# CHAPTER 1

# INTRODUCTION

## 1.1 Ferromagnetic Disordered Alloys

The term "disordered alloys" in general and "amorphous alloys" in particular way include liquid, vapour or plasma quenched materials as well as alloys obtained by solid state synthesis, whose X-ray diffraction patterns show characteristic broad rings. Among them the term "metallic glass" is used to denote only liquid quenched products. Amorphous magnetic materials mainly belong to this subcategory. These alloys lack long-range atomic order and consequently exhibit high metallic resistivity (100-200 $\mu\Omega$-Cm) and no macroscopic magnetocrystalline anisotropy due to the absence of crystal structure. As a result, ferromagnetic metallic glasses based on 3d transition metals are generally good "soft" magnetic materials with both low dc hysteresis loss and low eddy current dissipation. In addition, they are characterized by high elastic limit (i.e. they resist plastic deformation) and for certain compositions, they show good corrosion resistance. Amorphous magnetic alloys containing appreciable fractions of rare earth metals show magnetic anisotropy and magnetostriction that can be varied almost continuously with compositions upto very large values. These characteristics combined with the expectation that metallic glasses can be economically mass fabricated, has led to a broad commerical interest. To physicists, the attraction lies in seeing how the absence of crystal structure modifies the collective magnetic phenomena, which are mainly governed by short-range interactions.

Because of the lack of atomic ordering it was believed for many years that ferromagnetism could not exist in amorphous solids. However, in 1960 Gubanov [1] predicted, on the basis of theoretical analysis, that amorphous solids would be ferromagnetic. This was based on the evidence that the electronic band structure of crystalline solids did not change in any fundamental way on transition to the liquid state. This implies that the band structure and hence ferromagnetism depends on short-range atomic order and should not be destroyed in the corresponding amorphous solid. In 1950, Brenner et al [2] first reported the amorphous metllic alloy of nickel phosphorous prepared by electro deposition. The present great interest in amorphous metal research stems from reports [3] by Duwez et al in 1960 on the preperation and properties of amorphous metallic alloys. In 1967 Duwez and Lin [4] reported a liquid quenched Fe-P-C alloy exhibiting a saturation magnetization of 7 KG, low coercivity (3 Oe), rather high Curie temperature and good stability at room temperature against crystallization. Luborsky et al [5] first demonstrated the reduction of coercivity in Fe-Ni-P-B alloys down to less than 10 mOe by suitable annealing and showed that the changes in properties correlated with the relief of internal strain.

Amorphous states for pure metals like Fe,Co,Ni etc. are obtained only at low temperature whereas this state is stable for above alloys at room temperature. The stability increases with the number of components in alloys. Two important classes of amorphous magnetic materials are being studied intensively in recent times. They are the transition metal metalloid (TM-M) glass and the rare-earth transition metal glass (RE-TM) [6,7]. TM-M glasses are stable for composition around 75-80% of TM (Fe,Ni,Co etc or in combination of them). Typical composition for RE-TM glass is $RE_{33}$-$TM_{67}$ where the REs are heavior rare-earth metal like Gd, Tb, Dy etc and TMs are Fe, Co. Later metalloids in TM-M glasses are replaced by non-magnetic metals [8] like Zr, Hf and are being studied for the last several years.

Many good reviews of amorphous alloys are available, covering a variety of physical properties [9-17]. Among those, the review [14] by Moorjani and Coey presents a wealth of information on metallic as well as on insulating magnetic systems. Wohlfarth [10] examines many aspects of magnetism in light of itinerant theory. Kaneyoshi [13] reviews theoretical issues related to exchange and moment fluctuations as well as spin-wave state. Luborsky treats anisotropy, moment variations, coercivity and losses [10]. O'Handley reviewed the recent development in the physics of ferromagnetic amorphous alloys in details [17].

## 1.2 Preperation of Ferromagnetic Amorphous Alloy

The basic principle to prepare an amorphous alloy is that the molten alloy must be cooled very rapidly so that it must pass quickly enough through the temperature range where nucleation can occur. The cooling rate is of the order of

$10^5$ °C $s^{-1}$ or higher [18]. A wide variety of different processes with low cost production techniques have been reported. The most widely used technique to prepare TM-M metallic glass is the liquid-quenching method [19]. In this method, a rapidly spinning copper or steel wheel is used to conduct the heat away rapidly and continuously from the melt. This method is suitable to produce metallic glass in the form of ribbons. The typical dimension of the ribbon is few cm in width and 20-60 μm in thickness. The other methods are splat cooling, sputtering, irradiation by energetic neutron, vapour or electro-deposition [19]. RE-TM glasses are normally prepared by sputtering or vapour deposition techniques [19]. Some new techniques to obtain metallic glass are still under development. These are laser glazing [20], electric field emission of ions from the melt [21] and spark erosion technique [22]. Very recently, a new method has been developed which produces glassy metal wires less than about 100 μm in radious by squirting a jet of molten liquid into a rotating bowl of water [14, P.42].

## 1.3 Characterization

The physical, chemical and magnetic characteristic of amorphous magnetic materials have been studied by various techniques. Since the magnetic properties of these materials will be discussed in the following chapters, their physical and chemical aspects will be discussed here in brief.