Thin Film Technology and its Applications

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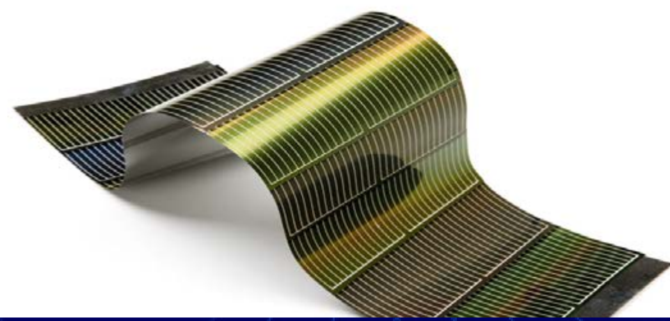
Define Thin Film

What is a "thin film" ?

- ***A thin film is a layer of material ranging from fractions of a nanometer (monolayer) to several micrometers in thickness. Thin film technology is a "self organizing" structural evolution.***
- ***Ex: In ancient times, people already knew how to beat gold into a thin film (< 1 μm thickness) with hammers and knew how use this "gold leaf" for coating allkinds of stuff.***



- thin = less than about one micron (10,000 Angstroms, 1000 nm) film = layer of material on a substrate

Thin Films

Ultra thin films (50-100 Å)	Very thin films (100 - 1000 Å)	Thick films (>1000 Å)

- *Homogeneous solid material into two directions (x,y)*
- *z- thickness of the film.*
- *Bulk to thin.*
- *Electrical and optical properties*
- *Reliability of performance.*

Applications

Mainly used for:

1. Electronic semiconductor devices.
2. Optical coating.

Examples:

- Household mirror.
- Two way mirrors.
- Larry bell.

Applications

Examples:

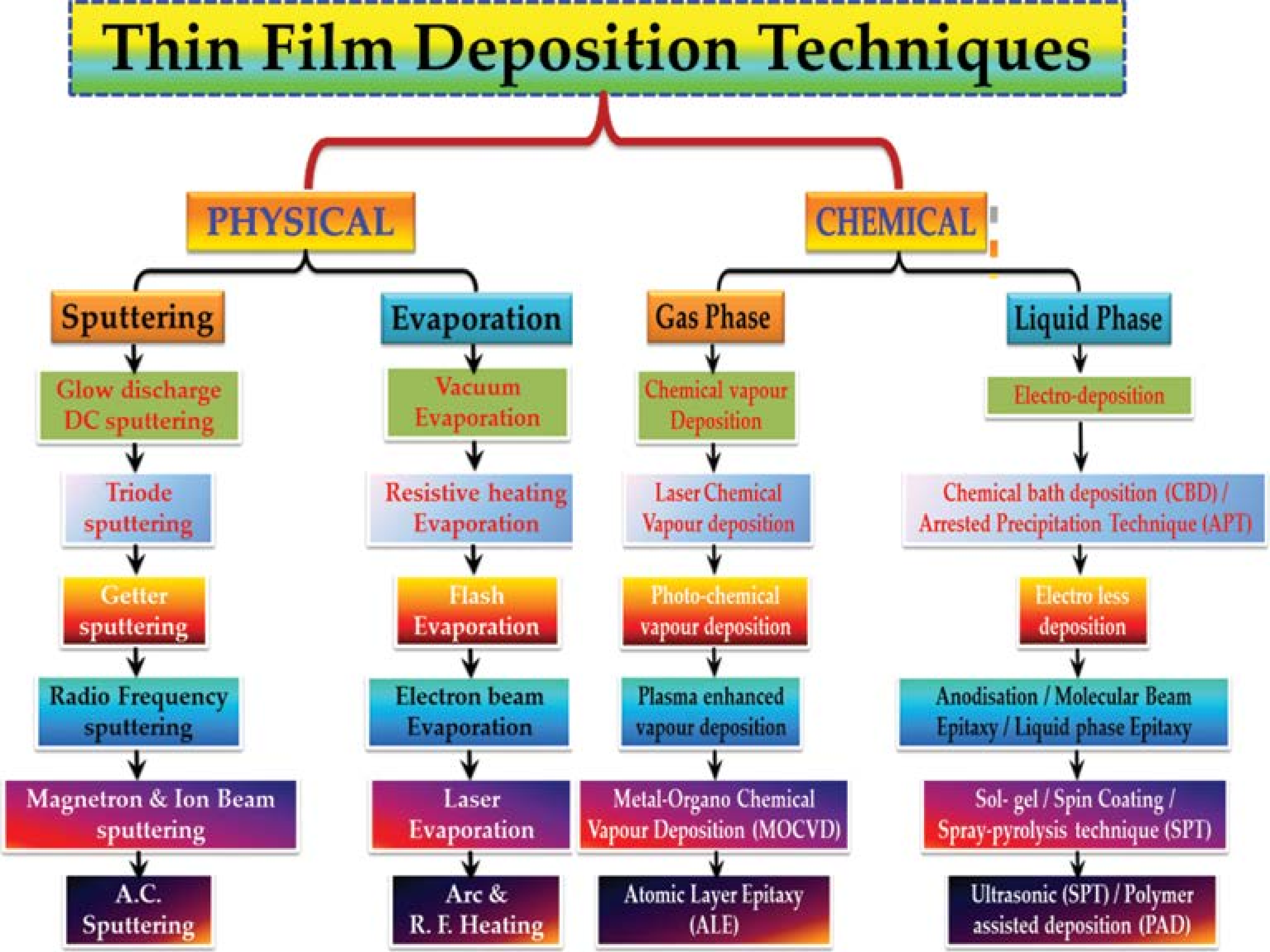
- **AR coating.**
- **Thin film drug delivery.**
- **Dye-sensitized solar cell Ceramic thin films.**
- **Thin film photo voltaic cells.**

