Practical Work Book

MY-402: Advanced Materials

Name ________________________
Roll No______________________
Batch_________________________
Year_________________________
Department___________________

Department of Metallurgical Engineering
NED University of Engineering and Technology

Practical Workbook

MY-402: Advanced Materials

PREPARED BY

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This is to certify that this practical book contains ____________ pages.

Approved by:

Chairman
MYD

Department of Metallurgical Engineering
NED University of Engineering and Technology

CERTIFICATE

It is certified that Mr. / Miss ____
Student of class ________________________________ Batch__________________
Bearing Roll No. ____ has completed
His/her course work in the subject of ______________________________________
as prescribed and approved by Board of Review of Department of Metallurgical Engineering

His/her performance is reflected by index/contents of his/her practical workbook. This overall performance of the student is Excellent/Very Good/Good (satisfactory)/Not Satisfactory

____
Course Teacher

TABLE OF CONTENTS

MY-402: Advanced Materials

Practical No. 1

Objective

To Study the general safety rules of materials laboratories

SAFETY IN MATERIALS LABORATORIES

- Keep the work area clean. Wipe up oil and grease spills immediately to prevent injuries caused by slipping and falling. Keep paths to exits clear.
- Use eye protection. When doing practical work, wear approved safety glasses or a face shield.
- Store rags safely. Store oily and greasy rags in a fireproof metal container to prevent the spreading of spontaneous fires.
- Use the correct lifting method. Serious injury may result from straining due to incorrect lifting. Lift heavy objects with the leg muscles, not the back muscles. When lifting heavy objects, obtain assistance.
- Use proper tools. Always use the proper-sized tools and equipment for the job.
- Obtain the instructor's permission. Use equipment only with the instructor's permission. Notify the instructor immediately if you are injured.
- Wear proper clothing. Wear clothing that is not loose or bulky and wear hard-toed shoes with non-skid soles.
- Ground electrical equipment. Each electrical tool should be equipped with a three-prong plug and plugged into a grounded three-hole receptacle. When used outside, portable tools should be connected to ground fault circuit interrupter outlets.
- Restrain long hair. Restrain excessively long hair with a band or cap to keep hair from getting entangled in machines/equipments.
- Obtain the instructor's permission. Before using any tool or machine, you must obtain the instructor's permission. The instructor must be aware of all laboratory activities and will know if the equipment is in safe working order.
- Know emergency procedures. In the event of an emergency, all students involved in or observing the emergency should call for help immediately as well as assist in correcting the situation. You should know the location of fire extinguishers and fire blankets and

how to use them. You should also know the approved procedure for exiting the laboratory.

- Report all injuries or accidents to the instructor immediately, no matter how slight. The instructor will secure medical help.
- Use correct tools. Always use the right size tool and only for its intended purpose.
- Avoid horseplay and loud talk. Loud talking as well as pushing, running, and scuffling while working in the materials laboratories. It can cause serious accidents. Keep your mind on your work.
- Work in a well-ventilated area.

- Never touch suspected hot metal. Test metal with moistened finger tips before actually touching it. Use tongs or pliers for handling hot metal.
- Never work on containers that have been used for storage of combustible material without first having cleaned and safeguarded them.
- Protect cables and hoses when you are working. Keep cables and hoses from coming in contact with hot metal and sharp objects. Never point a flame at cables or hoses.
- Turn off all heat sources before leaving work area. Before leaving the laboratory or work station, make certain the heat source is shut off and cool.

Review Questions

Q1. What safety practices are used in your laboratories to promote general safety?

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Q2. What equipment and machines in your lab must run separate safety tests before you are allowed to operate them?

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Q3. What personal safety protection devices or clothing must you wear while working in the lab?

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Q4. What instructions are given for handling and storage of your job's material?

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Q5. What procedure should you follow if you see an accident happen?

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Practical No.2

Objective

To study the Magnetic field, Mapping, Patterns and Properties of magnetic lines of force in a bar magnet.

Apparatus

Card board, bar magnets, magnetic compass, iron filings

Activity 1:

Magnetic field:

Magnetic field is a region near a magnetised body where magnetic forces can be detected.

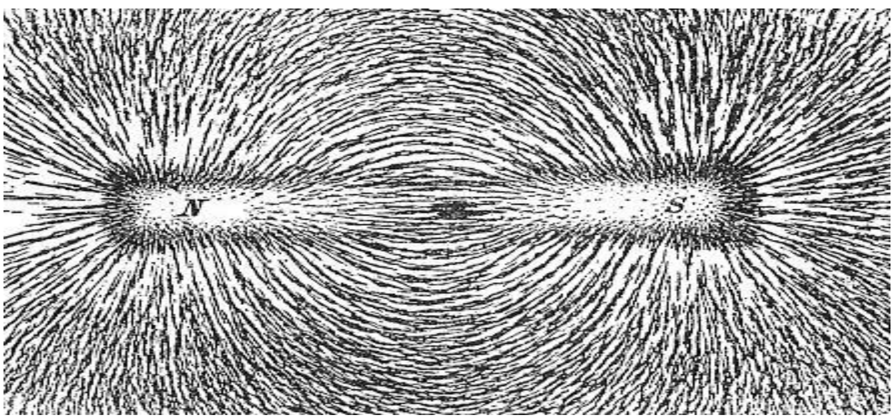


Figure: Magnetic Field around a magnet

Procedure:

1. Place a card board on a magnet.
2. Sprinkle some iron filings on the cardboard.
3. Tap the card board gently.

Observations

The iron filings align themselves in definite patterns. These patterns indicate the magnetic field of the magnet.

Activity 2:

Mapping of magnetic lines of force:

The magnetic field is represented graphically by lines of force. A pictorial representation that gives the direction of the magnetic field at various point in a Magnetic field, is called a map of magnetic field.

