Ten Years with Manuel: 1989–1999

A Short Report About a Long and Rewarding Time in the Department of Manuel at Max-Planck-Institut für Festkörperforschung in Stuttgart

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Ten Years with Manuel

I first heard about Manuel Cardona and the *Max-Planck-Institut für Festkörperforschung* (MPI-FKF) in Stuttgart during my Ph.D. work at the Hamburg Synchrotron Radiation Laboratory (HASYLAB) at *Deutsches Elektronen Synchrotron* (DESY) in Hamburg, Germany. In 1980, the lucky Ph.D. and Diploma students working with synchrotron radiation had the pleasure to broom clean the foundations of the new HASYLAB experimental hall under construction. We were rewarded by being given the opportunity to move into brand-new offices in the newly erected HASYLAB office building. On the first floor there was the office of a scientist from Manuel's department, Robert Johnson who was very busy setting up a photoelectron spectroscopy station named Flipper. (Worthy of note, this station was, virtually unchanged, more than 30 years in operation until 2013, when the DORIS storage ring was turned off). In 1984, bestowed with a Ph.D., or correctly speaking a doctor *rerum naturalium* (Dr. *rer. nat.*) as it is called in Germany, I went to the US, where I continued hearing about MPI-FKF and Manuel Cardona and started to realize how famous the man was. I met Manuel in person in 1989, when he was giving a talk on high temperature superconductivity (HTS) at Brookhaven National Laboratory (BNL) in a packed seminar room. It was the high time of HTS and nobody working on this subject at BNL wanted to miss what Manuel Cardona would have to say about HTS and phonons. As a hands-on experimentalist, he was spicing his talk with a little demonstration of the Meißner effect. Wearing thick gloves, he was cooling a piece of $YBa_2Cu_3O_7{-}\delta$ with liquid nitrogen below the transition temperature. Setting it onto a U-shaped magnetic slide, the levitating $YBa_2Cu_3O_7{-}\delta$ piece was practically frictionless. swinging back and forth until it warmed up an came to rest. It was a good method of getting the attention of warming up the audience and getting everybody's attention.

At that time, I had decided to go back to Germany and Robert Johnson had informed me that Manuel was looking for senior staff. He had also dropped my

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name and Manuel wanted to talk to me. When we sat down in the lobby of the National Synchrotron Light Source at BNL, Manuel started our conversation with the remark that good people were so very hard to find. Well, with the help of Robert it hadn't been too difficult for him to find me. Anyway, I decided to take it as a compliment. The job description that Manuel outlined was very attractive, we parted in mutual agreement and I joined his department at MPI-FKF in September.

Manuel had arranged attractive start-up funds, which allowed me to bring the first scanning tunnelling microscope at MPI-FKF into operation, an ultra high vacuum (UHV) machine that has produced numerous nice papers. However, Manuel still "owned" an old X-ray photoelectron spectroscopy system (VG ESCA), dating back almost to his start at MPI-FKF, i.e. the founding of the institute in 1969, to which he obviously had some sentimental affection. Thus, he was keen that I inherited the instrument. It had not been in use for quite a while. With the excellent technical support of Wolfgang Stiepany we managed to get it to work after a few months. Not long after, I received a panic call that water was coming out of the lab.

Corrosion had eaten away the brazing of the water cooled X-ray anode; the tip had broken off, and through the opening water was flooding the UHV chamber, the analyser and the oil diffusion pumps. (In older times, oil diffusion pumps were chosen when high pumping speed without noise and magnetic fields was required.) The mechanical fore-pumps dutifully continued pumping now the oil-water suspension into the exhaust lines at the ceiling from where it rained down into the lab. Cleaning up the lab took days. In a heroic effort, Wolfgang cleaned the whole UHV system, bathing it, including the electron analyser, in trichlor. It took months to get the ESCA system into operation again and to take the first spectrum from gold—when the high voltage supply failed. At this point, even Manuel agreed to retire this beloved and ancient piece of equipment.

We then started a very fruitful project on the growth and characterisation of epitaxial films of high temperature superconductors, fruitful already in view of the generous funds which we could acquire with Manuel's help and good name. With the new equipment we could grow the 90 K superconductor $YBa_2Cu_3O_7{-}\delta$ under ultra-clean conditions, unravel the very early stages of growth and produce films of YBa2Cu3O7$-\delta$ with record values of the critical current [1, 2]. A lasting memory from that time is our visit to Beijing and the Forbidden City (see Fig. 1), where I had the pleasure of being given a private lecture by Manuel on ancient pottery and china/porcelain in general.