Thin Film Technology

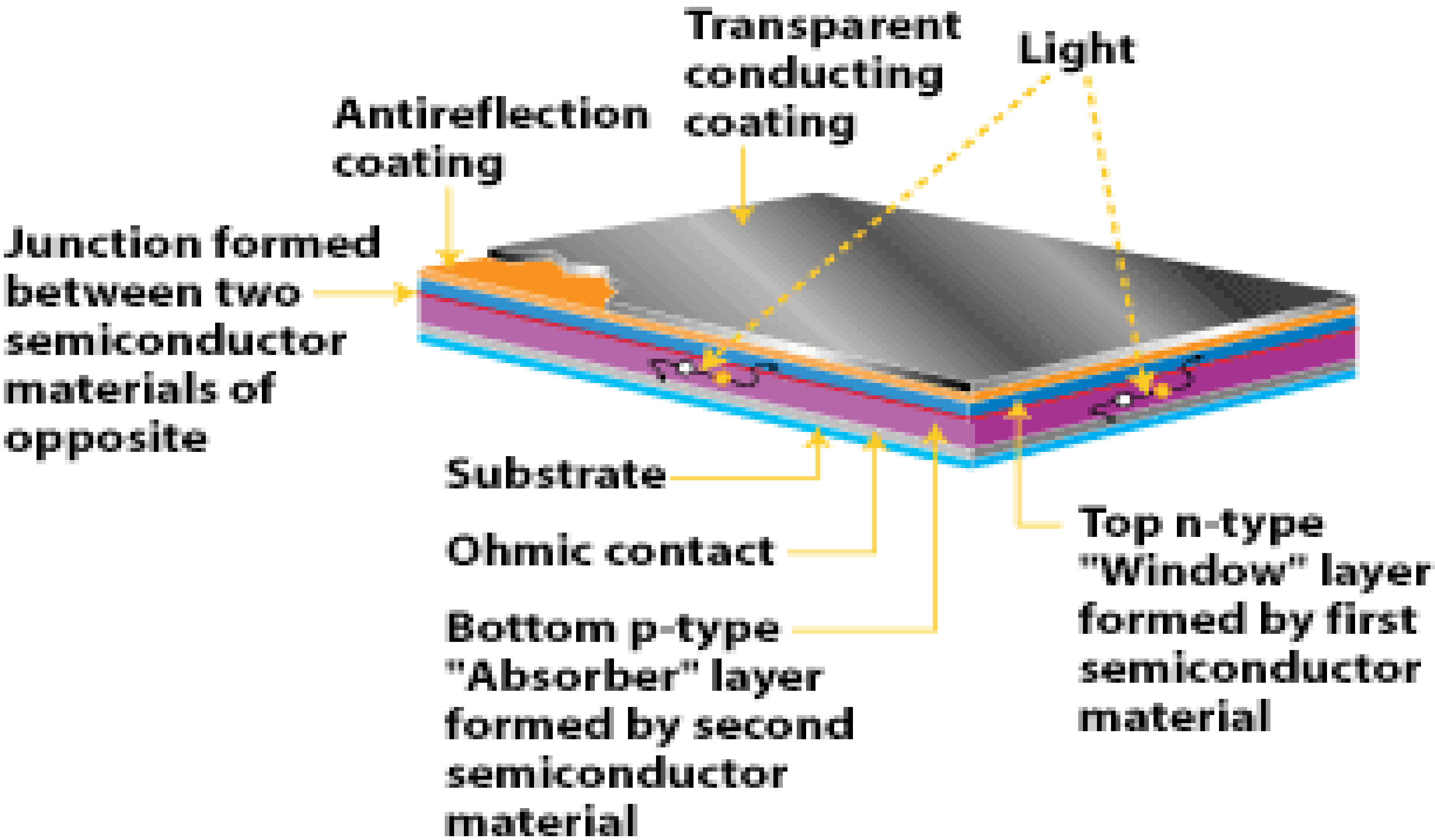
- Thin film technology involves deposition of individual molecules or atoms.
- “Uniform ultra-thin film coatings onto stents, catheters, balloons, endoscopic instruments, pacemakers, heart valves, glucose monitors, sensors, medical textiles, blood collection tubes, surgical implants.


