

***Workshop Report:***

**Modern Valence Band Photoemission Spectroscopy - A Legacy of W. E. Spicer and a Powerful Tool for Materials**

Workshop held in conjunction with SSRL 31<sup>st</sup> Annual Users' Meeting, October 20, 2004

In memory of William (Bill) E. Spicer, co-founder of SSRL and pioneer in photoemission spectroscopy, a joint SSRL/ALS workshop on modern valence band photoemission spectroscopy was hosted at SLAC on October 20, 2004 in conjunction with SSRL's 31st Annual Users' Meeting. This workshop was initiated and organized by Ingolf Lindau, Donghui Lu, Piero Pianetta, Zhi-Xun Shen, and Neville Smith, who are former students and postdocs of the extended Spicer group. In addition to remembering Bill Spicer and his pioneering work on modern valence band photoemission spectroscopy, this meeting aimed to survey the latest development in the field with special emphasis on high resolution angle-resolved photoemission studies of novel materials. The planned new photoemission beam line at SSRL was also a subject of discussion. More than 60 individuals participated in this workshop, including 17 invited speakers from 12 institutes in US, Canada, and Japan.

The workshop started with the welcome remarks from SSRL director Keith Hodgson, followed by two talks on the historic remarks on the legacy of Bill Spicer. In the first talk, Neville Smith (ALS) focused on the scientific legacy of Bill Spicer in launching the new era of ultraviolet photoemission spectroscopy both experimentally and conceptually. In the second talk, Ingolf Lindau (SSRL) reviewed the Spicer legacy at the start of synchrotron radiation research at Stanford. In the next session, Sebastian Doniach (Stanford University) reviewed the role of photoemission spectroscopy in modern solid state physics from the theoretical point of view, while Zhi-Xun Shen (Stanford University) presented highlights of the latest advancements in the field of high resolution angle-resolved photoemission studies of complex materials.

The focused sessions started after a brief break, with the first session on the polaronic and charge ordering effects in complex oxides. The first talk was given by George Sawatzky (University of British Columbia) in which he presented a theoretical survey on the polaron and bi-polaron problems - the electron-phonon coupling in the extremely strong coupling regime. Dan Dessau (University of Colorado) next reviewed ARPES studies on the colossal magnetoresistive (CMR) materials and the polaronic effects in the system. In the following talk, Kyle Shen (Stanford University) presented the recent ARPES results on the doping evolution of electronic structure from Mott insulator to high- $T_c$  cuprates and discussed how the polaronic effects help us to understand some important "unresolved mysterious". More detailed discussion on this issue was elaborated by Naoto Nagaosa (University of Tokyo) with a theoretical calculation on the interplay of spin and lattice degrees of freedom and their implication on high- $T_c$  superconductivity.

The workshop resumed after the lunch break. The first session in the afternoon was devoted to the electron-phonon interaction from the view point of single phonon processes rather than the polaronic process that involves many phonons. Ward Plummer (ONRL/University of Tennessee) presented a spectroscopic view of electron-phonon coupling at metal surface by introducing the maximum-entropy-method to

extract the Eliashberg function. The following three talks were focused on the electron-phonon coupling effects in high- $T_c$  cuprates. Alessandra Lanzara (UC Berkeley) showed data suggesting strong isotope induced changes in ARPES spectra that are indicative of strong electron-phonon interactions. On the other hand, Tanja Cuk (Stanford University) presented a detailed ARPES study on the momentum and temperature dependence of the electronic renormalization effects in optimally doped Bi2212, which reveals the importance of a particular oxygen bond-buckling phonon. A comprehensive theoretical calculation was then discussed by Thomas Devereaux (University of Waterloo). This model calculation, which reproduces the key features in ARPES spectra, demonstrates the highly anisotropic nature of the electron-phonon coupling, completely different from the conventional wisdom of electron-phonon interaction that is isotropic in momentum.

In the session after a short break, Anders Nilsson (SSRL) introduced their recent experiments on probing chemical bonding and ultra fast phenomena using X-ray emission and photoemission spectroscopy. A case study of hydrogen bond in water and ice was presented. Zahid Hasan (Princeton University) next discussed their recent ARPES results on  $\text{Na}_x\text{CoO}_2$ , a new class of doped Mott insulator with rich phase diagram.

The final session in the afternoon was focused on the novel low dimensional systems, a field with growing importance. In this session, Stephen Kevan (University of Oregon) discussed the recent ARPES experiments on the Cr(110) thin film with emphasis on the Fermi surface nesting and commensurability. It has been demonstrated that the film thickness can be a useful non-thermal parameter to engineer phase diagrams while mixing other non-thermal parameters offers the further ability to modify the phase diagram. Franz Himpsel (University of Wisconsin Madison) next presented ARPES studies on the low-dimensional electrons in the atomic chains (Au on Si), where a tunable band filling tunable 1D/2D coupling can dramatically change the electronic structure. In the last talk, Andrea Damascelli (University of British Columbia) used  $\text{Sr}_2\text{RuO}_4$  as a model system to demonstrate ARPES as a powerful tool in studying both bulk and surface electronic structure of low dimensional systems by determining the Fermi surface topology in unprecedented detail and measuring other fundamental physical quantities such as Fermi velocity and effective mass.

After the dinner, the Nobel laureate Walter Kohn delivered a wonderful speech titled "Electricity from the Sun", in which he commented on the remarkable contributions from Einstein to modern quantum physics. In addition, he also remarked on the Bill Spicer legacy by telling his own stories of interactions with Bill.

This workshop received very positive feedback from workshop attendees. It was very informative by providing a comprehensive picture of current status in the field of high resolution photoemission spectroscopy, but also helped to finalize the proposal for a new photoemission beam line at SSRL. The organizers thank the DOE Office of Basic Energy Sciences for supporting this extremely successful workshop.

Donghui Lu and Zhi-Xun Shen  
SSRL  
Menlo Park, CA