CHAPTER 1. INTRODUCTION TO SMALL PARTICLES

1. Small Particles and Materials

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1. Small Particles and Materials

   One of several ways to classify materials is to divide them into the following groups:

   1. Metals
   2. Ceramics
   3. Polymers-Plastics and Elastomers (Rubber)
   4. Cellulose-Wood-Paper
Figure 1-1 shows these groups of materials and some typical important uses of them. Many materials also contain different kinds of additives and auxiliary chemicals: e.g., fillers in polymers-plastics, rubber, paper. A closer examination will show that many products of different materials, and many additives as well, are made of or consist of small particles. Ceramics are thus made of metal oxides, e.g. oxides of aluminum, silicon, zirconium, or nitrides of, for instance, carbon. Fillers in plastics and paper may consist of small particles, e.g., various types of clays. Porous structures, which form the basis of such structures as catalysts, adsorbents, and membranes, are frequently made of small particles. Inorganic binders may consist of small particles of silica or alumina.

![Diagram showing small particles in materials]  
**Fig. 1-1.** Small particles play an important role in the material world.

A fundamental question, which has fascinated physicists and theorists for a long time, is what happens when one, two, tens, hundreds, thousands, or millions of atoms bind together to larger systems such as ultrafine particles, powders or solids. Today we have good knowledge of the first building block, the atom, and of the final result, macro-scale solids, whereas our knowledge of intermediate systems is relatively modest. Many properties of atoms and solids can be found in handbooks with tables and diagrams. The periodic table is one of the most comprehensive general compilations wherein the position of an element gives information about some of its special properties. However, handbook values almost always refer to the properties of the solids in bulk form, i.e. without reference to specialized forms such as finely divided particulates, spongy forms, etc., each of which may have vastly different properties than the bulk form.

Atoms are often characterized by such properties as electron configuration, ionization energies, oxidation states, and electron affinity. For solids the discrete energy levels of the atom have been broadened to energy bands and the first ionization energy corresponds to the work function. Moreover, solids are often characterized by a certain crystal structure and can be classified as conductors, semi-conductors, or insulators, with different electrical and optical properties; Fig. 1-2. There is today a great deal of interest in fundamental as well as applied research to investigate how properties change when atoms, one by one,