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Spatial inhomogeneities in the Fe chalcogenide superconductors

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Much remains unknown of the microscopic origin of superconductivity when it materializes in atomically disordered systems as in amorphous alloys or in crystals riddled with defects. A manifestation of this conundrum is envisaged in the highly defective iron chalcogenide superconductors. How can superconductivity survive under such crude conditions that call for strong electron localization and scattering? With vacancies present both at the K and Fe sites in the $K_xFe_{2-y}Se_2$ superconductor, superconductivity is bordering a semi-metallic region below x ˜0.7 and an insulating and antiferromagnetic region above x ˜0.85. In this talk, I will discuss our recent results on the bulk local atomic structure and single crystal work that show striking differences between superconducting and non-superconducting compositions regarding the ordering of the Fe and K sublattices. In a related system, the intercalation of $LiFeO_2$ in the tetragonal lattice of $Fe_{1-y}Se$ leads to a great enhancement of the superconducting transition temperature, T_C ˜43 K and possibly to an antiferromagnetic transition at 8.5 K. While the $LiFeO_2$ layer acts as a charge reservoir, its Fe^{3+} ion ($3d^5$) is magnetic that may create a magnetic buffer layer. Most recently, we developed a new synthesis method to control the Fe concentration in the intercalating layer as well as the filling ratio of the $Li_{1-x}Fe_xO_2$: FeSe layers. Neutron scattering measurements were carried out on powder samples of $(Li_{1-x}Fe_xO2)_yFeSe$. With the intercalation, no crystal structural transition from the P4/nmm symmetry occurs but the c-axis lattice constant expands substantially, evidence of the intercalation. Our results indicate that the amount of Fe in the $LiFeO_2$ layer has a direct correlation to the transition temperature.