China Glass
Network

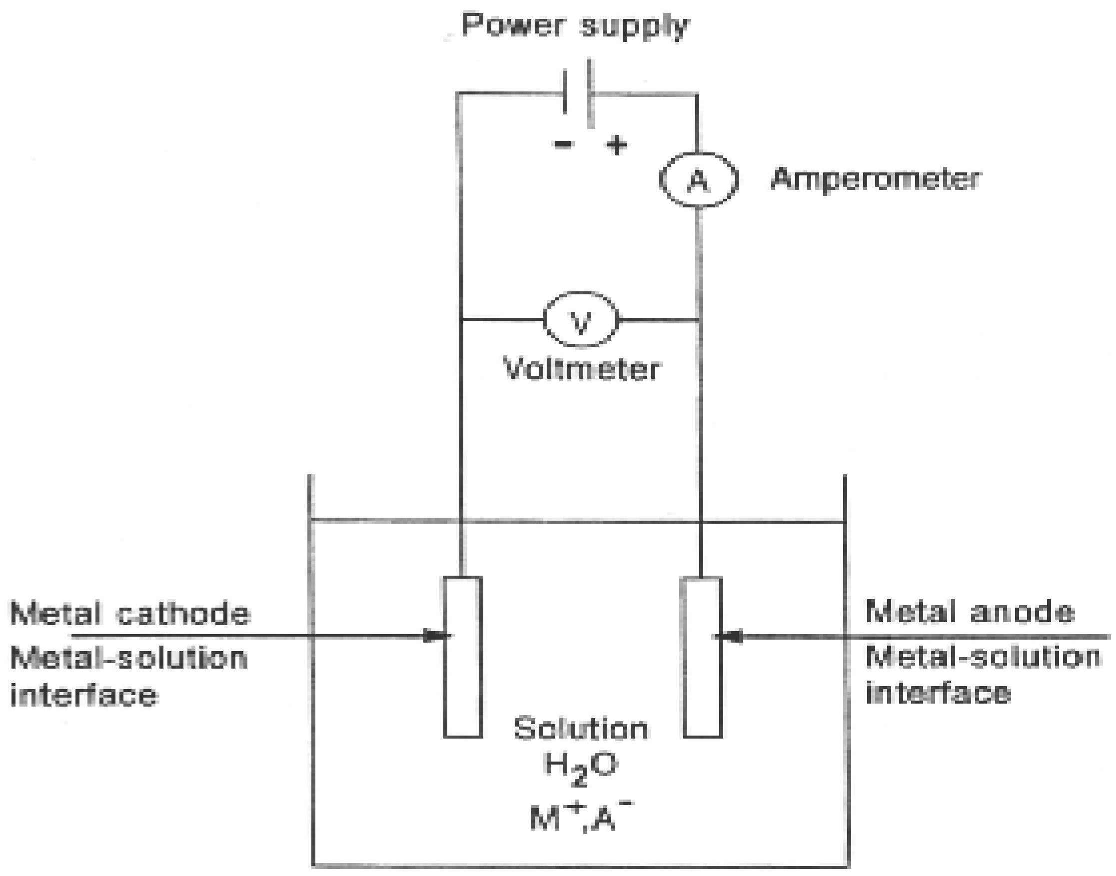
AR Coating


Thin Film Deposition Techniques
PHYSICAL
CHEMICAL
Sputtering
Evaporation
Gas Phase
Liquid Phase
Glow discharge DC sputtering
Triode sputtering
Getter sputtering
Radio Frequency sputtering
Magnetron & Ion Beam sputtering
A.C. Sputtering
Vacuum Evaporation
Resistive heating Evaporation
Flash Evaporation
Electron beam Evaporation
Laser Evaporation
Arc & R. F. Heating
Chemical vapour Deposition
Laser Chemical Vapour deposition
Photo-chemical vapour deposition
Plasma enhanced vapour deposition
Metal-Organo Chemical Vapour Deposition (MOCVD)
Atomic Layer Epitaxy (ALE)
Electro-deposition
Chemical bath deposition (CBD) / Arrested Precipitation Technique (APT)
Electro less deposition
Anodisation / Molecular Beam Epitaxy / Liquid phase Epitaxy
Sol- gel / Spin Coating / Spray-pyrolysis technique (SPT)
Ultrasonic (SPT) / Polymer assisted deposition (PAD)

