QUANTUM STATES

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QUANTUM DESIGN:

SPOTLIGHT ON DR. ADO UMEZAWA, APPLICATIONS PHYSICIST

As Senior Applications Physicist for Quantum Design, Dr. Ado Umezawa is helping customers develop new measurement techniques and to understand and interpret their data. He is also helping Quantum Design define new products which reflect a clear understanding of customer's needs.

Customers who call Quantum Design for applications-related support will find Dr. Umezawa to be knowledgeable in physics, materials science, and cryogenics as well as measurement techniques. He earned B.Sc., M.Sc., and Ph.D. degrees in physics from the University of Alberta under Professor Stuart Woods. For his master's degree, he studied magnetization of UPt$_3$, a heavy fermion superconductor. From 1986 to 1991, he conducted his Ph.D. research on magnetic anisotropy of YBa$_2$Cu$_3$O$_7$ as a member of Dr. George Crabtree's group in the Materials Science Division of Argonne National Laboratory. From 1991 until 1993, he focused on electromagnetic characterization of (BiPb)$_2$Sr$_2$Ca$_2$Cu$_3$O$_x$ silver-sheathed tapes as a post-doctoral fellow in Professor David Larbalestier's group at the Applied Superconductivity Center of the University of Wisconsin. He is author or co-author of over 50 publications in *Applied Physics Letters, Physica C, Physical Review B*, and other journals.

A main focus for Dr. Umezawa is increasing communication between Quantum Design and its customers. Through direct interaction with the applications science team and the sales and customer service departments, he facilitates the exchange of information between the two groups, provides technical and application data for sales and support literature, creates applications notes and white papers and coordinates the development of tutorial applications literature written by experts in the scientific community. He also provides technical support to the sales and service departments on a daily basis. Dr. Umezawa comments, "As Quantum Design's product lines become more complex and vast, and as the company continues to cater to a greater range of customers, the requirements for good customer communications will become increasingly important and more difficult. We must continue to improve the strong customer-company relationship that Quantum Design has provided in the past."

"With respect to new equipment," Dr. Umezawa said, "my first priority is to help Quantum Design decide how to expand the PPMS product line. The Physical Property Measurement System was designed as a multipurpose temperature and magnetic field platform. QD will also offer a variety of plug-in modules designed for specific experiments. My job is to understand our customers' needs well enough to determine which modules we should offer and what specifications they should meet."

Dr. Umezawa reports that the transition from researcher to applications physicist has been remarkably easy. "As a researcher for 10 years, I had to understand a lot about measurement and instrumentation, but I was mostly interested in the science. At Quantum Design, I have to understand a lot about the science, but I'm mostly interested in the measurement techniques and instrumentation. It's a subtle change. The major difference is that Quantum Design is helping me learn a new set of skills and develop a new understanding of the role of marketing in building a strong and successful business. For now, I just hope my participation in the company will benefit our customers."

■

IN THIS ISSUE

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THERMAL–WAVE–SUSCEPTOMETRY & CONTACTLESS MAGNETOCALORIMETRY USING THE SAMPLE ILLUMINATION SYSTEM FOR THE MPMS

The investigation of atomic thin magnetic layers epitaxially grown on thick nonmagnetic substrates requires an enhanced sensitivity and measurement dynamics to separate the magnetic response of the layer from that of the substrate. Conventional susceptometry cannot distinguish between both signals, even if the diamagnetic contribution of the substrate is the dominant one. The method suffers from mechanical instabilities which cannot be avoided during the sample's movement through the pick-up coil of the SQUID-fluxtransformer, and the detection bandwidth is rather broad from DC up to the preselected cut-off frequency of the low-pass filter.

