**ME213 Homework set6**

**Problem 1**

(a) At high temperature the iron oxidizes at a linear rate. The addition of more than 12% Cr decreases the rate of oxidation significantly, and leads to an oxidation rate that is parabolic. Explain this result, which is a key feature in the behavior of stainless steels.

*Cr oxidizes very easily and so forms a protective oxide layer of Cr2O3 on the surface of stainless steel that provides protection from further corrosion. However, exposure to Cl or sufficiently high temperatures can negate this protection*

(b) Why is the coefficient of thermal expansion of the protective coating an important issue?

*Oxide layers or coatings that expand/contract easily with changing thermal environments can cause the layer to crack or buckle, exposing bare metal to more corrosion and continuing the oxidation cycle. Good films or coatings have low coefficients of expansion which allow them to stay intact under changing conditions and continue to protect the underlying material.*

**Problem 2**

(a) Draw a simple sketch of the band diagrams of an n-type and a p-type semiconductor. Indicate the position of the Fermi level relative to the center of the band gap in each material at moderate temperature.

(b) Roughly sketch the band structure of an n-p junction in which the two materials are joined and allowed to come to equilibrium.

(c) Explain qualitatively why the n-p junction conducts electricity much more easily in one direction

than in the other.

*When an n-p junction is under a forward bias (N side connected to negative potential, and P side connected to positive potential), extra electrons are pumped in the N-type region and tend to migrate toward to recombination zone. Likewise, electrons are pulled from the P-type region which creates more holes. This concentration of electrons and holes in the recombination region (n-p boundary) cause electrons from the N side to jump to the holes in the P side which in the aggregate causes a current to flow once a certain minimum electrical potential is reached (usually around 0.6V). When under negative bias, the electrons and holes tend to move away from the boundary and toward to terminals which stops the flow of current unless there is a sufficiently high negative voltage to overcome this effect.*

**Problem 3**

(a) A material that is made of atoms that have permanent magnetic moments must be paramagnetic, ferromagnetic or antiferromagnetic. Describe these three magnetic states. Which do you expect at high temperature?

*In a paramagnetic material, individual atoms have small permanent dipoles which are oriented randomly but will tend to align with an external magnetic field. This small positive susceptibility creates a flux density slightly above that of a vacuum.*

*In a ferromagnetic material, atoms have strong permanent dipoles due to cumulative electron spins. Ferromagnetic materials a large positive susceptibility and create large magnetic fluxes in the presence of an external magnetic field.*

*Antiferromagnetic material also has atoms with strong dipoles but unlike with a ferromagnetic material, they are oriented in alternating anti-parallel directions which result in a net zero magnetic moment when averaged over the bulk material.*

*At high temperature, atoms tend to vibrate more which will randomize their orientation and at some critical temperature called the Curie temperature, the saturation magnetization will fall to 0, and the material will not be able to be magnetized.*

(b) Describe the difference between a "hard" and a "soft" ferromagnet. Why is a hard magnet hard?

*Soft magnetic materials can change their magnetic orientation very easily and exhibit a small hysteresis loop due to high permeability and low coercivity. This is useful for applications that need magnetic fields that need to alternative direction on very fast time scales such as in transformers and generators.*

*Hard magnetic materials exhibit the opposite characteristics, with a large hysteresis loop and high coercivity and are difficult to demagnetize. Hard magnetic materials are useful for applications where a permanent magnet is needed with a specific orientation that is very difficult to change such as in audio devices.*

*Hard magnetic materials are hard because the boundaries between magnetic domains are difficult to move which increases coercivity and susceptibility, and this means a very strong magnetic field is needed to demagnetize the material.*

(c) If you were choosing a material for a magnetic disc to store information, would you prefer a hard or a soft ferromagnet? Would you want to coat the disc with small, discrete particles or with a continuous ferromagnetic film?

*For data storage applications you want a relatively hard magnet to prevent bit errors in the case of magnetic domains changing orientation. You need to be able to change bits, of course, but with a sufficiently strong and precise read/write magnetic field this is possible even with hard ferromagnetic material. You would also want very small and homogenous magnetic domain “grains” so that different data orientations can be stored in close proximity to each other, as a continuous film would give you virtually no data density.*