Some novel uses for three-dimensional data from SPM and stereo SEM

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Conversion of pictures, taken in or from more than one direction, into augmented reality settings and three dimensional models is something that even smartphones do these days. In addition, computerized data on three dimensional structures is increasingly possible to move in the other direction i.e. to be printed as physical objects of whatever size one prefers. Scanning probe microscope images, and scanning electron images taken from more than one direction, are especially promising sources of topographic information to take advantage of these technologies.

In this presentation we want to mention two promising areas, namely the use of SEM data to provide quantitative information on object *mass densities* given an independent way (like the quartz fishpole balance [1-3]) for weighing picogram-sized and larger objects, and the use of both SEM and SPM data to provide researchers and students with physical macroscopic models of microworld and nanoworld structures, accessible for tactile as well as visual examination “first hand”.

The simplest part of this story involves scanning probe microscope images, because “height” images taken with an atomic force or scanning tunneling microscope are already three-dimensional topographic maps, in some cases with sub-Angstrom vertical resolution, which can be directly printed into three-dimensions. We do this by converting the images, with e.g Mathematica, into STL files. The STL files are then translated into print instructions e.g. by Makerbot or other 3D printer software. SPM images will work well with 3D printers because they often build objects with the sort of scanning tip raster used by an SPM to take data. The main disadvantage, of course, is that the image is convolved with the SPM tip’s point-spread-function, which may have time-domain components (associated with the feedback loop’s response) as well as spatial components associated with an unknown tip shape [4].

Scanning electron microscopes instead use an electron probe, whose shape is likely smaller and more predictable than an SPM tip’s shape. They are also able to examine more “convoluted” structures, like free standing particles. The caveat is that information on topography is available only indirectly, e.g. by inferring it from the lateral displacement of recognizable points in images taken from two, three, or many directions [5-7]. In addition, of course, the tilt range of SEM stages may be limited, and remounting of specimens for a wider range of views may be easier said than done.

That said, the incentives to make routine this type of 3D data acquisition have increased. In addition to the value of being able to print macroscopic versions of microscopic and nanoscopic objects for use with everyday senses not requiring an “electron physics” interpretation, there are also aspects of three-dimensional metrology that deserve mention.

In particular, consider the fact that the volume and surface area data available from 3D models allow one to connect microscopic observations to macroscopic properties, like surface area per gram or grams per cubic centimeter. In particular, if one knows the density of an object being examined then a volume measurement allows one to determine each object’s mass. Conversely if one can weigh a small object, like the few-micron sized interplanetary dust particles discussed here [8], then one can determine its density. As mentioned above and in references [1-3], direct measurements of small-object mass in the picogram and up range require surprisingly little in the way of advanced technology.

References:

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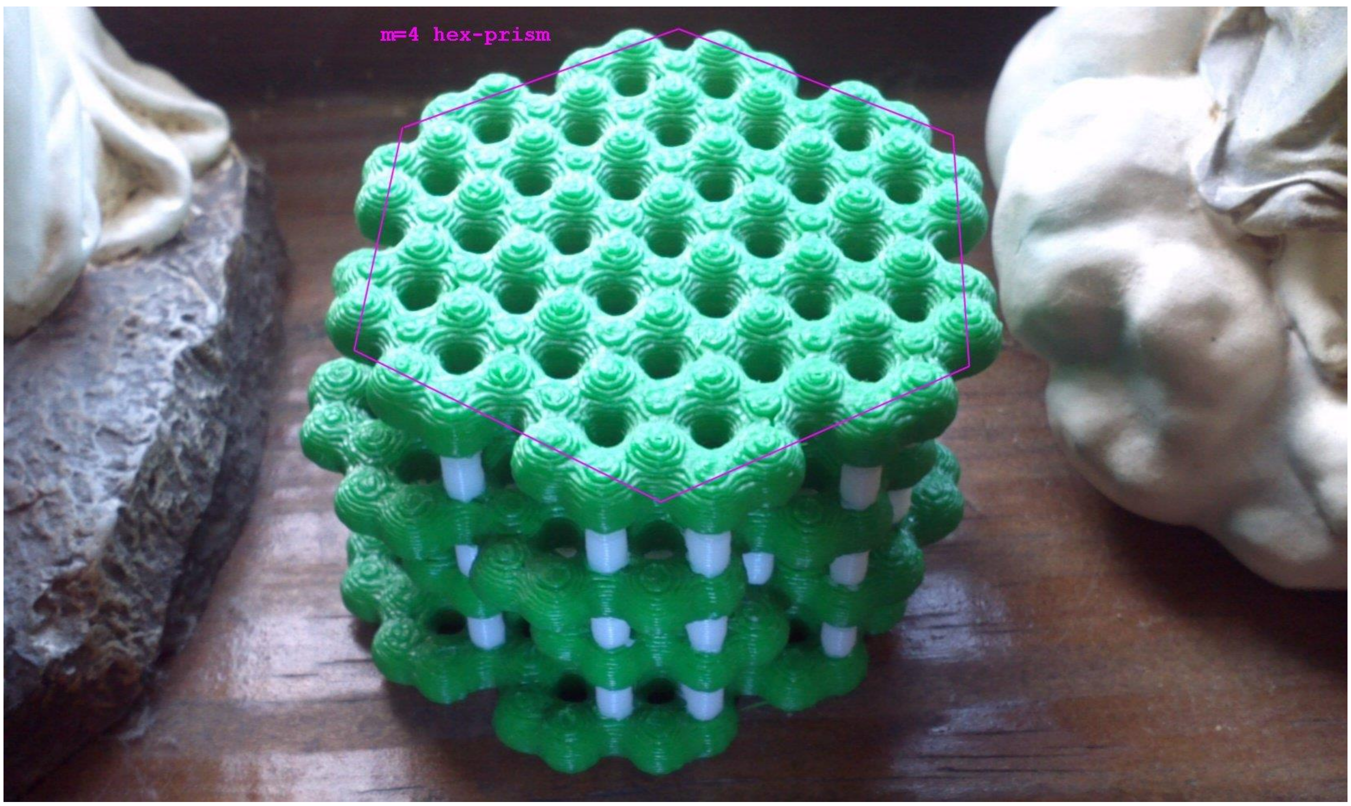

Figure 1. Print of a graphite molecular model at the 1 Angstrom = 3 millimeters scale. One can easily imagine 3D printed versions of the nanometer-high steps into an alpha recoil pit in HF etched mica, or dimer row steps only 1.3 Angstroms high on a super flat silicon wafer even before one begins to deposit individual molecules for examination.