Thin film PV cells



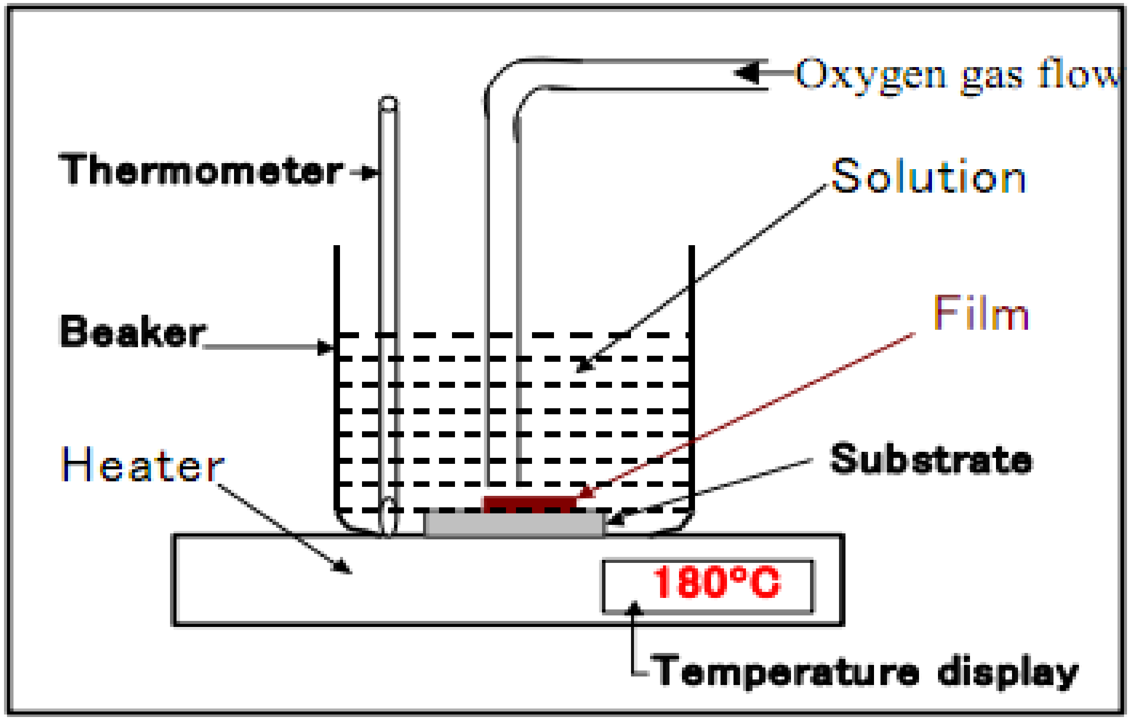
Electro deposition method



Electro deposition method

- The role of the reference electrode is to establish a stable potential.
- On the other hand, the function of the counter electrode is to convert ionic conduction in the electrolyte to electronic conduction by electrochemical reaction.
- Deposited material properties, i.e., structural, electrical and optical properties of the film were influence by several parameters, such as ionic concentrations, stirring rate, temperature, pH, and deposition voltage and deposition time

Chemical bath deposition.

