Nanotechnology: Where are the error bars?

We recently published a paper in Physical Review B dealing with the magnetoresistance properties of 50-nm ferromagnetic/organic/ferromagnetic junctions. During the review stage, my colleague (Supriyo Bandyopadhyay from Virginia Commonwealth University) and I had to answer the following concern of one reviewer: "How repeatable are the results?" This forced us to investigate as many as 90 samples, which fortunately showed the same qualitative behavior, much to the delight of both the reviewer and us. However, the magnitude of the effect varied from sample to sample. The point of bringing this up here is that there is often very little concern for repeatability. Many papers in the nanoscience and nanotechnology areas would selectively report results observed only in "lucky" samples. It is perfectly fine to report the best result, as long as one presents "error bars" showing the range of results over a reasonably large sample space. We all know that nanostructures are not exactly reproducible and therefore there will be a spread in results, with large error bars. It is important to know those error bars since they tell us what kind of error correction schemes would be required if we were to make large scale systems from many nanodevices. If the error bars are too large, then perhaps we cannot make any large scale system out of the products. That would save us both grief and embarrassment in the long run.

The last thing the nanotechnology community needs is hype that blows into a bubble that ultimately bursts, causing a debacle. This brings me back to the title of this newsletter, a plea for error bars in any publication reporting the next groundbreaking discovery in the field of nanotechnology. It is rather difficult to show an error bar when the measurement has been confirmed on one sample only and, hopefully, that is not what people imply when they do not even mention anything about the number of samples which were measured. We were recently sensitized to this through our experience. Measuring 90 samples at liquid helium temperature cost a lot of money and lot of time (over 6 months), but in the end we were satisfied and proud. Theorists are not exempt from this message. Anyone involved with modeling at the nanoscale knows very well how sensitive the results are to the parameters of the nanoscale structures and/or devices. Thus, there are error bars in theoretical results as well since the parameters used in the model have their own error bars. The best validation of a model is to test it against exhaustive measurements with well displayed error bars. Only then can we hope that nanotechnology will offer the great promises which are always listed at the end of every paper.

Do not get me wrong. I am not trying to pontificate and I am all for nanotechnology. Besides, I was not without sin when I decided to cast this stone. Nanotechnology is a very exciting field and we are very lucky to live at a time when it is booming. However, there is no point building a sandcastle and not worrying about the tidal waves. By reporting the experimental error bars and the sensitivity of theoretical predictions to the variation of parameters, we will be able to better assess and establish the foundations of the field, and move forward on firm grounds.

As always, I have updated the various links with new entries but I also added a new topic to my list where I plan to give a list of the nanocenters which are popping up all over the world. Of course, my list is far from exhaustive. I hope you will have come this far in this newsletter to quickly check that I forgot that important center you belong to. If so, let me know ASAP about it (send me an email at marc.cahay@uc.edu) so I can add it to the list. When this list starts getting pretty long (like around 100 entries) I will try to catalog the centers by using some kind of scheme, most likely by country and by alphabetical order. The idea for adding this new link came about after receiving many requests from students to know Who's Who is a specific field in the nanoscience and nanotechnology areas. This is a very positive note on which to finish this newsletter. Young people are getting on the Nanotrain!

I would like to finish this newsletter with a few words from Wen J. Li, who is co-chairing the IEEE Nano2007 meeting in Hong-Kong: "More than 470 papers were submitted online to this 7th annual conference of the IEEE Nanotechnology Council. The Technical Program will consist of 30 regular sessions of oral presentations, 20 Plenary Keynote Speakers, and many other worldclass researcher as Session Invited Speakers spanning over 10 Invited Sessions on advanced topics of Nanotechnology.
We accepted a total of 408 papers, including Invited Session papers.
Some key areas covered by the conference include Novel Nano-material Synthesis, NEMS and Nano Sensors, Nano-Bio Fludics, Nano/Molecular Electronics and Devices, Nano-material Metrology and Characterization,
Nano Tube, Wires, and Particles, AFM-based Nanorobotics, Spintronics, and Molecular/Quantum Computing".

I hope to see many of you in Hong Kong for IEEE Nano2007. I am not looking forward to the long hours on the plane but my wife told me that electronics is pretty cheap over there and she would REALLY appreciate one of those cheap digital camera and Ipod. I will comply! ☺

By the way, if you come to Hong-Kong, don't forget to bring your error bars!

Sincerely yours,
Marc Cahay

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