Nanoscale Chemical Phase Separation in $FeTe_{0.55}Se_{0.45}$ Superconductor

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The search for high-temperature superconductors that could be used in power transmissions without any loss or as interconnects in high-speed computers has led to the discovery of superconductivity in transition metal compounds, such as copper (Cu) or iron (Fe) based materials. In either case, superconductivity is achieved by adding a new ingredient to the parent compound. One of the most fundamental aspects of these superconductors seems to be spatial clustering (phase separation), either chemically or electronically. To study this, one needs a probe that can see and identify atoms (chemical inhomogenities) and at the same time image the electronic properties. This can be achieved by using a scanning tunneling microscope (STM). As demonstrated on the right, we unveil the atomically-resolved structural and electronic properties of $FeTe_{1-x}Se_x$ using single crystals grown at LSU. The figure shows our image of the optimally doped (x=0.45) superconducting sample where we have proven by statistical counting that the bright (yellow) atoms are Te and dark (blue) ones are Se. Compared to simulations (bottom figures) for random and phase separation cases, we conclude that Te/Se distribution seen by STM is not random. Surprisingly, the tunneling spectroscopy shows no difference between Te and Se sites. This is in contrast with what is seen in Cu-based superconductors, which are chemically homogeneous but electronically inhomogeneous.

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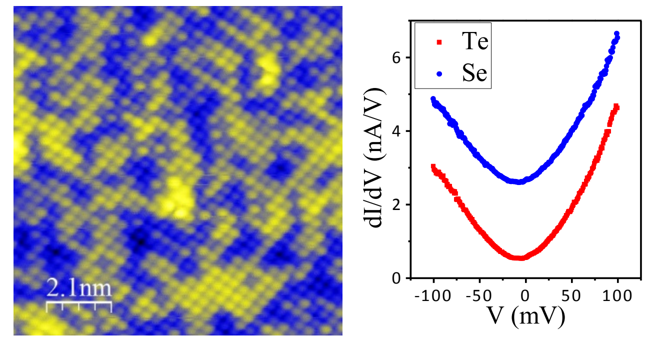
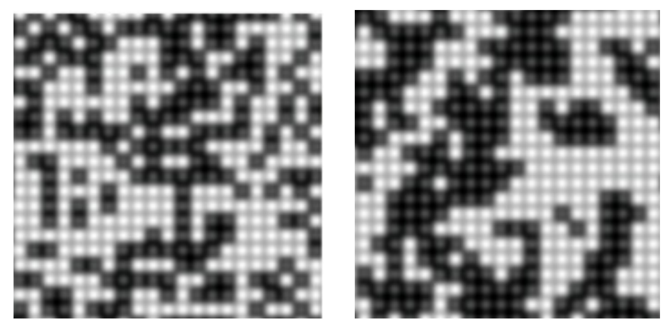


Nanoscale phase separation between Te and Se atoms in $FeTe_{0.55}Se_{0.45}$ was revealed directly through STM, while the tunneling spectroscopy shows no sign of inhomogeneity in the local electronic properties.



A simulation shows what one would expect for a random distribution (left) and phase separation (right) of the two atomic species. Our STM image of $FeTe_{0.55}Se_{0.45}$ agrees with the simulated phase separation scenario.

Cultivating the Future Scientists

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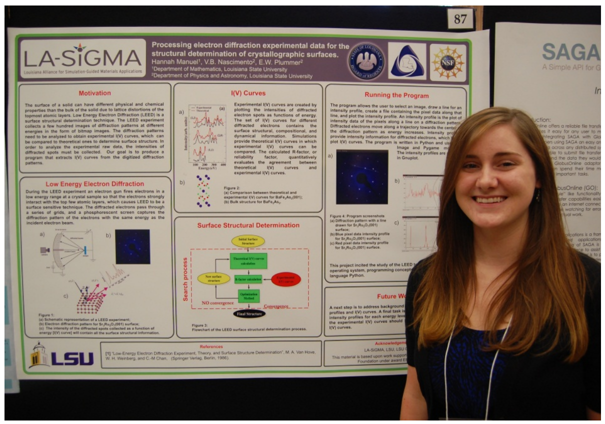
Our research group has developed unique expertise in the structural determination of solid surfaces by Low Energy Electron Diffraction (LEED), and we have used this capability as a training vehicle for undergraduates and to establish international collaborations. Hanna Manuel, an under-graduate in Math at LSU joined our research group, won the outstanding poster award at the REU competition run by the Louisiana Alliance for Simulation-Guided Materials Applications (NSF funded). She is shown with her poster above.



Also we have established a collaboration with the Federal University of Minas Gerais (UFMG) in Brazil on the development and utilization of LEED codes. Mr. D. D. dos Reis, a graduate student will join the LSU (Plummer) group.

As one of the *LSU Chancellor's Future Leaders in Research*, our undergraduate, Donovan Myers (see his picture below), has been conducting experimental research in Jin's laboratory. He has not only learned various materials synthesis techniques including the state-of-the-art single crystal growth method (called the floating-zone technique), but also succeeded in growing high-quality and large-size $La_{1-x}Ca_xMnO_3$ single crystals (see the picture below). This material is known to exhibit colossal magnetoresistance effect, which is fundamentally interesting and has potential application for information storage.