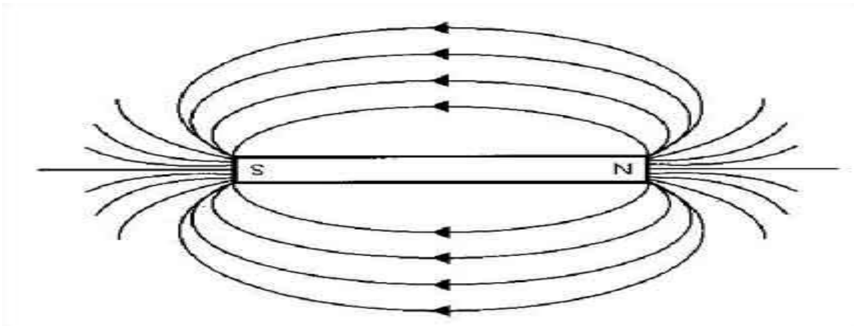


Figure: Magnetic lines of Force

Procedure:

- Fix a sheet of paper on a drawing board.
- Place a bar magnet over a sheet of paper.
- Trace the bounder and as of the bar magnet.
- Place a compass at the North Pole (what do you observe) the magnetic needle comes to rest in a particular direction.
- Mark the other end of the needle.
- Now, move the compass towards the south pole of magnet.
- Mark the new position of its north pole.
- Repeat this until the other end of magnet is reached.
- Join the points.
- Similarly, place the compass at different points near the North Pole of the magnet and map the lines of force.

Observations:

These points form a curve. The curve line represents magnetic lines of force.

Activity 3:

Patterns of magnetic lines of force

A: Pattern due to bar magnet:

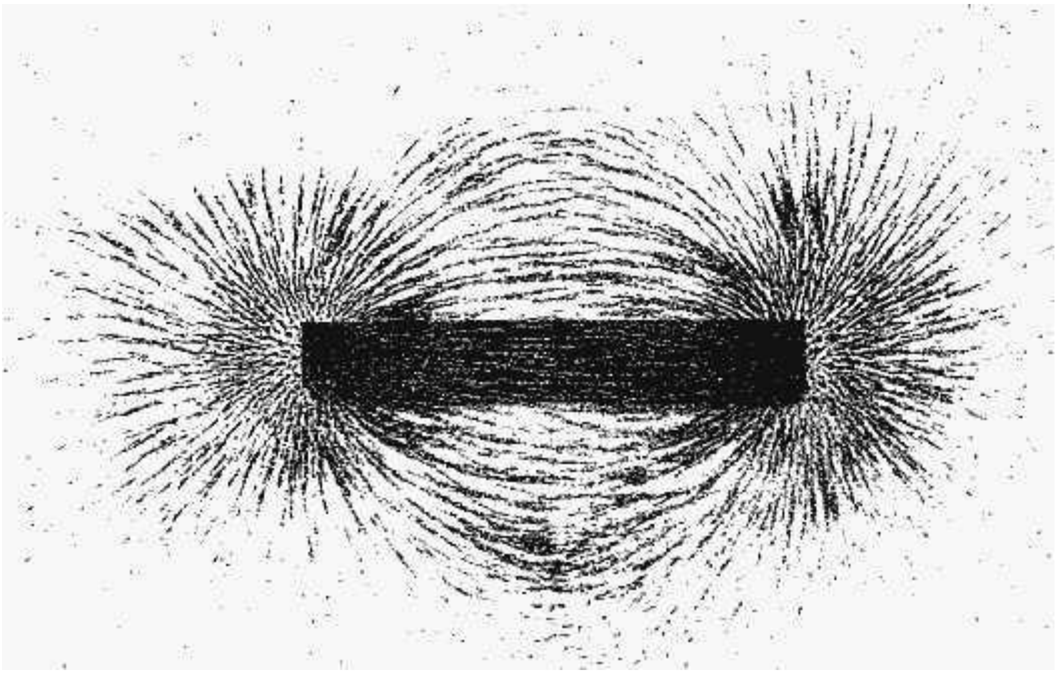


Figure: Patterns of Magnetic Lines of Force around a magnet

Procedure:

1. Place a bar Magnet on a card board.
2. Sprinkles some iron filings on a piece of paper and place it on the magnet.
3. Tap the paper gently.

Observation:

The iron filings arrange themselves in a specific pattern.

B: patterns due to bar magnets placed with opposites poles facing each other:

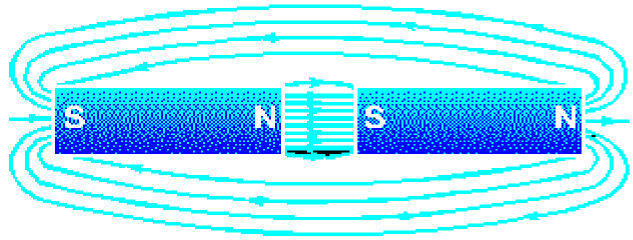


Figure: Unlike poles attract each other

Procedure:

1. Place two bar magnets with their poles adjacent to each other.
2. Sprinkles some iron filings on a piece of paper and place it over the two magnets.
3. Tap the paper gently.

Observations:

Iron filings align themselves about the bar magnets.

C: pattern due to two bar magnets placed with likes poles facing each other:

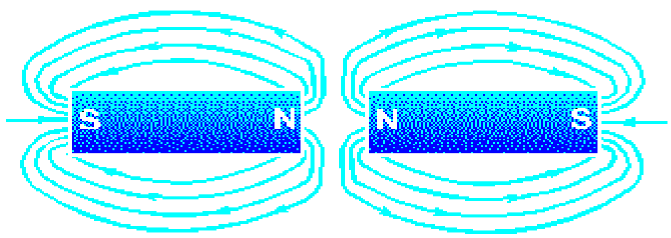


Figure: Like poles repel each other

Procedure:

1. Place two bar magnets with their like poles adjacent to each other.
2. Sprinkles some iron filings on a piece of paper and place it over the two magnets.
3. Tap the paper gently.

Observations:

Iron filings align themselves about the bar magnet.

Activity 4:

Properties of magnetic lines of force

Let us summarize the properties of magnetic lines of force.

1. They are closed and continuous curves.
2. Outside the magnets, the lines of are directed from the North Pole towards the south pole of the magnet, where as within the magnet the magnetic lines are directed from the South Pole towards the North Pole.
3. Lines of force repel each other.
4. Lines of force never intersect.

Review Questions

Q1. How do you define a MAGNET?

Q2. Outside the magnet, the direction of magnetic lines of force is from North-Pole to South-Pole while, inside the magnet, it is from South-Pole to North-Pole. Explain why?

Q3. Why the magnetic lines of force never intersect each other?