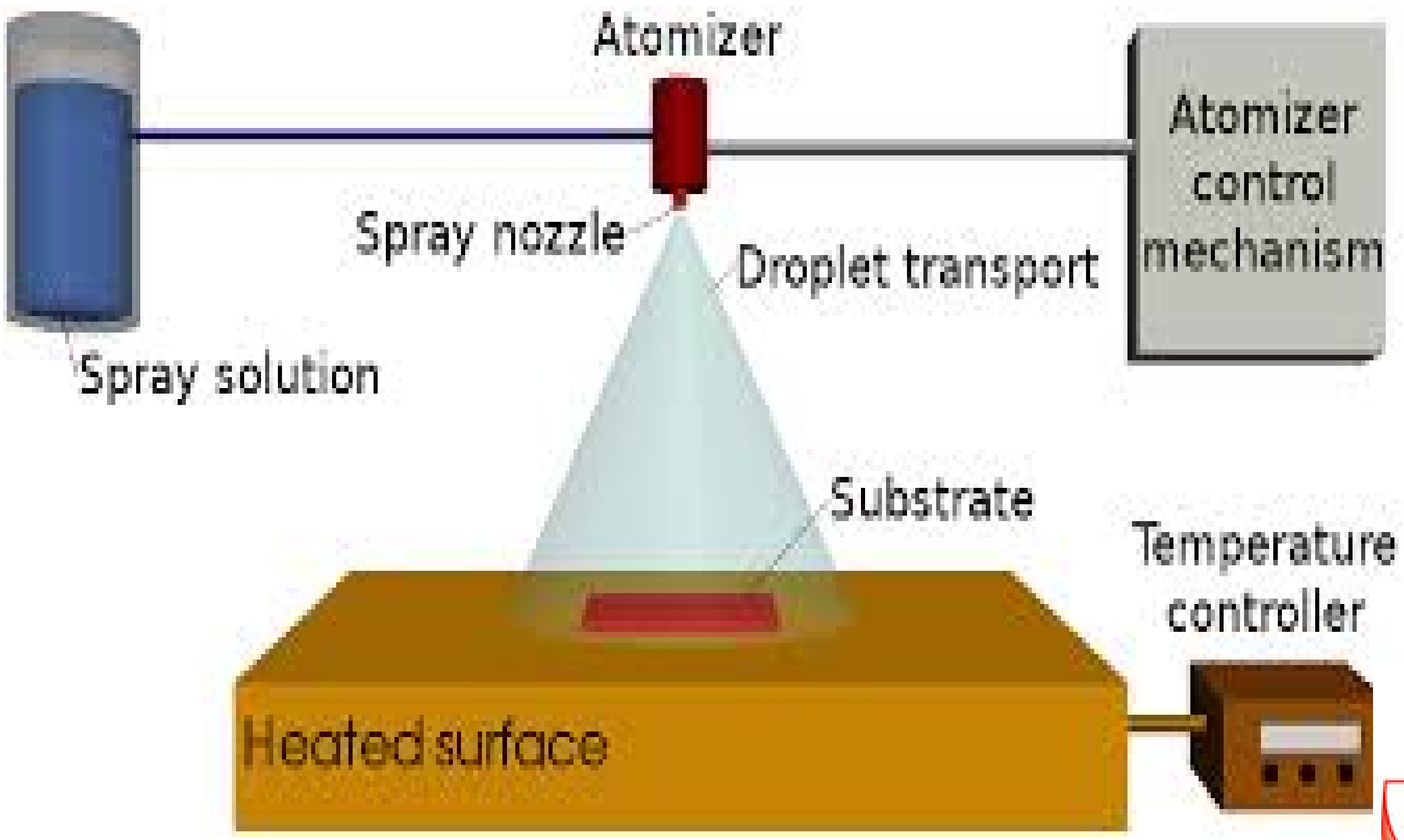


The technology is based on slow controlled precipitation of the desired compound from its ions in a reaction bath solution.

Advantages of CBD:

- **The advantages of the CBD techniques are low cost, large area deposition and relatively low deposition temperature (usually less than 80^{o}C).**

Spray Pyrolysis



- **Spray pyrolysis technique involves spraying of a solution containing soluble salts of the desired compound on to preheated substrates, where the constituents react to form a chemical compound.**

- **The basic principle involved in spray pyrolysis technique is pyrolytic decomposition of salts of a desired compound to be de deposited**.

ADVANTAGES

- Spray pyrolysis is a simple and low-cost technique for the preparation of semiconductor thin films.

- It has capability to produce large area, high quality adherent films of uniform thickness.

- Spray pyrolysis does not require high quality targets and /or substrates nor does it require vacuum at any stage, which is a great advantage if the technique is to be scaled up for industrial applications.

Key advantages of every method

- **Uniform films over large area.**
- **Irregularly shaped surfaces.**
- **Non equillibrium alloys.**
- **Minimal quantity of electrolytic solution used.**

Key advantages of every method

- Prevents overheating.
- Wide range of industrial experience.
- Attractive in terms of cost, high throughput and scalability .

Coating Processes

Electro deposition

Chemical coating

Conversion coating

Spraying

Welding

Molecular beam epitaxy

Vapour deposition

Chemical vapour deposition

Physical vapour deposition

Electrochemical deposition

- **Advantages**
- Low temperature treatment
- High hardness
- Low friction
- Applicable to a wide range of metal substrates
- Thick layers possible

- **Disadvantages**
- Poor thickness uniformity on complex components
- Hydrogen embrittlement
- Not applicable to insulating substrates
- Possible environmental concerns with plating baths

electr chemica.mp4

Chemical Coatings

- **Advantages**
- Low temperature treatment
- More corrosion resistant than electrodeposited chromium
- Can coat complex shapes uniformly
- Hard particles can be incorporated to increase hardness
- PTFE can be incorporated to reduce friction
- Can coat most metals and some insulators

- **Disadvantages**
- More expensive than electroplated chromium
- Heat treatment is needed to develop optimum properties

conversion chemical.3gp

Chemical Vapour Deposition (CVD)

- Gaseous compounds react to form a dense layer on a heated substrate. The most widely deposited wear-resistant coatings are TiC, TiN, chromium carbide and alumina. Deposition temperatures are generally in the range 800-1000°C which restricts the range of materials which can be coated and can lead to component distortion. Thicknesses are limited to about 10μm due to the thermal expansion mismatch stresses which develop on cooling which also restrict the coating of sharp edged components.

