Localization in thin alkali films

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Thin alkali films when covered at helium temperature with impurities show a dramatic increase in their resistance. In Fig.1 the conductance of a thin Cs film, 18 at. layers thick is shown as a function of Pb coverage. At a Pb thickness of 1.5 at. layers the film becomes insulating. We investigated the insulating film with the superconducting proximity effect and found that on the length scale of the film thickness the Cs is still conducting. This means that the electrons in the Cs film are localized and the localization length is larger than the film thickness. To our knowledge this is the first time that a pure metal is forced into a localized state by the contact with another metal.

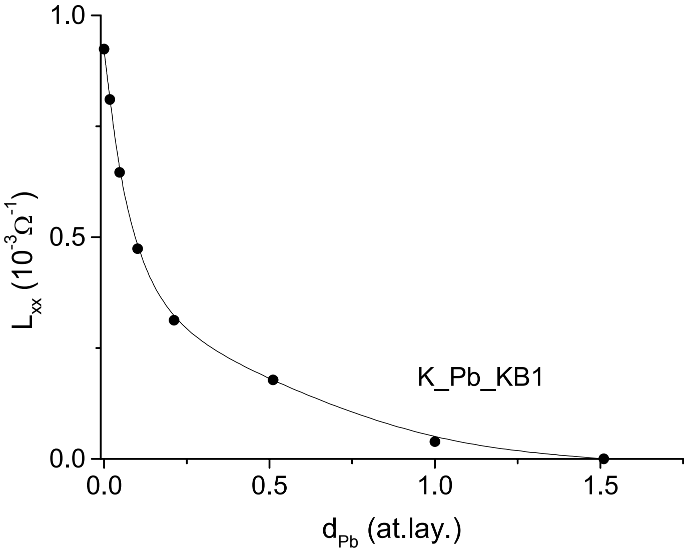

Fig.1: The conductance of a Cs as a function of the coverage with Pb. At 1.5 at. layer of Pb the film is insulating

In a perfect metal the electrons can freely propagate from point A to any other point B along a straight. If one introduces disorder into the metal (one reduces the mean free path of the electrons) then the electrons can still travel from A to B along several small straight lines (similar to a pedestrian walking in a city from A to B block by block). When the disorder reaches a critical value then each electron is confined to a small area whose size is given by the localization length. At this critical disorder the metal makes a metal-insulator transition (MIT). Within the distance of the localization length the electrons can move freely but they cannot move over large distances, i.e. they cannot carry a direct current (the metal becomes insulating).

To achieve such a MIT one normally has to dilute the metallic atoms or start with a semiconductor which is artificially made conducting. Our observation that a simple metal (the potassium) is made insulating by the contact with a Pb mono-layer is very remarkable.

Studies of the not so simple alkali metals

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Education:
Four graduate students (Doug Garrett, Funing Song, Manjiang Zhang and Go Takeishi) performed the measurements to this work. Furthermore we introduce undergraduate and high school students into basic research. In July 2004 the PI initiated a physics education program for local high school students. Below a demonstration of the Magdeburg hemi-spheres.

Societal Impact:
Alkali metal films found in recent years important applications in the storage of hyper-polarized noble gases. Hyper-polarized noble gases such as He3 are the future way to make the human lungs visible in MRI. A thin alkali metal film on the wall of container of the polarized gas increases the life time of the polarization by a factor 10. Alkali are the only metal which yield this improvement. Nobody understands the mechanism and what makes alkali metals to special. We hope and expect that our experiments contribute to the understanding and improvement of the unusual storage ability of the alkali metals.