Practical No.3

Objective

To analyse & calculate the effect of No. of turns of a solenoid coil carrying a ferromagnetic core inside, on the magnetic field strength

Apparatus

Copper wire, demagnetized iron bar, DC source

Theory

A solenoid is a coil wound into a tightly packed helix. The term solenoid refers to a long, thin loop of wire, often wrapped around a metallic core, which produces a magnetic field when an electric current is passed through it. Solenoids are important because they can create controlled magnetic fields and can be used as electromagnets.

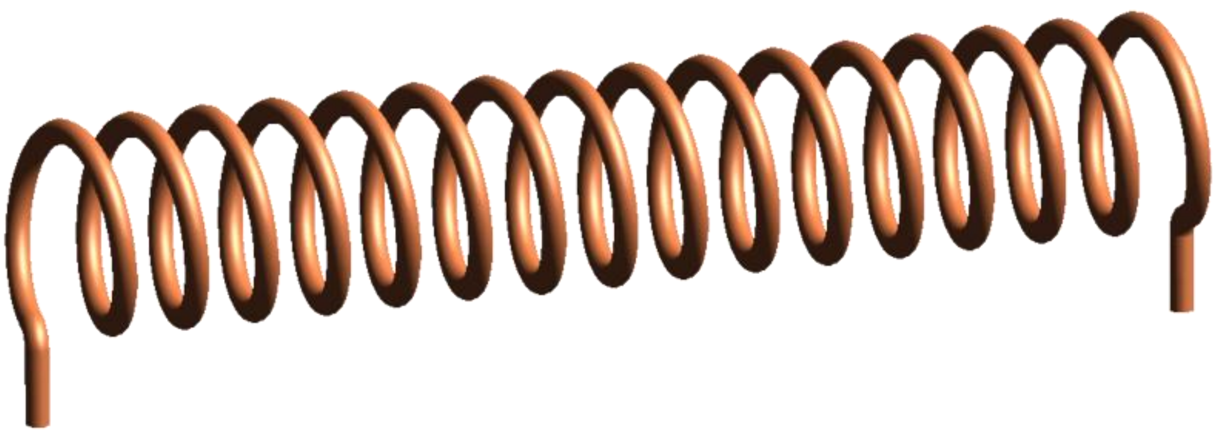
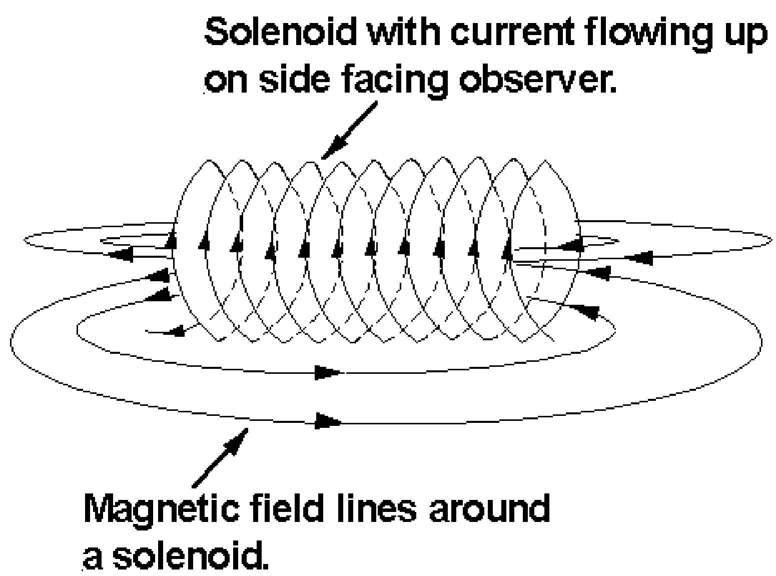


Figure: A Solenoid Coil without Core



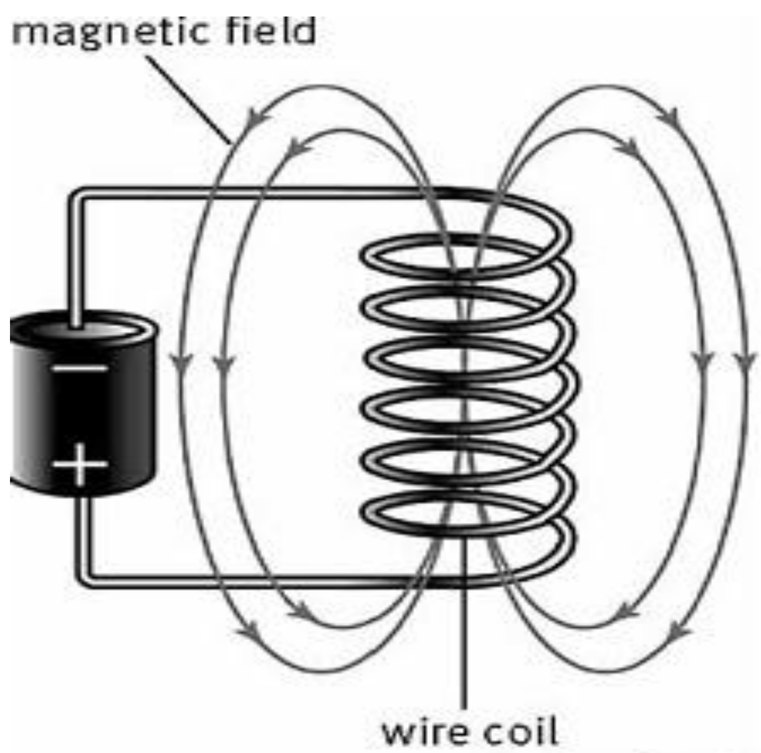


Figure: Electromagnetic solenoid coil

If a current flows in the coil, a magnetic field is generated. All the randomly oriented domains of the iron core then align in the presence of the field of the solenoid. Thus, the core greatly enhances the strength of the electromagnet.