The Sample Illumination System (SIS) developed for the MPMS of QD offers an unique opportunity to escape from these problems. Applying the novel method of **thermal-wave susceptometry [1]**, the sample is rigidly located within a fiberoptic quartz-rod and rests at the pick-up coil position. A fiber bundle transmits near-ultraviolet light onto the top-face of the epitaxial layer of the sample. The light absorbed within the thin layer produces a heat-source near the surface, which excites – due to the chopped light - thermal waves. The thermal diffusion length (and consequently the decay depth of thermal excitations) is much longer than the overall thickness of the crystalline sample (being essentially the transparent substrate). Thus the thermal properties of the substrate and of the surrounding helium contact gas (which controls the average temperature) determine the oscillation amplitude ΔT(ω) of the thermal wave. In the case of *optically thick*, but *thermally thin* samples as described, the profile of the oscillating temperature is very homogeneous over the sample cross-section and *independent* on the thermal and magnetic properties of the epitaxial layer itself. Equation 1 gives an expression for the temperature amplitude:

$$\Delta T(\omega) = \frac{1}{2\kappa_H\sigma_H + k_s\sigma_s^2 d_s}\,\frac{I_0(\omega)}{2} \qquad \textbf{(1)}$$

H-, S-indices label the thermal parameters of the helium contact-gas (at reduced pressure) and of the substrate material. κ_i are the heat-conductivities, and σ_i depend on the heat-capacities c_v, mass densities ρ as well as on the frequency ω of the chopped illuminating light intensity $I_0(\omega)$, as given by Equation 2:

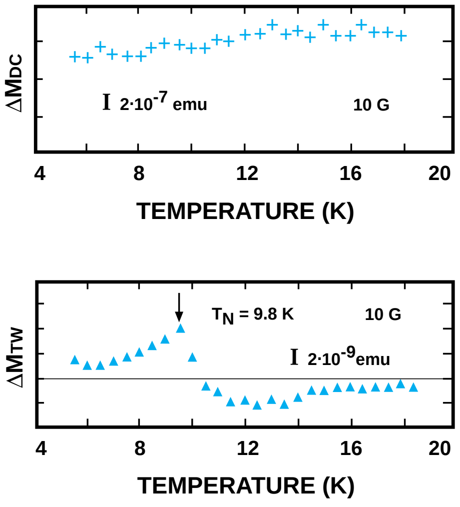
$$\sigma(\omega) = (1 + i)\sqrt{\frac{c_v\,\rho\omega}{2\kappa}} \qquad \textbf{(2)}$$

The thermal waves are phase-shifted with respect to the impinging chopped light, as inferred from the complex prefactor (1+i). The magnetization of the epitaxial thin film is commonly temperature-dependent. Thus it becomes modulated by the temperature wave (Equation 3):

$$\Delta M = \frac{\partial M}{\partial T}\,\Delta T(\omega) = \left[\frac{\partial M_S}{\partial T} + \frac{\partial M_L}{\partial T}\right]\Delta T(\omega) \qquad \textbf{(3)}$$

For *diamagnetic* substrates (S) the first part in the brackets vanishes, thus the thermal-wave-modulated magnetization ΔM arises entirely from the layer (L) alone. *Thus the method is selective for registering thin magnetic layers.* The signal-to-noise ratio can also be drastically enhanced if lock-in detection and narrow electronic filtering are applied.

FIGURE 1



Upper Panel: *Standard DC magnetization at H=10 G of a 2.5 µm EuTe-epitaxial layer on 0.65 mm BaF_2-substrate. The accuracy is reduced to $2 \cdot 10^{-7}$ emu due to the high diamagnetic background of the BaF_2.*

Lower panel: *Thermal-wave (TW) magnetization of the same sample. The accuracy is $<2 \cdot 10^{-9}$ emu due to the selectivity of the method to the epitaxial layer and due to the reduced electronic bandwidth of the lock-in detection. The antiferromagnetic phase-transisiton of the layer is clearly resolved.*

