POTENTIAL TECHNOLOGY DIRECTIONS OF MOLECULAR METALS

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In the past decade, anisotropic molecular conductors have been found which possess unusual electrical, optical, magnetic, and in some cases mechanical properties. Exploiting these properties for specific devices is inevitable, and a number of diverse applications of molecular metals have been reported over the past few years. Specifically, these materials have found some use as components in batteries, electrolytic capacitors, thermistors, electrochromic displays, optical printing techniques, electrophotography, as electrodes, antistatic coatings, etc. A more critical and detailed review of the state of the art in this area is given in a paper by Dr. Yoshimura at this NATO-ARI. The scope of this study group is to evaluate the status of applications, to indicate problem areas, and to identify some fruitful directions for future work. But, it must be kept in mind, that since this is a young field where potential applications are still in a very early stage of development. Consequently, a certain amount of speculation and generalization is unavoidable.

While new applications to conventional problems continue to emerge, their ultimate potential may lie in the rather unique combination of several novel and useful properties possessed by these materials. Some of these properties other than high conductivity are:

(1) anisotropic optical and electrical properties
(2) low ~~weight~~ (density)
(3) ease of fabrication via vacuum deposition and solution casting techniques.
(4) sensitivity of conductivity to external influences (e.g. electric fields, temperature, gases, doping)
(5) molecular engineering to alter properties.

When the conductivity is considered in connection with some of these above-mentioned properties, some interesting applications can be envisioned. For example, TTF donors were found to undergo photo-oxidation in halocarbon solvents to give conducting TTF halides. Light could therefore be used to "turn on" high conductivity in a film of insulating TTF-halocarbon. This effect has been applied as a method of optically printing highly conducting, multicolored patterns. Thus, information can be stored optically (input), and this written information either optically or electrically sensed (output). In other applications, the sensitivity of the conductivity to external influences have suggested uses as sensors or switches. The use of metal-insulator phase transitions in some molecular metals as temperature controlling devices, and the sensitivity of conductivity in anhydrous KCP salts to water vapor as humidity sensors are just two early examples of this combination of useful properties.

Eventual commercial applications of molecular metals will depend to a large degree on breakthroughs in materials fabrication and processing techniques. The evaluation of long-term stability, toxicity, mechanical properties, etc., and the ability to modify and improve these properties will be important considerations in terms of how useful potential applications will be. In this regard, a promising development has been the discovery that free-standing, large-area, films of polyacetylene can be readily prepared. These films can be either acceptor or donor doped to yield both p- and n-type materials which exhibit a wide range of conductivities, spanning insulating to metallic behavior.

Attempts to combine the useful mechanical properties of polymers (e.g. film-forming, adhesion, flexibility, etc.) with the electrical properties of these crystalline molecular metals is at least one area which deserves more attention. One approach to this problem has been to incorporate small amounts of a conducting organic charge-transfer salt (as low as 5% weight) within an insulating polymer matrix. By stretching the polymer film, conductivities as high as 1/ohm-cm have been observed. In another approach, insulating π-donor polymers have been prepared which maintained many of the desired polymer properties, such as solubility and good film-forming properties. After films have been cast, the material is converted to a moderate conductor by exposure to halogen.

In terms of research directions on the applications of molecular metals, the following seem of special interest:

(1) the study of junction characteristics (p-n junctions, Schottky barriers) between synthetic molecular metals and traditional metals and semiconductors.
(2) the use of these materials in energy storage (batteries) and generation (solar cells).
(3) development of mechanically and thermally stable highly conducting polymers and/or composites.

(4) study of the modification of electrical properties by external influences such as gases, temperature (phase transitions) and applied electric fields.

(5) the study of non-linear transport phenomena in these materials and their potential use in microelectronics.

(6) development of improved materials fabrication and processing techniques for molecular conductors, such as in the preparation of large area thin films.

Continued basic research on these molecular conductors is very important in gaining a better appreciation of the real potential of this field. In particular, a better understanding of how changes in molecular properties influence the resulting solid state properties will be helpful in the controlled modification and design of molecular solids with specific properties.