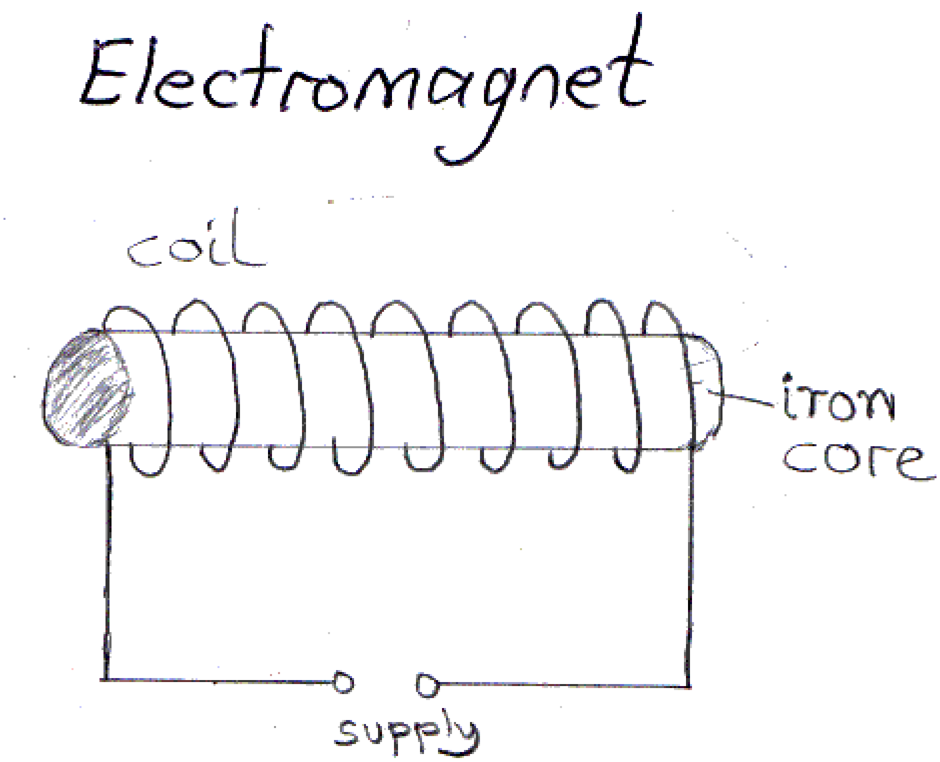


Figure: Solenoid with Iron Core

The magnetic field strength around the solenoid can be calculated as:

$$\mathbf{H=4\pi ni/l}$$

Where

H = Magnetic Field Strength in Tesla (T)

n = No. of Turns of coil

i = Current in Ampere (A)

l = Length of Solenoid in meters (m)

Procedure

Calculations

Observations

Review Questions

Q1. What is ferromagnetism? List down atleast three (03) ferromagnetic metals?

Q2. How do you define an electromagnet?

Q3. What is a demagnetized Fe bar? How can you demagnetize a magnetized Fe bar?

Q4. Why the magnetic field strength of the solenoid has been increased by placing a ferromagnetic core inside?

Q5. If an AC current is passed through a ferromagnetic Ni or Cobalt bar, what will be its effect on the magnetic domains?

Practical No.4

Objective

To study different electrical power transformer core materials and their effects on core losses

Theory

Transformer is a device that transfers electric energy from one circuit to another, usually with a change in voltage. Transformers are important in the distribution of electric power. They raise the voltage of the electricity generated at a power plant to the high levels needed to transmit the electricity efficiently. Other transformers reduce the voltage at the locations where the electricity is used. Many household devices contain transformers to raise or lower house-current voltage as needed. Television sets and stereo equipment, for example, require high voltages; doorbells and thermostats, low voltages.

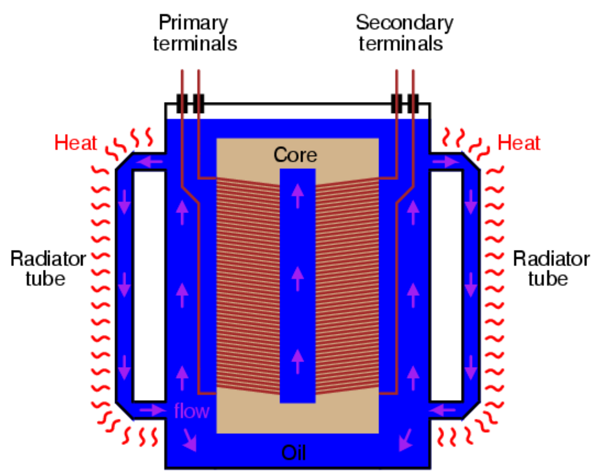
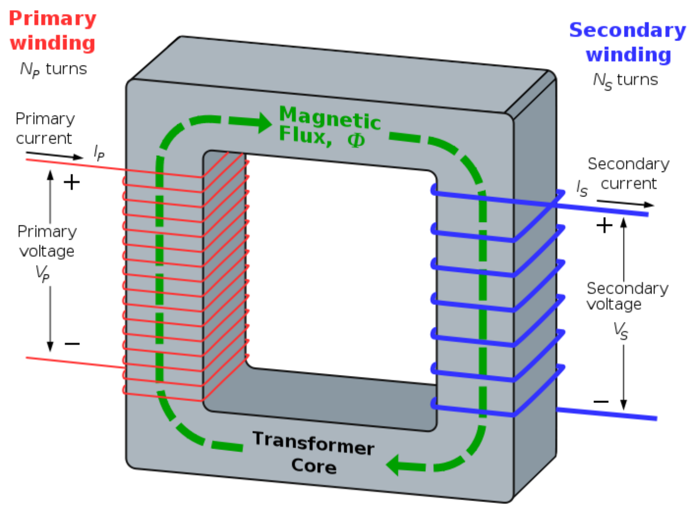


Figure: Core type Transformer

A simple transformer consists essentially of two coils of insulated wire. In most transformers, the wires are wound around an iron-containing structure called the core. One coil, called the primary, is connected to a source of alternating current that produces a constantly varying magnetic field around the coil. The varying magnetic field, in turn, produces an alternating current in the other coil. This coil, called the secondary, is connected to a separate electric circuit.



If a load is connected to the secondary, an electric current will flow in the secondary winding and electrical energy will be transferred from the primary circuit through the transformer to the load. In an ideal transformer, the induced voltage in the secondary winding (Vs) is in proportion to the primary voltage (Vp), and is given by the ratio of the number of turns in the secondary (Ns) to the number of turns in the primary (Np) as follows:

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

By appropriate selection of the ratio of turns, a transformer thus allows an alternating current (AC) voltage to be "stepped up" by making Ns greater than Np, or "stepped down" by making Ns less than Np.

Core Losses

1. Hysteresis losses

Each time the magnetic field is reversed, a small amount of energy is lost due to hysteresis within the core. For a given core material, the loss is proportional to the frequency, and is a function of the peak flux density to which it is subjected.