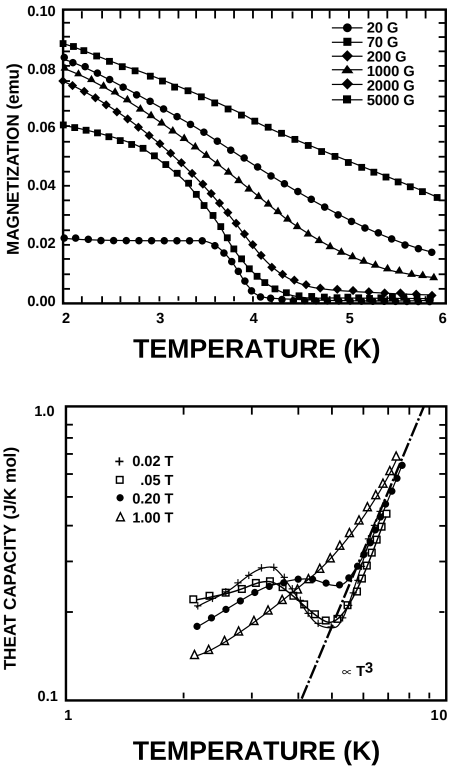
Figure 1 (upper panel) shows that conventional susceptometry at reduced fields ≈10 G cannot resolve any antiferromagnetic phase-transition of a 2.5µm epitaxial EuTe-layer on a rather thick diamagnetic BaF_2 insulating substrate (EuTe is a prototype of a magnetic semicondutor). Using thermal-wave-susceptometry this transition is clearly resolved at 9.8 K as shown on the lower panel of Figure 1. One estimates a sensitivity of <2e-9 emu. Ultimate sensitivities even far below 1e-9 emu are expected, dependent on the choice of experimental parameters (e.g., light intensity, thermal parameters, thinned substrates).

The validity of the thermal wave method can be experimentally proven by the characteristic frequency dependence of Equation 1 which is tranferred also to ΔM of Equation 3. If for higher frequencies the second part of the denominator of Equation 1 dominates, ΔT(ω) can be simplified. Inversion of Equation 3 and using the simplified expression for $\Delta T(\omega)$ yields (yet assuming a *bulk magnetic* sample S):

$$\Delta T(\omega) = \frac{\Delta M_s}{\frac{\partial M_s}{\partial T}} = \frac{1}{c_v \rho \omega d_s} + \frac{I_0(\omega)}{2} \qquad (4)$$

Apart from trivial parameters (ρ, d_s, ω, I_0) the heat capacity c_v of the sample S is left for evaluation (the heat conductivity κ cancels out). ΔM_s is the magnetization detected by thermal-wave-susceptometry, $\partial M_s/\partial T$ the numerically differentiated DC magnetization as measured by conventional susceptometry. (Note that *bulk* samples are investigated). Equation 4 can be solved for the unknown quantity c_v rather straightforwardly. The method to combine magnetization *and* heat-capacity gives us the opportunity to check the fundamental Maxwell's relations of equilibrium thermodynamics which connect; e.g., magnetic with calorimetric quantities. In disordered systems like spin-glasses these relations are often violated.

FIGURE 2



Upper Panel: *DC magnetization vs temperature of the* ***bulk*** *ferromagnetic disordered semiconductor* $Pb_{1-x-y}Mn_xSn_yTe$ *(x = 0.03, y = 0.72) for various magnetic fields. Note the decrease of the spontaneous magnetization with the magnetic field at T = 2 K.*

Lower Panel: *Molar specific heat of the same sample vs temperature, as determined by the thermal-wave-susceptometry for various magnetic fields. The* T^3*-dependence comes from the* ***non-magnetic*** *contribution of the crystal-lattice. The results are obtained by* ***contactless*** *measurements.*

Figure 2 gives an example of a ferromagnetic semiconductor $Pb_{1-x-y}Mn_xSn_yTe$ using the new concept of **contactless magnetocalorimetry**. The upper panel shows the DC magnetization $M_s(T)$ for various magnetic fields. The saturation magnetization at low temperature depends strongly on the field, thus the system reveals an intermixed state of a ferromagnet and a spin-glass, which is even more emphasized by the heat-capacity measurements shown on the lower panel of Figure 2. The plot demonstrates that not only the *magnetic* contribution to the heat capacity, but also the *nonmagnetic* one from the lattice ($\propto T^3$) is correctly reproduced. The phase-diagram of this disordered magnetic semiconductor can be extracted from such combined measurements of magnetization *and* heat capacity.