Early on, Manuel had started to explore isotope effects in HTS using Raman and IR spectroscopy. These studies provided a wealth of information and the finding that phonons and thus BCS theory could not account for the pairing. As a spin-off of this work with isotopes, Manuel kicked off a strong activity in the investigation of isotope effects in materials [3].

Crystals made of different isotopes of the same material exhibit at low temperature slight differences in lattice constant [4]. Manuel had found a publication with X-ray measurements on the lattice constant difference of germanium isotopes. He had good reasons to doubt the accuracy of the results and suggested to me to repeat the measurements. Studying the corresponding paper in detail, I realized that

Fig. 1 At the Forbidden City in Beijing, China during the conference on materials and mechanisms of high temperature superconductors, February 28 to March 4, 1997. *Left* Manuel, the chairman, and me; *right* Where is the chairman?

with the technique used it was very difficult to minimize experimental errors. It was likewise difficult to obtain the isotopic pure crystals of germanium needed for the experiment.

A guest scientist from Russia, Alexander Kazimirov, had the clever idea to use a new approach for the measurements. A material grows on a crystal of the same material but with a different isotopic composition perfectly lattice matched at sufficiently high temperature, i.e. above the Debye temperature which is 360 K for Ge. However, upon cooling down, the epitaxial layer will strain to adopt its own lattice constant. An X-ray standing wave (XSW), produced by reflection from Bragg planes from the underlying crystal, reaches through the epitaxial film and represents a perfect yardstick [5] (cf. Fig. 2). Using an epitaxial film with N lattice planes enhances the effect N fold, since the change in surface layer position with decreasing temperature equals N times the individual change in lattice plane spacing. The position of the surface layer(s) can be measured by the photoelectrons excited by the maxima of the XSW. Growing a perfect pseudomorphic epitaxial film is more difficult than one might naively expect, but we succeeded and determined the dependence of the lattice constant of Ge and Si on the isotopic composition with very high precision [6, 7]. A later high resolution X-ray backscattering study confirmed these XSW results perfectly [8].

The scientific life in Manuel's department was very busy, with many visitors, papers constantly circulated by Manuel and two seminars every week. Not too long after I started, Manuel surprised me with presenting me with a bottle of wine to the occasion of my birthday. The present was accompanied, however, with the kind request that I should please attend the seminars regularly, what I did from then on. Unforgettable are the annual departmental meetings, coined the Cardona days. Former members were keen on joining and we always had some guests. Later, the meetings were held at Ringberg castle at Tegernsee [9]. Every postdoc, graduate and undergraduate student of Manuel's department had to report about their work. The short talks were typically followed by some questions and at the end

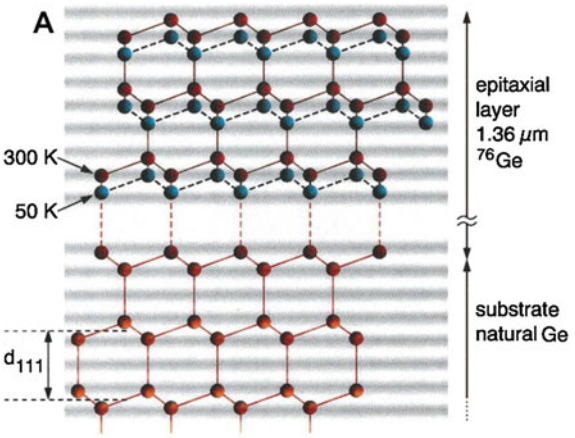

Fig. 2 Schematically: X-ray standing wave and the isotopic effect on the lattice constant

unavoidably by a longer instructive blackboard tutorial by Manuel on the specific subject.

I am grateful for the time I could spend at MPI-FKF in the department of Manuel, since I learned so much (e.g. what polyglot and bibliographical knowledge means). When I left the MPI-FKF in 1999 for the European Synchrotron Radiation Facility (ESRF) in Grenoble, Manuel was very supportive (and continued to be so when needed). He pushed hard that "my" whole lab equipment could be transferred to the ESRF, where it continued to educate Ph.D. students and postdocs and to produce excellent science.

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