- **Advantages**
- High coating hardness
- Good adhesion (if the coating is not too thick)
- Good throwing power (i.e. uniformity of coating)
- **Disadvantages**
- High temperature process (distortion)
- Sharp edge coating is difficult (thermal expansion mismatch stresses)
- Limited range of materials can be coated
- Environmental concerns about process gases

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Physical Vapour Deposition (PVD)

- **Advantages**
- Excellent process control
- Low deposition temperature
- Dense, adherent coatings
- Elemental, alloy and compound coatings possible
- **Disadvantages**
- Vacuum processes with high capital cost
- Limited component size treatable
- Relatively low coating rates
- Poor throwing power without manipulation of components

- **low pressure coating processes in which the coating flux is produced by a physical process. There are two main types:-**
- Evaporation
- Sputtering
- In both cases the source material is a solid (metal or ceramic). A reactive gas may be used in the deposition chamber to deposit compound coatings from an elemental source or maintain the stoichiometry of coatings from compound sources. Typical coating thicknesses range from 1-10µm for wear-resistant coatings, though thinner layers are used in microelectronics and thicker layers are used for high temperature corrosion protection of gas turbine components.

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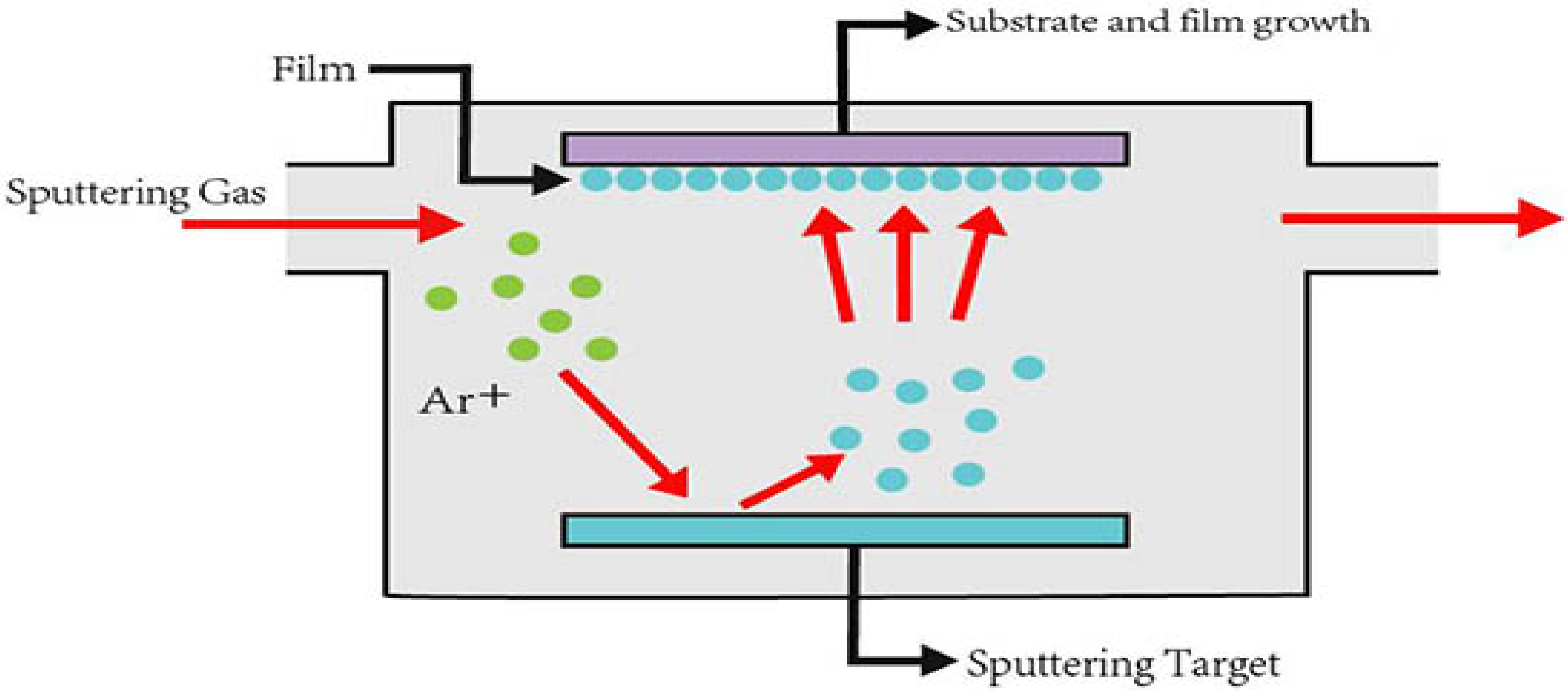
Advantage of thin film deposition: CVD and PVD