In summary, QD's MPMS combined with the Sample Illumination System (SIS) opens novel possibilities to measure magnetic and caloric properties of magnetic materials at an enhanced dynamic range and sensitivity. The method of thermal-wave-susceptometry is particularly suitable for investigations of ultrathin magnetic layers and layer-systems.

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PROFILE

INTERVIEW WITH:

DR. NEAL LANE

DIRECTOR

NATIONAL SCIENCE FOUNDATION

What does the future hold for the American scientific enterprise?

The future of science is bright. Science has always been important to the citizens of our country and to the advancement of our civilization, and it will continue to be. The public recognizes and values the good things that have come out of science and remains intrigued about the new discoveries and the mysteries that still remain. When I say science, I include mathematics and social sciences as well as the fundamental aspects of engineering.

We live in a time of change. During the Cold War, our overriding concern was the threat from the former Soviet Union, and we needed the knowledge and the technologies that came out of scientific research to stay ahead in the world and protect our citizens. With the end of the cold war, we are developing a new paradigm influenced by other needs of our society, such as environmental protection, civilian industrial productivity, jobs, health, and general concerns about human welfare. Our citizens have high expectations that science can help to solve the country's most important problems, and they are willing to seek the federal investment to make that happen. They will hold scientists, all of us, accountable for the results.

What resources will be available to scientists under this new paradigm?

For the near term, at least through 1998, budgets will be tight in all the discretionary sides of the ledger as we try to get the budget deficit under control. Within that flat discretionary budget, science will do relatively well, but it is not a time when one can expect the kind of growth we have seen in recent years.

What can scientists do to maximize the resources available to them?

We have to communicate better to the public the value of science, to explain how and why our work has a positive impact on people's lives. We haven't done as much of that in the past as may be necessary in the future.

How do you think scientists can convey that message?

Many professional societies representing different sectors of the scientific community are good at disseminating information. In many cases, their primary tasks have been to publish scientific information and to hold conferences where information is exchanged. These activities must continue; they have become an important part of the infrastructure of science in this country. In addition, professional societies have a great opportunity to translate the scientific opportunities and the great discoveries into language more appropriate for the larger public, and I think they need to do more of that.

At the same time, scientists simply need to get out into the wider community and interact with more people, so others can understand that scientists have the same concerns they do about the needs of society and are not only interested but also committed to doing what they can to help.

I also think scientists will have to look at what they are doing, and those who feel they can bring their own talents and capabilities to bear on problems of more immediate concern to society should consider doing that. This nation's scientists have a tremendous capability to help solve society's problems. Members of the scientific community could help our entire enterprise by looking hard at these problems and identifying ways in which science can do more than it is currently doing.

What are some key areas in which scientists can contribute?

The recent budget submissions to Congress list some high-priority areas that require the attention of more scientists, such as global climate change, environmental protection, and manufacturing. Advanced manufacturing technology has an important science base and a fundamental engineering base; both require more attention. Within the broad envelope of information and communication, there are a lot of fundamental research questions that require the attention of the best scientists in the country. Scientists who contribute in those areas will not only be doing interesting fundamental research but also helping to achieve some of society's major goals. I believe this is how the support of science will grow in future years, through the demonstration that science is indeed important to these strategic goals.

What will be the nation's policy regarding curiosity-driven science with no obvious relationship to strategic goals?