2. Eddy current Losses

Ferromagnetic materials are also good conductors, and a core made from such a material also constitutes a single short-circuited turn throughout its entire length. Eddy currents therefore circulate within the core in a plane normal to the flux, and are responsible for resistive heating of the core material. The eddy current loss is a complex function of the square of supply frequency and inverse square of the material thickness. Eddy current losses can be reduced by making the core of a stack of plates electrically insulated from each other, rather than a solid block; all transformers operating at low frequencies use laminated or similar cores.

Core Material

Soft iron

"Soft" iron is used in magnetic assemblies, electromagnets and in some electric motors; and it can create a concentrated field that is as much as 50,000 times more intense than an air core. Iron is desirable to make magnetic cores, as it can withstand high levels of magnetic field without saturating (up to 2.16 teslas at ambient temperature.

Unfortunately, due to the electrical conductivity of the metal, at AC frequencies a bulk block or rod of soft iron can often suffer from large eddy currents circulating within it that waste energy and cause undesirable heating of the iron.

Typical EI Lamination

Laminated magnetic cores are made of thin, insulated iron sheets. Using this technique, the magnetic core is equivalent to many individual magnetic circuits, each one receiving only a small fraction of the magnetic flux (because their section is a fraction of the whole core section). Furthermore, these circuits have a resistance that is higher than that of a non-laminated core, also because of their reduced section. From this, it can be seen that the thinner the laminations, the lower the eddy currents.

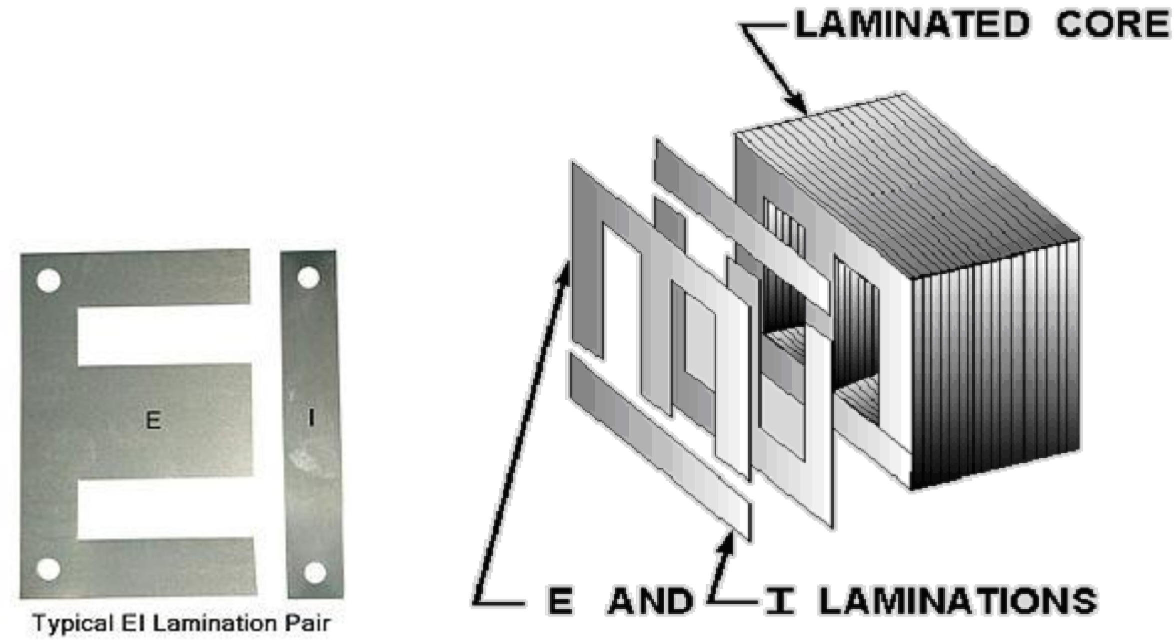


Figure: Core EI Construction

Iron-Silicon alloy

A small addition of silicon to iron (around 3%) results in a dramatic increase of the resistivity, up to four times higher. Further increase in silicon concentration impairs the steel's mechanical properties, causing difficulties for rolling due to brittleness.

Among the two types of silicon steel, grain-oriented (GO) and grain non-oriented (GNO), GO is most desirable for magnetic cores. It is anisotropic, offering better magnetic properties than GNO in one direction. As the magnetic field in inductor and transformer cores is static (compared to that in electric motors), it is possible to use GO steel in the preferred orientation.

Review Questions

Q1. Why ferromagnetic cores are used in electrical power transformers?

Q2. In electrical power transformers, the cores are usually made of soft magnetic materials. Why? Explain the reason.

Q3. If a hard magnetic material or a permanent magnet is used as transformer core, what will happen?

Q4. What do you understand by core hysteresis losses?

Q5. What is EDDY-CURRENT?

Q6. What do you understand by core eddy-current losses?

Q7. How transformer core losses can be reduced?

Practical No.5

Objective

To study the fabrication process of Silicon nanowires using VLS technique

Apparatus

CVD system (tube furnace, quartz tubes), carrier gas, inert gas, control panels, Silicon substrates etc

Theory

Nanowire

Nanowires are one dimensional structures fabricated at nano scale used as primarily building block materials for electronic devices.

VLS technique

VLS stands for Vapor Liquid Solid mechanism for nanowire growth. In this process an impurity or catalyst is purposely introduced to direct and confine the wire growth on a specific orientation on a confined area. This is a three step process:

1. Ramping up (rising the temperature)
2. Holding up (keeping temperature constant)
3. Cooling down

Procedure

The susbstrate is first placed in the transparent tube of diameter 2 cm and then this tube is inserted in another tube of wider diameter of 3cm which is placed in the tube furnace.

Evacuation is carried out first before starting the three step process. Then the furnace is started to rise in its temperature for 20 degree C per minute. When the temperature meets the melting point of the catalyst metal the carrier gas is allowed to flow which first enters the precursor source and carries it along with then is allowed to flow into the chamber. Here as the melting temperature of the catalyst has met so the catalyst is in liquid form and as the carrier gas vapor enters the chamber it interacts with the liquid droplets of catalyst and in this way the solid nanowire growth starts.

As the precursor inlet flow is disconnected the cooling down of the furnace is sarted. And after cooling down the samples are ejected of the furnace and ready to be characterized.

