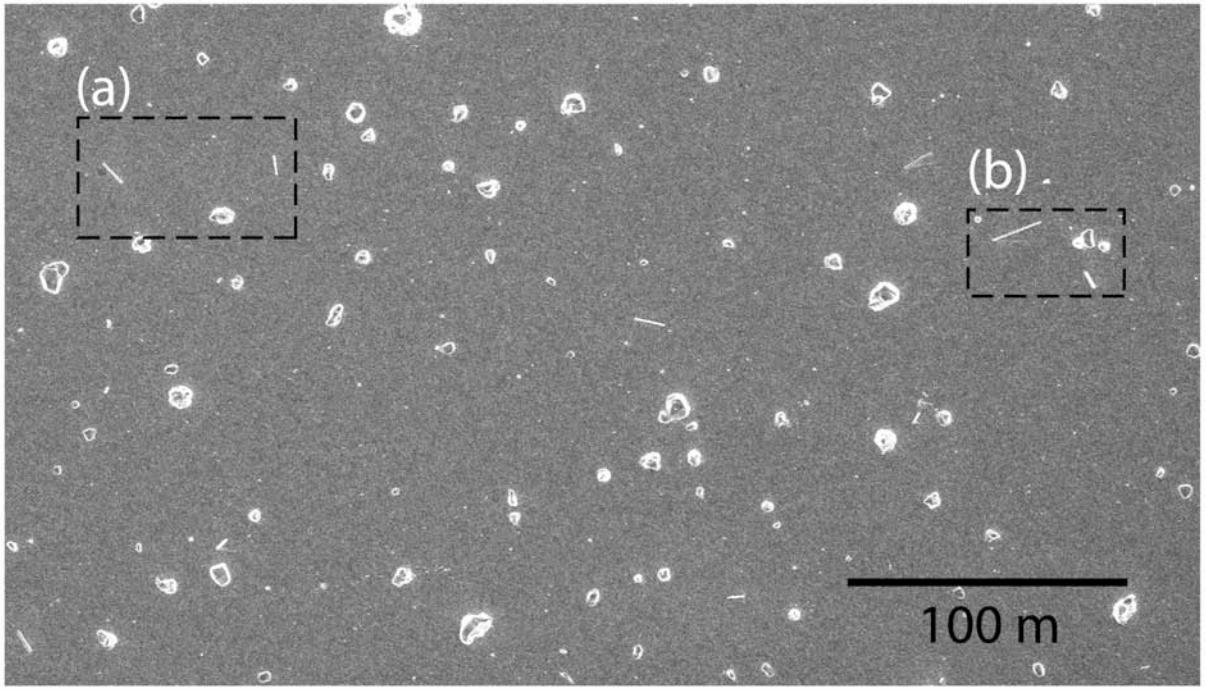
Sn Oxide Film: Test Schedule



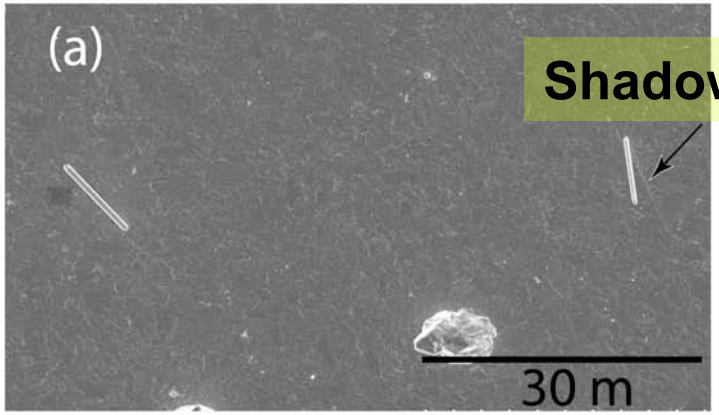
Sn Oxide Film: Result 1

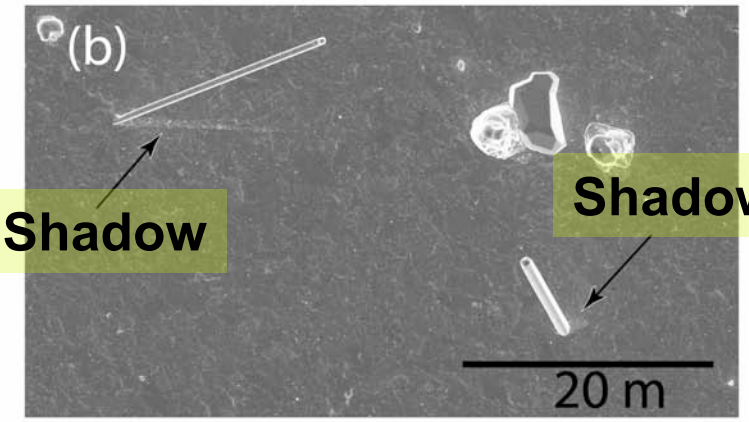


Sn Oxide Film: Result 2



Sn whiskers are growing even after removing the Sn oxide film, which implies that there is little influence of oxide film





Conclusions

- Base on EBSD analysis of bright Sn electrodeposits on phosphor bronze cantilever beams, deposit growth direction is <113>, and preferred orientations of grains are (665) and (111). This result may be a response to reduce strain energy by easy slip to a high stress level during bright Sn deposition. Nevertheless, hillocks show a scattered growth direction regardless of a strong textured deposit.
- In order to test the effect of Sn surface oxide film on Sn whisker growth, Sn-3 wt%Cu alloy on pyrophosphate copper was analyzed by Auger & SEM. Sn whiskers grow even after removing the oxide film, which implies that there is little influence of the oxide film on whisker growth.