We should never stop investing in areas of science that have no immediate connection with strategic areas, because we never know where major discoveries will be made. We must maintain strong programs of basic science across all major fields. One of the administration's technology goals is world leadership in basic science, mathematics, and engineering. But within that goal of world leadership in all important fields of science and engineering, we will emphasize those areas that can be identified with strategic goals.

How will the United States identify its strategic goals?

We will establish the broad umbrella of national strategic goals through a political discussion in the best sense, in which representatives from all sectors of society participate to clarify the nation's most critical needs. The next step is to identify the science and engineering questions we must address to get the knowledge which is needed. These questions tend to be multidisciplinary, so we need scientists from several areas interacting and helping to define the research agenda. For example, the study of global climate change requires people with expertise in informations communications, high-performance computing and atmospheric chemistry. In summary, it takes a mix of potential users of the research outcome as well as researchers themselves to set the priorities. This approach is new in the science community, so we in Washington must make sure we have the right mechanisms to get the necessary advice, and members of the scientific community must be willing, as they always have been, to provide that advice.

What can universities do to prepare young scientists for this new environment?

Since many of the most interesting and important fundamental problems lie at the interface between two or more disciplines, I think universities should expand their efforts to engage scientists and engineers from different departments in common research and education programs. We need to provide more opportunities for faculty to do research across disciplinary lines and for students to study across them. Cooperation with people from other disciplines is valuable for students because teamwork will be an important skill in their professional lives, particularly in industry. I expect university-industry collaborations will grow in areas where industry welcomes interactions with academic scientists and where those interactions are also good for the educational mission of the universities.

It's important to make sure students understand how valuable their graduate degree really is. The Ph.D. is too often considered a narrowing experience. It's really not. It prepares young people to solve incredibly complex problems, to ask the right questions, to construct good models, to get the required data, to interpret the data in the best possible way, to criticize one's work and to be criticized by others. All those aspects of the Ph.D. experience are valuable for a variety of jobs in business, financial management, science policy, government, and, of course, teaching at all levels. A Ph.D is really far more valuable than most people think; we know this is true because we see young people with Ph.D.'s succeed in a variety of careers. We need to make clear to students coming in and to potential employers the value of this kind of educational experience.

I think universities should look at their science and engineering curriculum to make sure it really does prepare students for a broader range of opportunities than basic research. We have a serious job problem now in many fields of science. It can be a great personal disappointment for individuals who have invested a lot of their life getting an advanced education to find that the opportunities they expected are not there. I'd like to believe that in the future, our society will have an ever-increasing need for highly educated professionals with the special set of skills, knowledge, and abilities people develop while getting a Ph.D in science, engineering, or mathematics. But it's hard to make predictions. For now, we need to make sure young people have accurate information about these degrees and to encourage universities to identify things they can do that will give the students greater opportunities after graduation — perhaps broadening the curriculum to include courses in business and engineering.

I think it would be a good idea to consider new kinds of professional master's degrees specifically designed to prepare students for careers in industry. Through the years, there have been many successful professional master's degree programs in engineering, but the concept is far less common in the natural sciences. Universities could ask industry what kind of preparation would be most valuable, then design a program of scientific training which addresses the specific and immediate needs of society.

What are the characteristics of industrial research in the new paradigm?

Many feel scientists may not have such a significant role because industry has changed the structure of its research laboratories, focused them on projects with obvious near-term relevance to their product line, and, in some cases, downsized them. That change represents a qualitative shift in the way research is handled in many industries. The word on the minds of industry seems to be agility — corporate research labs need versatile people who can tackle a variety of difficult problems and change direction quickly if the market changes or a given line of research doesn't prove fruitful. I think that means students getting their Ph.D. should have an opportunity to do more than one thing. Most doctoral research is that way now; a student might have to shift gears several times before he or she finds a useful approach. That's the nature of research, and I hope it will increasingly be recognized as valuable to industry.

What is the role of NSF in the new paradigm?

