Along two dimensions

Superconductivity as it is now most widely known is a bulk effect. It occurs in metals and metal compounds in which the conduction electrons and the forces that affect their behavior can operate in three dimensions.

For several years a number of physicists, especially a group from Stanford University and Bell Telephone Laboratories under the leadership of Dr. T. H. Geballe, have been investigating the possibility of superconductivity in systems where activity is limited to one or two dimensions. One reason for this search is that some specialists in the field believe that if superconductivity can exist in one or two dimensions, the way will be open to devising systems in which it will appear at temperatures much higher than those at which it is now seen. So far superconductivity is not known at temperatures much higher than 20 degrees K.

Last year the Stanford-Bell Labs group reported that superconductivity appears in metal compounds that they had rendered effectively two dimensional. Thus they believed that they had evidence for two-dimensional superconductivity (SN: 6/20/70, p. 602).

Last week Dr. F. J. DiSalvo of Stanford told the meeting of the American Physical Society at the University of Washington in Seattle that further experimentation has yielded more evidence of superconductor-like behavior in two-dimensional substances and strengthened the group's belief that they are seeing two-dimensional superconductivity.

For superconductivity to exist, the conduction electrons of a substance must form pairs in which the spins of the two electrons are oppositely directed. Then the pairs can move without encountering the resistance that impedes flow in normal electric currents. Since electrons normally repel each other, the intervention of an intermediary that changes the balance of forces to a net attraction is necessary for them to pair. Theorists generally believe that vibrations of the metal's crystal lattice called phonons or a more general class of disturbances known as excitons can be the intermediaries.

Another criterion for superconductivity is the possibility of ordering the spins of the electrons, making them point exactly opposite to one another instead of in random directions as they normally would. Many theorists doubt that the forces acting in one or two dimensions are sufficient to bring about such ordering. Since similar kinds of ordering underlie superfluidity and various kinds of magnetism, a demonstration of superconductive ordering in two dimensions might have important influences on those subjects too.

To make a two-dimensional substance generally requires isolating a sample one molecule thick so that the conduction electrons have effectively nowhere to go in the third dimension. To do this physically is extremely difficult so the Stanford-Bell Labs group found a way to do it chemically.

Certain compounds called metal chalcogenides form in mono-molecular layers that are tightly bound horizontally but only weakly bound vertically. If certain organic compounds are introduced, they form between the layers of metal chalcogenide and push them apart.

The idea is to push the metal-chalcogenide layers far enough apart that they behave as two-dimensional systems and do not influence each other. The Stanford-Bell Labs group believe they have done this. They also think that the observation of superconductivity in such sandwiches shows that it is occurring two dimensionally. Critics have reported that since the layers are nevertheless connected together, some weak third-dimensional effect might still be present.

The group has studied a variety of such compounds including some in which the metal-chalcogenide layers (which are 5 or 6 angstroms thick) are separated by as much as 50 angstroms. They find that the superconductive effects appear independent of the spacing between layers. This, they believe, tends to argue against third-dimensional effects.

They have also studied the changes in heat capacity of these substances as the temperature is varied. In an ordinary metal the heat capacity drops off steadily as the temperature goes down. In these substances at a particular point in the graph there is a bump. This bump is characteristic of superconductors and is believed to be brought about by the beginning of superconductive ordering of the electrons. Its presence in these substances strengthens the case for two-dimensional superconductivity.

Other studies, involving electrical conductivity and the effects of magnetic fields, tend to show differences according to whether they are taken horizontally or vertically that further support the two-dimensional hypothesis, reports Dr. DiSalvo.

In sum, Dr. DiSalvo says his group is convinced they are observing two-dimensional superconductivity and two-dimensional superconductive ordering. But they cannot now prove that weak three-dimensional effects are not affecting the order somehow. □

A test for detecting lung cancer

By the time lung cancer is detected it is usually too late to treat and save more than five to eight percent of its victims. Other forms of cancer have higher cure rates because early detection tests have been developed that enable doctors to treat the disease in its early stages. The Pap test for uterine cancer, for example, is inexpensive, easily performed and capable of detecting malignant cells at the first stages of the disease. Detecting lung cancer by testing the sputum is not as easy because, during the first stages, the sputum may contain only a few cancerous cells; a Pap smear may contain thousands. And once the abnormal lung cells are detected, there is still the problem of locating the exact area of the malignancy.

A research team at Johns Hopkins University in Baltimore reported last week that it has developed a means of doing this. Using a flexible bronchoscope, a doctor can insert a tiny balloon into each of the five lobes of the lung. Each of these sections is sealed off in turn and sputum samples are taken, enabling identification of the affected lobe. After the malignancy is located, a special X-ray technique is used to identify pinpoint areas of cancer.

The research team, headed by Dr. John K. Frost, believes the method can detect the disease early enough to save 50 percent of the patients. So far the researchers have used the technique on 600 men and found three malignancies. The Mayo Clinic in Rochester, Minn., has received a National Cancer Institute grant and will begin using the Hopkins' test on 6,000 men.

The major drawback is the expense. The process takes about two months because each sputum sample requires 10 hours of preparation before it can be studied under a microscope by the lab technician. After seven samples are studied the patient is asked to return for the balloon test if any sign of cancer has been found. All of this costs about $100. But Dr. Nathaniel Berlin of the NCI, which supplied $500,000 to Johns Hopkins for its research, predicts that the test can be simplified and, like the Pap test, made inexpensive enough ($2 or $3) for mass use within 5 to 10 years.