- CVD
  - Reactive gases interact with substrate
  - Used to deposit Si and dielectrics
  - Good film quality
  - Good step coverage
- PVD
  - Used to deposit metals
  - High purity
  - Line of sight

SPUTTERING PROCESSES



Sputtering Processes

- Main sputtering processes:-
- DC diode sputtering
  (for conducting targets)
- RF sputtering
  (for insulating targets)

- When energetic ions strike a surface, material is ejected by the transfer of momentum from the ion to the target atoms (akin to billiard ball collisions at the atomic scale). This can be conveniently achieved in a low pressure glow discharge of an inert gas such as argon.
- In such a process the target material is made the cathode and is raised to a potential of several hundred volts. Electrons leaving the cathode stream out into the gas phase where they can impact with argon atoms, ionising them. The positively charged argon is then accelerated to the cathode where it impacts and sputters away material.
- The sputtering yields of different elements for given impact conditions do not vary very much so target alloy compositions can be maintained in the coating except in cases where there are large differences in the atomic weights of alloy constituents.

The coating rate scales with the electrical power used to sustain the discharge. The coating rate also depends on the plasma density, so techniques to increase this (e.g. by confining the electrons close to the target using magnets) will increase the coating rate. However, as much as 95% of the power is dissipated as heat in the target so good cooling is essential.

sputter.mp4

Ion Implantation

- **Advantages**
- Low temperature process
- Very versatile - every stable element in the periodic table can be implanted into any vacuum compatible target
- Highly controlled
- No distortion - can be applied to finished components
- Not a coating process
- **Disadvantages**
- Line of sight process
- Expensive vacuum equipment needed
- Very thin treated layer

- A vacuum process in which a beam of ions is directed at the surface and injected into it. The ions lose energy in collisions with the target atoms and come to rest in the surface layer of the material with an approximately Gaussian distribution. The ion penetration depth depends on the ion species, ion energy and target material, bur is generally less than 1μm. For steels the main ion used is nitrogen, which hardens the surface by forming nitride precipitates and solid solutions. The damage introduced by the implantation process also introduced a compressive residual stress which improves fatigue performance.

•Ion implantation is routinely used for semiconductor doping and treatment of expensive plastics injection moulding tools where any wear is detrimental.

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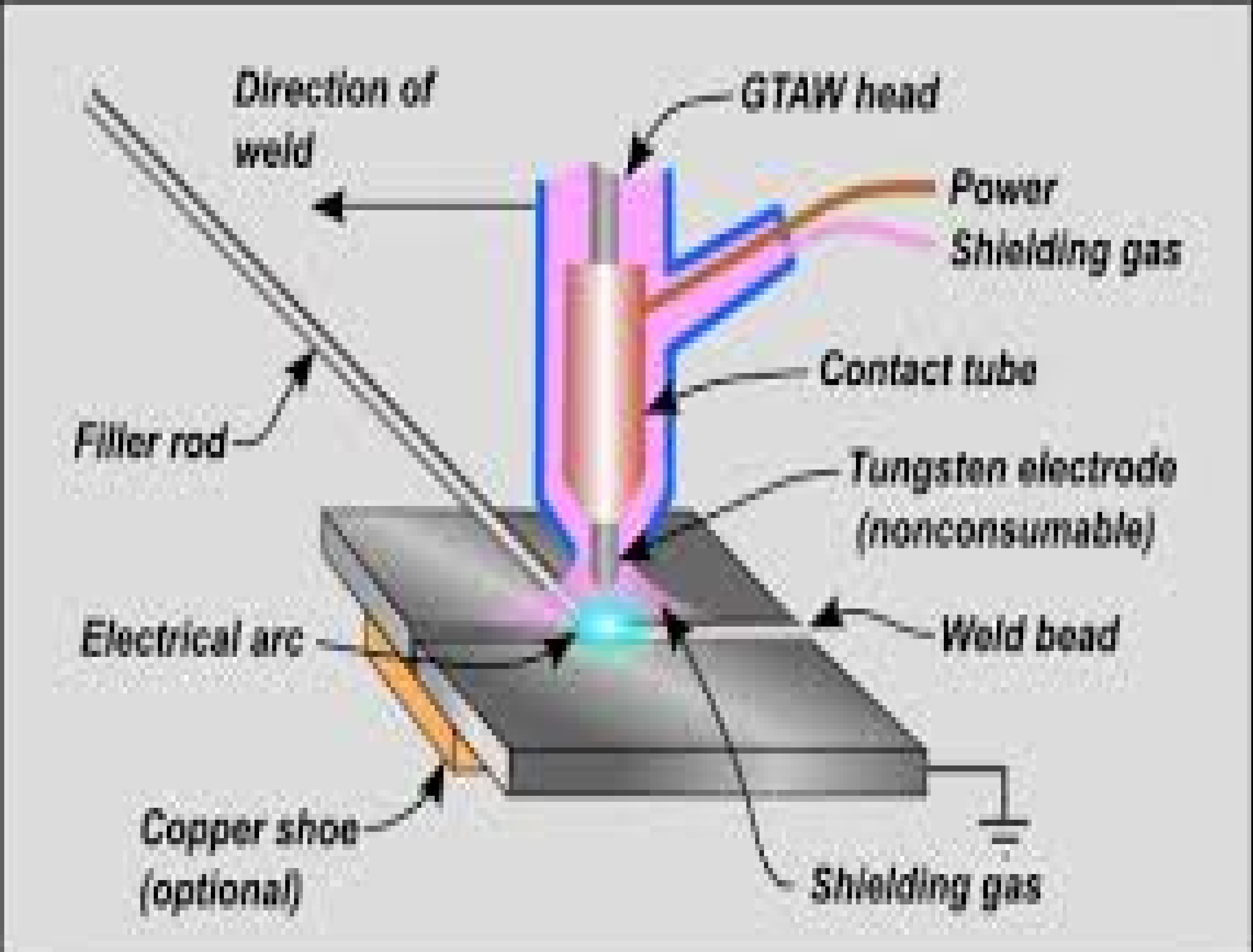
videoplayback ion implatation.mp4

