Abstract to be submitted to the IUVSTA 15th International Vacuum Congress/ AVS 48th International Symposium/ 11th International Congress on Solid Surfaces October 29-November 2, 2001 San Francisco, California

Decay characteristics of surface nanostructures: (100) vs (111) surfaces[1]

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The stability of nanostructures after their creation is a critical issue for nanotechnology. Here we study the fundamental mechanisms of atomic scale mass transport on surfaces with regard to the instability of surface nanostructures. Pyramidal mounds were created on Cu(100) and (111) surfaces at 297 K by molecular beam deposition of Cu atoms. The stability of the nanoscale mounds was then observed with a scanning tunneling microscope for up to 24 hours. Movies produced from sequential scans show that the mounds are unstable and the decay process is profoundly different for the (100) and (111) surfaces. Decay of the (100) mounds proceeds with removal of atoms from the base of the mounds and subsequent transport to the bottom of pyramidal holes with the result that the mound walls become steeper with time. In contrast, the (111) mound decay is characterized by loss of atoms on all terrace levels producing a constant average slope. The mechanism for the decay on both surfaces at 297 K involves the diffusion of islands or terraces by periphery diffusion [2] to an edge where a rapid decay [3] or avalanche process may take place. Direct observation shows that this avalanche process is site selective on the (100) surface, but is not selective on the (111) surface. Kinetic Monte Carlo simulations [4] at 400 K show that the observed behavior is a consequence of selective vs. non-selective edge diffusion barriers and does not depend on the mechanism by which atoms are delivered to the edge.

1 Supported in part by the U.S. DOE through contract DE-AC05-00OR22725 with UT-Battelle, LLC, and in part by the NSF of China.

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Oral Session: SS19, Clusters and Nanostructures