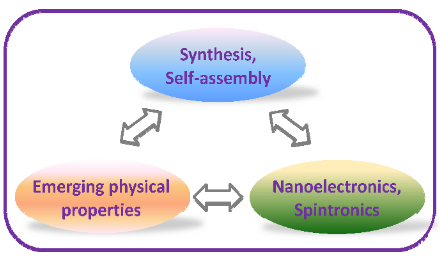
Emerging Nanoscale Oxides and Silicides: towards Next-generation Electronic and Spintronic Devices

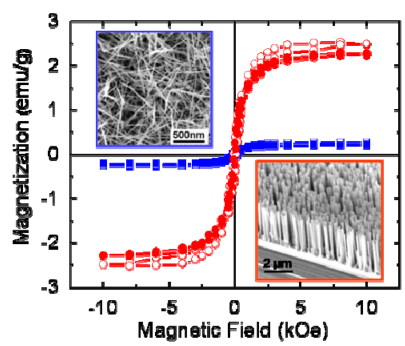
Tom Wu

Semiconductor roadmap finally is reaching its end. Transforming new physics into alternative technologies will help us to reap substantial economic rewards in the future. In the context of sustainable technologies, our research focus on emerging oxides, where the strong correlation between charge, spin, orbital and lattice produces rich spectra of physical properties*, i.e.,* ferromagnetism, ferroelectricity, superconductivity, just to name a few; they adapt to many technologies even beyond electronics, such as catalytic, mechanical, optical, acoustical, *etc*. Our grand aim is to reveal the synergy between novel synthesis and advanced charge/spin-based device applications, both rooted in emerging collective phenomena in fundamental condensed matter physics.



Functionality-oriented synthesis has moved beyond the era of serendipity and successes in the past encourage high-risk high-return research. State-of-the-art chemical/physical synthesis techniques, such as pulsed laser deposition and vapor transport growth, allow us to study a wide range of materials in the forms of bulk, thin film, nanowire, and their composites. In thin film growth, substrate-induced strain leads to coexistence of multiple electronic/magnetic phases in manganites and the associated charge/spin dynamics manifests in novel transport behaviors such as negative differential resistance and nonvolatile memory switching. Nanosynthesis presents new challenges/ opportunities: vapor supersaturation and dynamic oxidization create highly nonequilibrium growth, leading to myriad of morphologies, crystalline structure, chemical doping, and eventually physical properties. For example, decoration of minimal amount of Ti onto the surfaces of SnO_2 triggers the morphology transformation from ultrathin nanowires to ultrawide nanobelts and Cr doping/ oxygen vacancies produce bright visible luminescence in silica nanospheres.

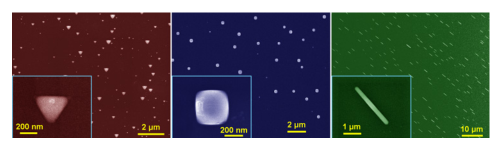
Our synthetic concepts involve not only exploring nano-confined low dimensional structures, but also the control of structural/ chemical disorder, taking advantage of the competition between short-range and long-range orderings. In particular examples of wide-band-gap oxides, Cu-doped ZnO and Cr-doped In_2O_3, diluted magnetism emerges from nonmagnetic constituents, and the ferromagnetism correlates strongly with the structural inhomogeneity and oxygen deficiency, indicating dominant polaronic interaction and subsequent percolation. Such nanoscale components from bottom up with tunable magnetic properties may find applications in advanced spintronics.



Structure/property correlation: in Cu-doped ZnO nanowires, compared with the conventional homogeneous growth, annealing a ZnO core/Cu shell structure leads to significantly enhanced room-temperature ferromagnetism.

Self assembly bridges the nanoscale synthesis and device fabrication through substrate engineering and epitaxial growth. For instance, nanoscale Cu_3Si has been grown on Si wafers through a template-free Au-nanoparticle-assisted vapor transport method. It was observed that their shape and morphology are well controlled by the substrate orientation. Such guided synthesis may help to construct next-generation nanoelectronic devices. In another effort, wurtzite ZnO nanowires were grown on perovskite manganites and basic *p-n* junctions were achieved.

"Digital synthesis" with atomic precision is prerequisite to investigate the proximity effect between materials with controlled charge/spin/strain redistribution. The emerging metallic interface between polar/ nonpolar insulating oxides is a serendipitous breakthrough to note. Extended to nanoscale confined oxides and silicides, realization of emerging physics is highly rewarding, and assisted by self assembly, the novel properties in transport, magnetic, thermodynamic properties will lead to the development of high-performance devices.



Self-assembled synthesis: nanoscale Cu_3Si triangles, squares, and wires were grown on Si (111), (100), and (110) substrates, respectively. The sides of nanotriangles and nanosquares and the growth direction of the nanowires are all along Si <110>, giving rise to long range ordering of the nanostructures.

Dr. Tom Wu is an assistant professor in the Division of Physics and Applied Physics. He obtained B. S. from Zhejiang University and Ph. D. from University of Maryland, College Park. After a three-year stint as a postdoctoral scientist in Argonne National Laboratory in Chicago, he joined Nanyang Technological University in July 2006.

Email: tomwu@ntu.edu.sg;
Web: http://www1.spms.ntu.edu.sg/~tomwu/index.htm

Relevant publications:

1. G. Z. Xing *et al.,* Adv. Mater. 20, 3521(2008);
2. Z. Zhang *et al.,* Nano Lett. 8, 3205(2008);
3. X. Wang *et al.,* Nano Lett. 8, 2643(2008);
4. Z. Zhang *et al.,* Appl. Phys. Lett. 92, 103113(2008);
5. G. P. Li, *et al.* Appl. Phys. Lett. 92, 173104(2008);
6. Z. Zhang *et al.,* Nanotechnology 2009 (in print);
7. G. Z. Xing, *et al.* Phys. Rev. B 2009 (in print);
8. D. Wang *et al.,* J. Phys. Chem. C 2009 (in print)