The mission of the NSF is clear in the statutes. We are to look to the progress of scientific research and education in the United States. Within that mission, the NSF has changed considerably through the years by bringing on line new programs and phasing out other programs as particular fields of science suddenly become exciting or important. Our policies and practices have evolved over the last four decades, but our fundamental mission has not really changed. I expect that 10 years from now the mission will be the same, but NSF will continue to evolve in a way that ensures the quality of the scientific enterprise and responds to the nation's needs.

These are tough times, and people have a lot of problems. If you just lost your job, you have immediate needs, so you will be less interested in what science might bring to bear on society in 20 years. Attention has turned to short-term issues, even with respect to science, and it's understandable that the public would feel that way. Those of us involved in science policy have to be careful to maintain the proper balance so that while we address society's immediate needs, we also continue to make substantial investment in science with a long-term payoff. If we don't do that, we'll find ourselves a decade or so down the road missing the direct benefits to society that would have come.

Have you seen changes in the relationship between the NSF and other agencies?

When I was at NSF a few years ago, we had friendly relations with other agencies, but I didn't see very many examples of close interaction or strong cooperation. Now I find all kinds of examples, particularly with ARPA in high-performance computing and communication, and with DOE in high-energy and nuclear physics.

NSF has been an important participant in the Technology Reinvestment Program, a strong interagency activity to facilitate defense conversion to dual use. That kind of activity is unprecedented, in my view. FCCSET, the coordinating committee of the previous administration, was an example of better coordination of activities across government agencies.

The President's new National Council on Science and Technology has elevated the whole process one level higher, to the highest level in government. The fact that the President chairs the National Council makes clear the high emphasis this administration places on science and engineering. Before the establishment of this council, there was no body at that level of government advising the President. Of course, all recent presidents have had a Science Advisor — Jack Gibbons is a key member of this administration — but there had never been a mechanism to pull together the directors of the agencies and the secretaries of the departments involved with science and technology to sit with the President and the Vice President and the Science Advisor and create a government-wide program. We can cooperate to identify the science needed to support strategic goals, invest taxpayer money to ensure that the science gets done, and eliminate overlap and duplication except in cases where it's desirable and the right hand knows what the left hand is doing. More than that, we are participating in agreements which run across the agencies, so the flow of information has improved greatly; we are exchanging people with other agencies and learning how those agencies work. With this process tightly controlled at the highest level of government, we remove the fear that an agency will lose out in some game-playing exercise. Throughout its history, the United States has never had such a mechanism. I see the whole process as very positive.

What is your most important message to the American scientific community?

The American scientific enterprise is an outstanding success story. It's critically important that we maintain its strength because it benefits all people in society. We must make it clear to the public that we are committed to ensuring that the public investment in science is good for the lives of people.

NSTC Membership

These are the 16 members of the National Science and Technology Council:

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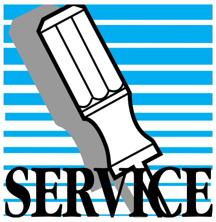

CUSTOMER SERVICE TIPS:

REPLACE THE LIP SEALS IN YOUR MPMS ONCE A YEAR

The Problem:

The MPMS sample rod slides through six lip seals which help to hold the vacuum in the sample chamber. These lip seals wear out over time. It's hard to tell by visual inspection whether the lip seals are damaged because even microscopic cracks and tears will allow air to leak into the sample chamber. Air in the sample chamber can create measurement problems because oxygen has a paramagnetic signal at low temperatures (see Quantum Design's Technical Advisory #8).

The Solution:

Replace the lip seals in your MPMS once a year. Call Quantum Design or your local service center to ask for a kit which consists of replacement lip seals, a pair of clip–ring pliers, and a set of instructions.

Tips for Protecting the Lip Seals:

1. Keep the sample rod in your MPMS lubricated with Apiezon M–grease.
2. When you pull a cold sample rod out of the MPMS, do so very slowly, over a period of about 30 seconds. A cold sample rod can tear the lip seals even if it's properly lubricated.

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