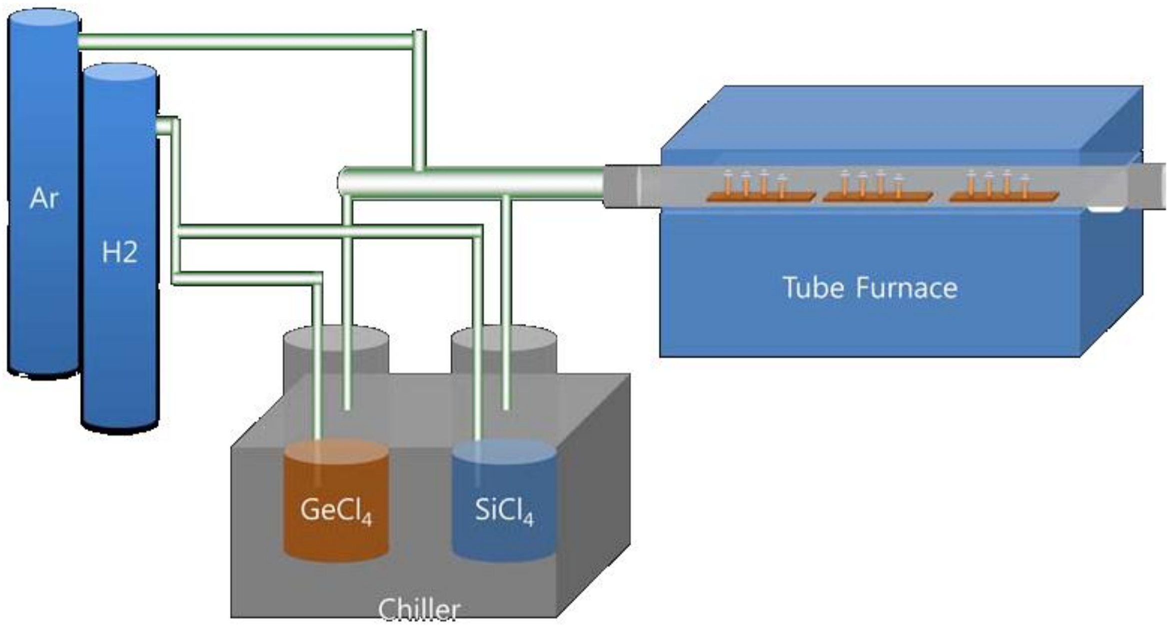


Figure: VLS System

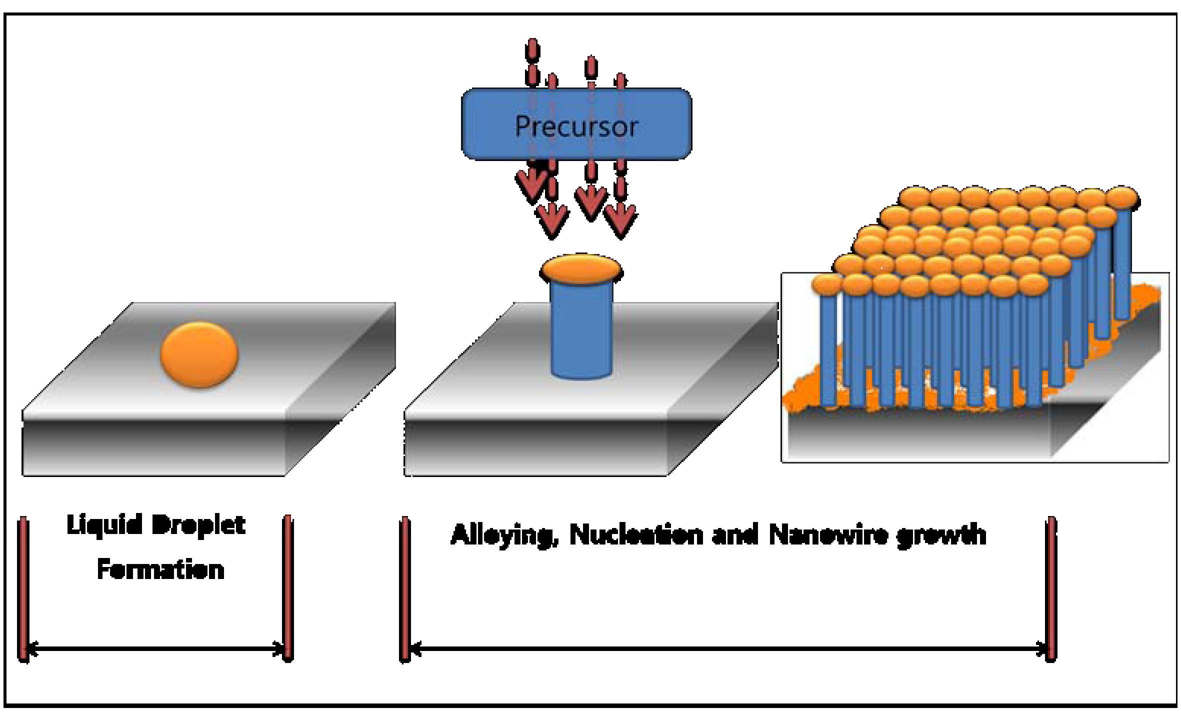


Figure: Steps involved during VLS process

Review Questions

Q1. Why the nanowire grows?

Q2. How the required diameter of the wire can be achieve?

Q3. What are the applications of Si nanowires?

Q4. What is difference between nanowires and nanotubes?

Practical No.6

Objective

To characterize the Silicon nanowires by using Scanning Electron Microscope (SEM)

Apparatus

SEM, DI water, stirrer, Hydro floric acid, platinum coater, handling tools

Theory

Si nanowires can be characterized to see their morphology, dimensions. This characterization can be carried out using different microscopes like SEM, TEM, AFM etc. this depends upon the purpose of view.

