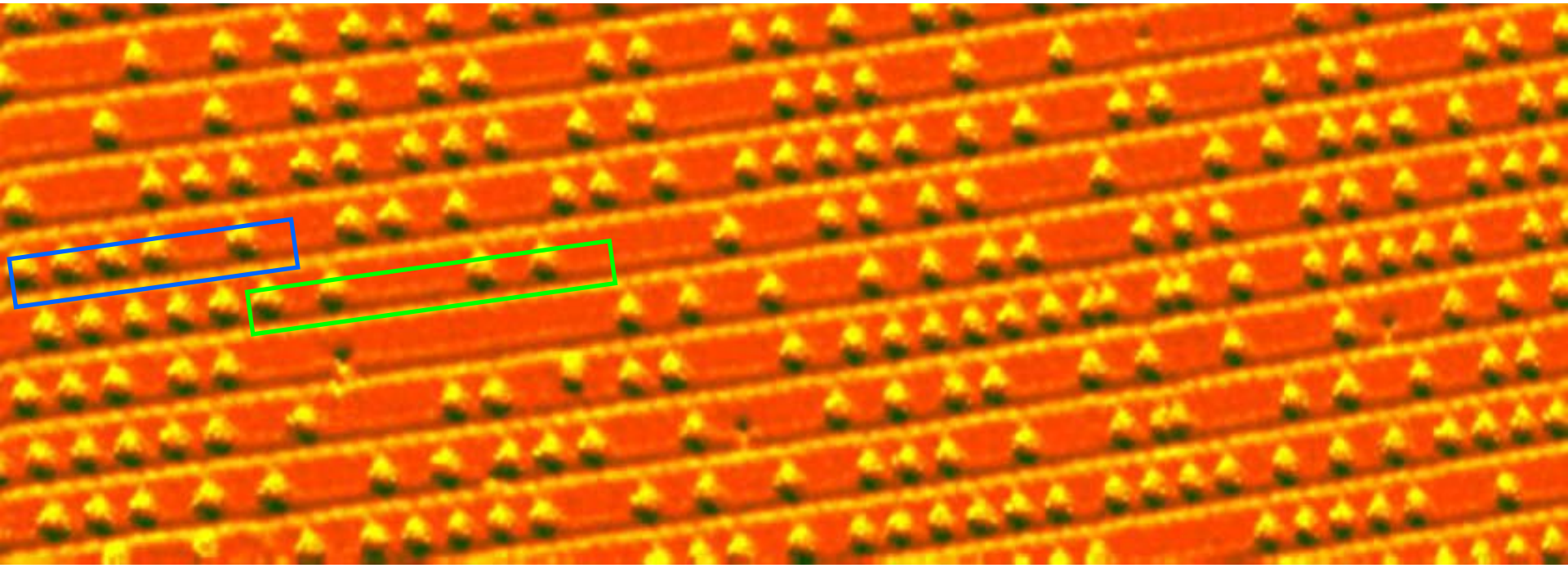
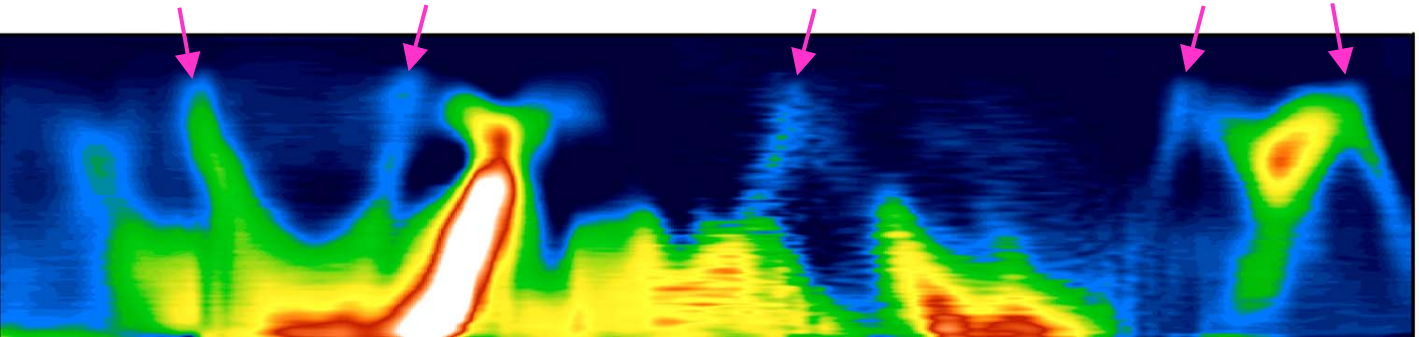
Understanding Self-Assembly of Silicon Atoms

F. J. Himpsel, University of Wisconsin Madison, DMR-0240937



- Atom chains with extra Si atoms on top. Used for an atomic scale memory.
- They form filled and empty sections. Why not evenly distributed ?
- Electrons determine the atom spacing, and extra atoms provide the electrons.



Jessica McChesney

This project is aimed at pushing silicon technology all the way to the atomic limit. We have built a memory where extra silicon atoms deposited on a silicon wafer store the bits, with the presence of an extra atom representing a 1, and the absence a 0 (see previous NSF nugget). There is a particular silicon surface where the atoms arrange themselves into tracks that are exactly 1.7 nm = 5 atom rows apart (strings of small yellow dots in this image). The extra atoms (large dots with shadows) occupy only half of the available sites, which matches the fact that one uses about equal numbers of 1 and 0 bits in data storage.

We want to find out why the silicon atoms form this particular pattren, and how we can steer them into arranging themselves into useful pattern by self-assembly. In collaboration with theorists (mainly Steven Erwin at the Naval Research Lab) we have found out that the chains are triggered by adding metal atoms to the surface (here 2/5 of a monolayer of gold atoms), which lead to the formation of pi-bonded ribbons of silicon (honeycomb chains). The fact that the extra silicon atoms occupy only half of the available sites is due to the electrons at the Fermi level (pink arrows), which are measured using synchrotron radiation at the SRC in Madison. They dictate a spacing of 4 lattice constants beteen the atoms (obtained from the spacing between the pink arrows). On the other hand, the density of extra atoms required for the optimum electron density corresponds to an average space of 8 lattice constans. That forces the atoms to leave empty spaces.

Pushing Silicon Technology to the Atomic Limit

Moore's Law ...

1.7 nanometer track

250 Terabit / inch^2

Year 2038