NANOTECHNOLOGY THROUGH SELF-ASSEMBLY OF CLUSTERS

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Atomic clusters have, for many years, been extensively studied because of the wide range of fascinating new physics and chemistry that is observed in such nanoscale systems. The possibility that clusters could be used as nanoscale building blocks for devices has, however, met with relatively little recognition. The majority of the effort in this area has previously been devoted to the production of new materials based on clusters, and device possibilities are little explored. Clusters can be conveniently made in a size range (100nm to 0.5nm) that spans the gulf between current lithographic fabrication technologies for integrated circuits and molecular electronics. What has limited their utility has been a lack of suitable processes for forming useful device structures. The achievement of *contacted* electronic devices, which are *self-assembled* from atomic clusters, is therefore the focus of this paper.

The key requirements for a nanotechnology based on clusters are:

- Cluster preparation methods which yield a wide variety of cluster materials in a useful size range, and which are able to take advantage of novel structures and properties [1].
- Suitable cluster deposition apparatus, including size selection with efficiencies necessary to achieve high deposition rates.
- Self-assembly methods which avoid time consuming positioning of building blocks.
- Lithography processes which are compatible with both cluster deposition technology and standard microelectronics fabrication protocols.
- Understanding of basic physical assembly processes in order to predict and control device formation, including availability of suitable computer simulations.

In this paper we discuss simple techniques which satisfy these requirements.

We have now demonstrated two different methods of formation of contacted cluster chains / nanowires, based on percolation theory [2] and surface templating [3]. Crucially, both technologies result in nanowires that are self-contacting and where electrical current can be passed through the wire as soon as it is formed. The smallest widths achieved are below 50nm, i.e. ~1/100th the dimension of the smallest lithographic features used. The templating technique relies on bouncing of energetic incident clusters to the apex of a V-groove [4]. Nanowires have been previously demonstrated by many groups to be effective components in devices ranging from chemical sensors to transistors. The example of cluster-assembled hydrogen sensors will be used to illustrate the applicability of cluster-assembled wires.

Cluster diffusion on flat surfaces is both a potential mechanism for building devices and a potential limitation on the placement of clusters in those devices. We therefore report on the assembly of compact and highly ramified islands, as well as unusual rectangular nanorods [5] and describe the detailed aggregation mechanisms responsible for these structures, as well as methods for control of the type of structure that is achieved.

Finally, molecular dynamics simulations will be discussed which allow an understanding of some of the key basic processes in cluster assembly. Simulations of cluster coalescence [6]

and of cluster bouncing will be highlighted.

References:

[1] M. Kaufmann, A Wurl, J. G. Partridge and S. A. Brown. Eur. Phys. J. D, in press.

[2] J. Schmelzer jr, S. A. Brown, A. Wurl, M. Hyslop, and R. J. Blaikie, Phys. Rev. Lett. **88**, 226802 (2002).

[3] J. Partridge, S. Scott, A. D. F. Dunbar, M. Schulze, S. A. Brown, A. Wurl, and R. Blaikie, IEEE Transactions on Nanotechnology **3**, 61 (2004).

[4] J. G. Partridge, S. A. Brown, A. D. F. Dunbar, M. Kaufmann, S. Scott, M. Schulze, R. Reichel, C. Seigert and R. Blaikie, Nanotechnology **15**, 1382 (2004)..

[5] S. Scott, S. A. Brown and M. Kral, to be published.

[6] S. Hendy, S. A. Brown and M. Hyslop, Phys. Rev. B. **68**, 241403(R) (2003).

Figures:

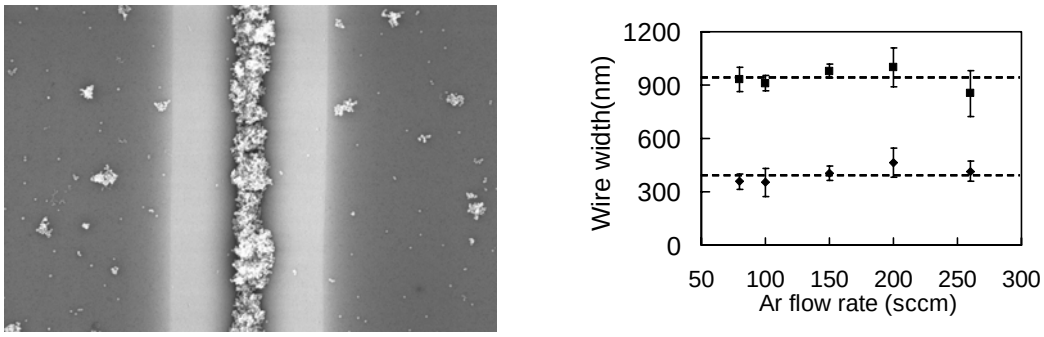

Figure 1. (left) Sb cluster assembled wire in a 2µm wide silicon dioxide coated silicon V-groove and (right) cluster wire width as a function of the cluster velocity, which is controlled by the source inlet argon flow rate, showing that the process is uniform and controllable.

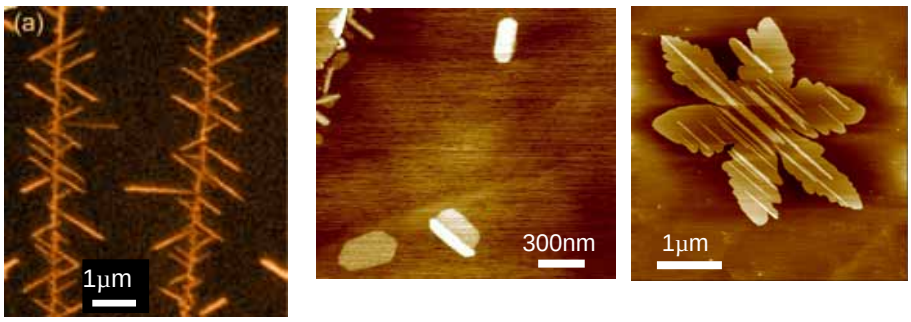

Figure 2. Example AFM images of nanorods and different island types that can be achieved by controlling diffusion limited aggregation of Bi_2 clusters.

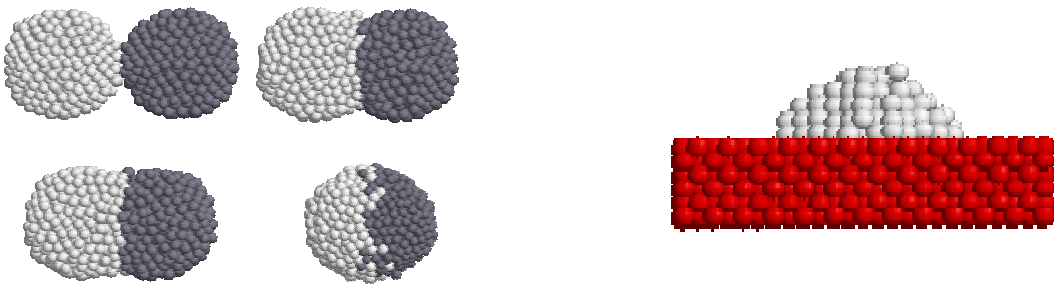

Figure 3. Left: Molecular dynamics simulation of cluster coalescence. Right: MD simulation of the wetting of a surface by a cluster.