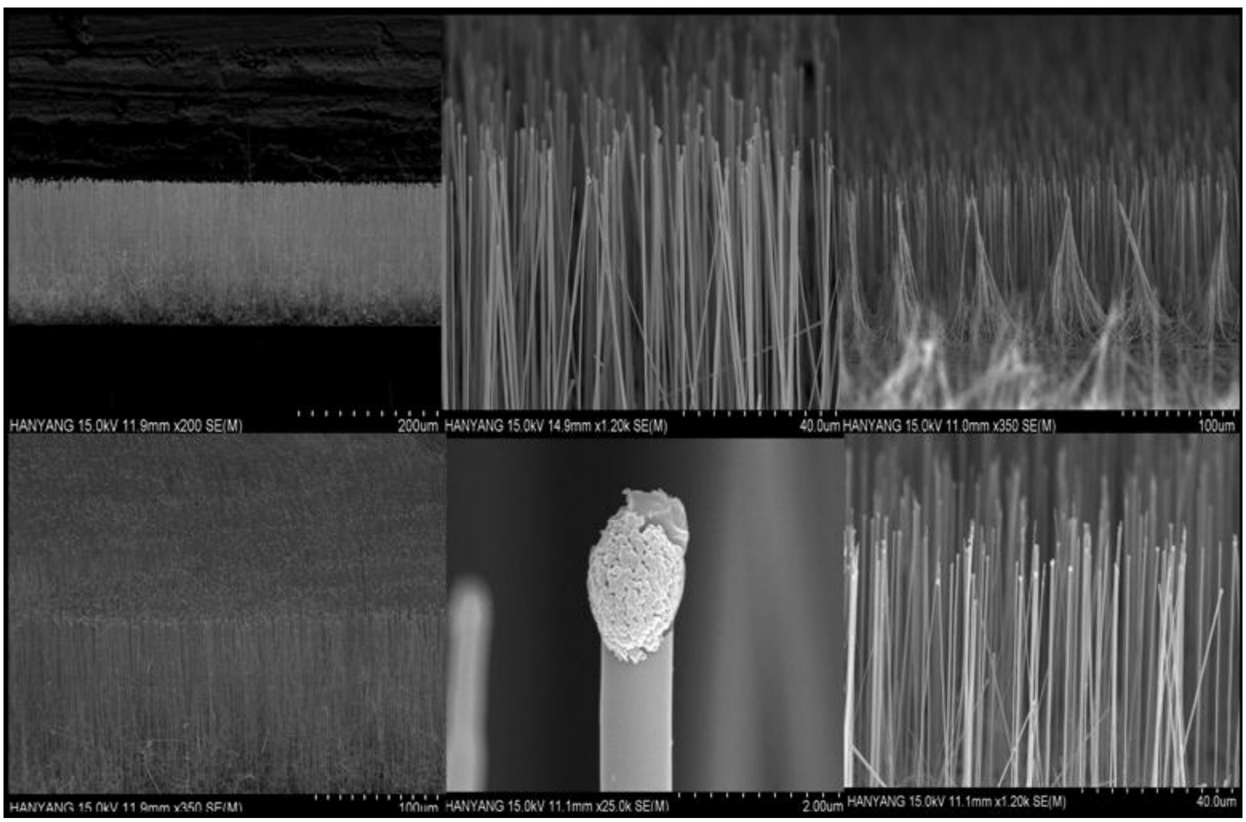


Figure: Cross-sectional SEM images of Si nanowires

Procedure

The substrates containing nanowires are first treated with a stirred solution of HF+ DI water to remove oxide layer. Then the samples are dried by nitrogen gas. The samples then are placed in platinum coater to provide a thin platinum layer on the substrate surface. Now the substrate is ready for SEM analysis. First the samples are loaded on boat and the boat is then loaded into the SEM. After some time as the electron scan the surface of the substrate and display the surface information on the monitor connected to the machine. There we can see the wire geometry and morphology.

Review Questions

Q1. Why platinum layer is applied to substrate?

Q2. What is the difference b/w SEM and TEM

Q3. Draw the process flow sheet of this experiment.

Practical No. 7

Objective

To study the Shape Memory Alloy Effect

Theory

Shape Memory Alloys

Shape Memory Alloys (SMAs) are a unique class of metal alloys that can recover apparent permanent strains when they are heated above a certain temperature. The SMAs have two stable phases - the high-temperature phase, called austenite and the low-temperature phase, called martensite. In addition, the martensite can be in one of two forms: twinned and detwinned, as shown in Figure 1. A phase transformation which occurs between these two phases upon heating/cooling is the basis for the unique properties of the SMAs. The key effects of SMAs associated with the phase transformation are pseudoelasticity and shape memory effect.

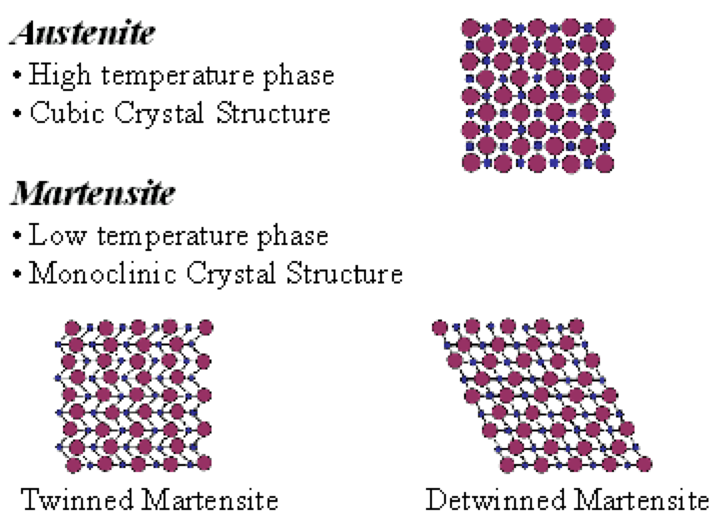


Figure: 1 Different phases of an SMA.

Upon cooling in the absence of applied load the material transforms from austenite into twinned (self-accommodated) martensite. As a result of this phase transformation no observable macroscopic shape change occurs. Upon heating the material in the martensitic phase, a reverse phase transformation takes place and as a result the material transforms to austenite. The above process is shown in Figure 2.

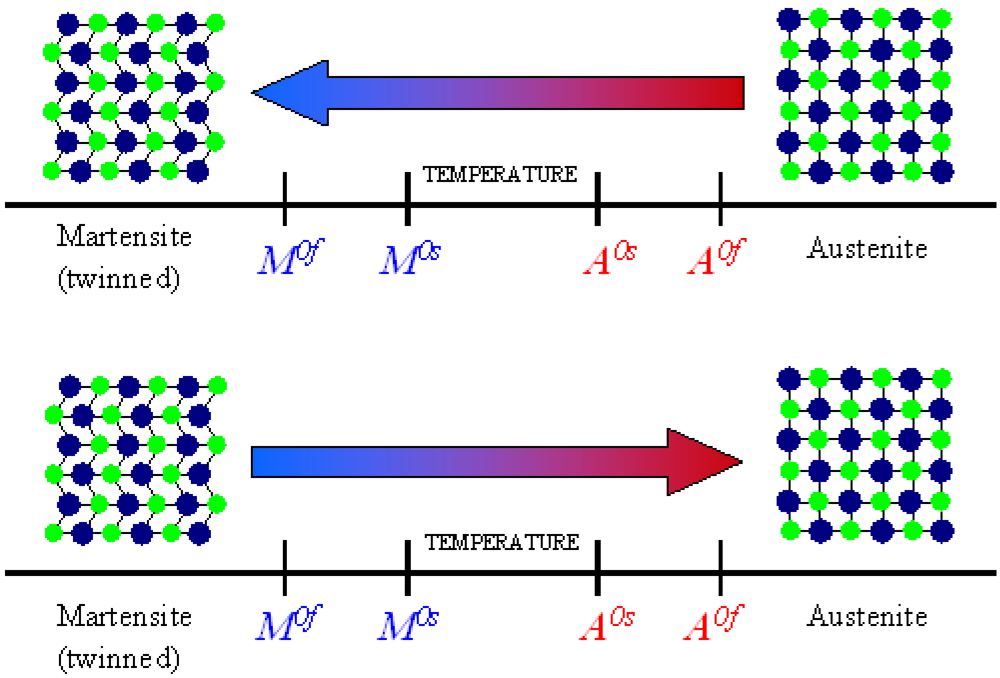


Figure: 2 Temperature-induced phase transformation of an SMA without mechanical loading.

Thermally-Induced Transformation with Applied Mechanical Load

If mechanical load is applied to the material in the state of twinned martensite (at low temperature) it is possible to detwin the martensite. Upon releasing of the load, the material remains deformed. A subsequent heating of the material to a temperature above A0f will result in reverse phase transformation (martensite to austenite) and will lead to complete shape recovery, as shown in Figure 3. The above described process results in manifestation of the Shape Memory Effect (SME).

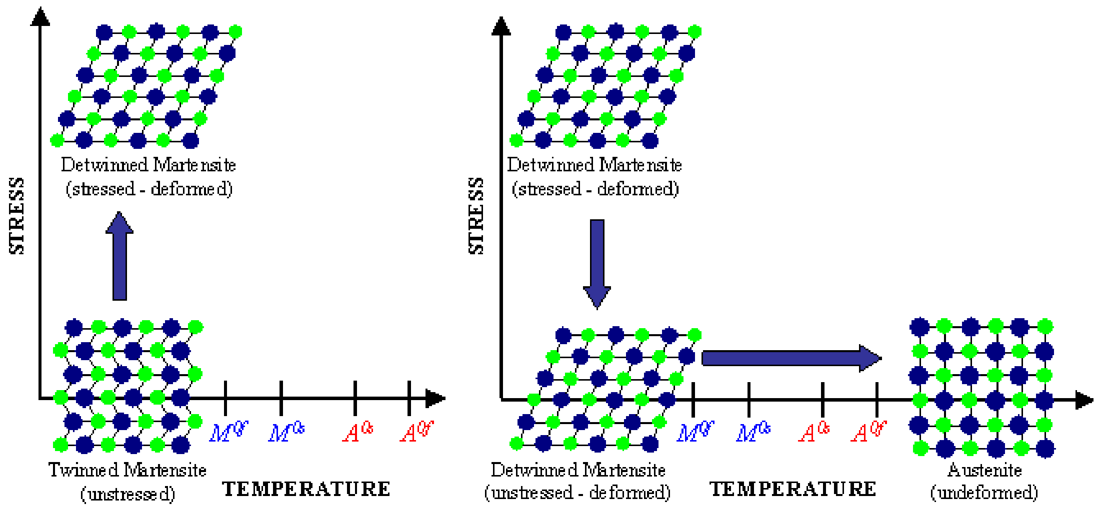


Figure: 3 Shape Memory Effect of an SMA

It is also possible to induce a martensitic transformation which would lead directly to detwinned martensite. If load is applied in the austenitic phase and the material is cooled, the phase transformation will result in detwinned martensite. Thus, very large strains (on the order of 5-8%) will be observed. Reheating the material will result in complete shape recovery. The above-described loading path is shown in Figure 4.

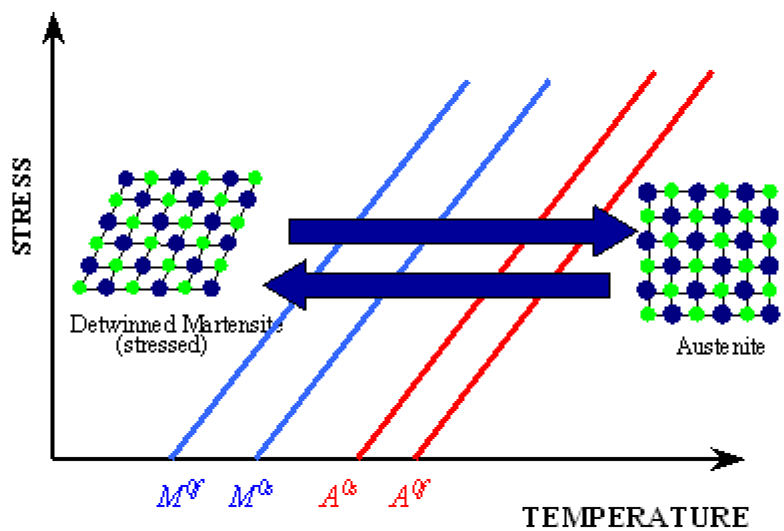


Figure: 4 Shape Recovery of an SMA

Review Questions

Q1. What is shape memory effect?

Q2. Why shape memory alloys regain their pre-deformed shape on heating above a certain temperature? Explain the reason.

Q3. What is pseudo elasticity?

Q4. How detwinned martensite can be produced directly from austenite?

Q5. How many stable phases do shape memory alloys have?

Q6. Write down some applications of shape memory alloys.