Welding Processes

- **Advantages**
- Cheap
- Applicable to large components
- Localised coating possible
- Excellent adhesion
- **Disadvantages**
- Limited range of coating materials
- Minimum thickness limits

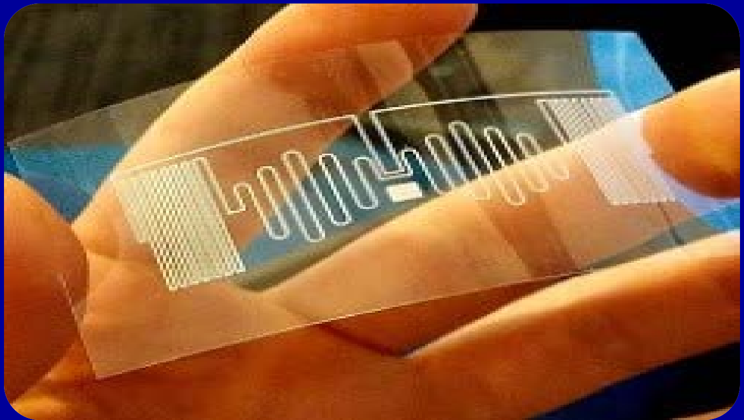
- The same methods which can be used for joining materials can be used to deposit wear resistant coatings (hardfacings). Coating materials range from low alloy steels to tungsten carbide composites.
- High deposition rates are possible and very thick coatings can be produced. It is impractical to produce layers less than 2-3mm thick.
- There can be problems with cracks in weld deposits



Direction of weld
GTAW head
Power
Shielding gas
Contact tube
Filler rod
Tungsten electrode (nonconsumable)
Electrical arc
Weld bead
Copper shoe (optional)
Shielding gas

Thin Film Advantages

- *Simple fabrication*
- *Requires low fabrication temp (300 °C)*
- *Manufacturing requires little materials. -thin cell to crystalline thickness= 1 to 300*
- *Flexible/ non-breakable o High voltage can be obtained*
- *No infrastructure needed to support cells*
- *Cell can double as building material (roofing tiles, walls, etc)*



Where can we apply it ??

- *Thin-film Batteries: Thin-film printing technology is being used to apply solid-state lithium polymers to a variety of substrates to create unique batteries for specialized applications. Thin-film batteries can be deposited directly onto chips or chip packages in any shape or size. Flexible batteries can be made by printing onto plastic, thin metal foil, or paper.*

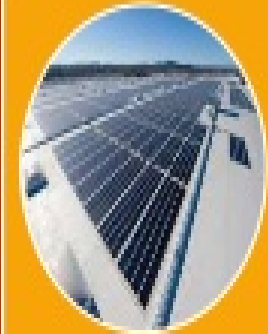
Applications of thin films

optics

electricity

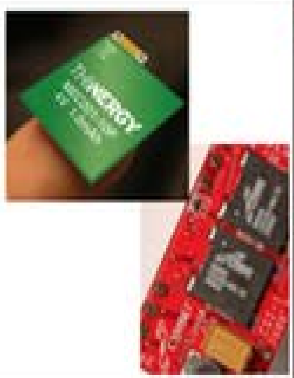
computer

magnetics

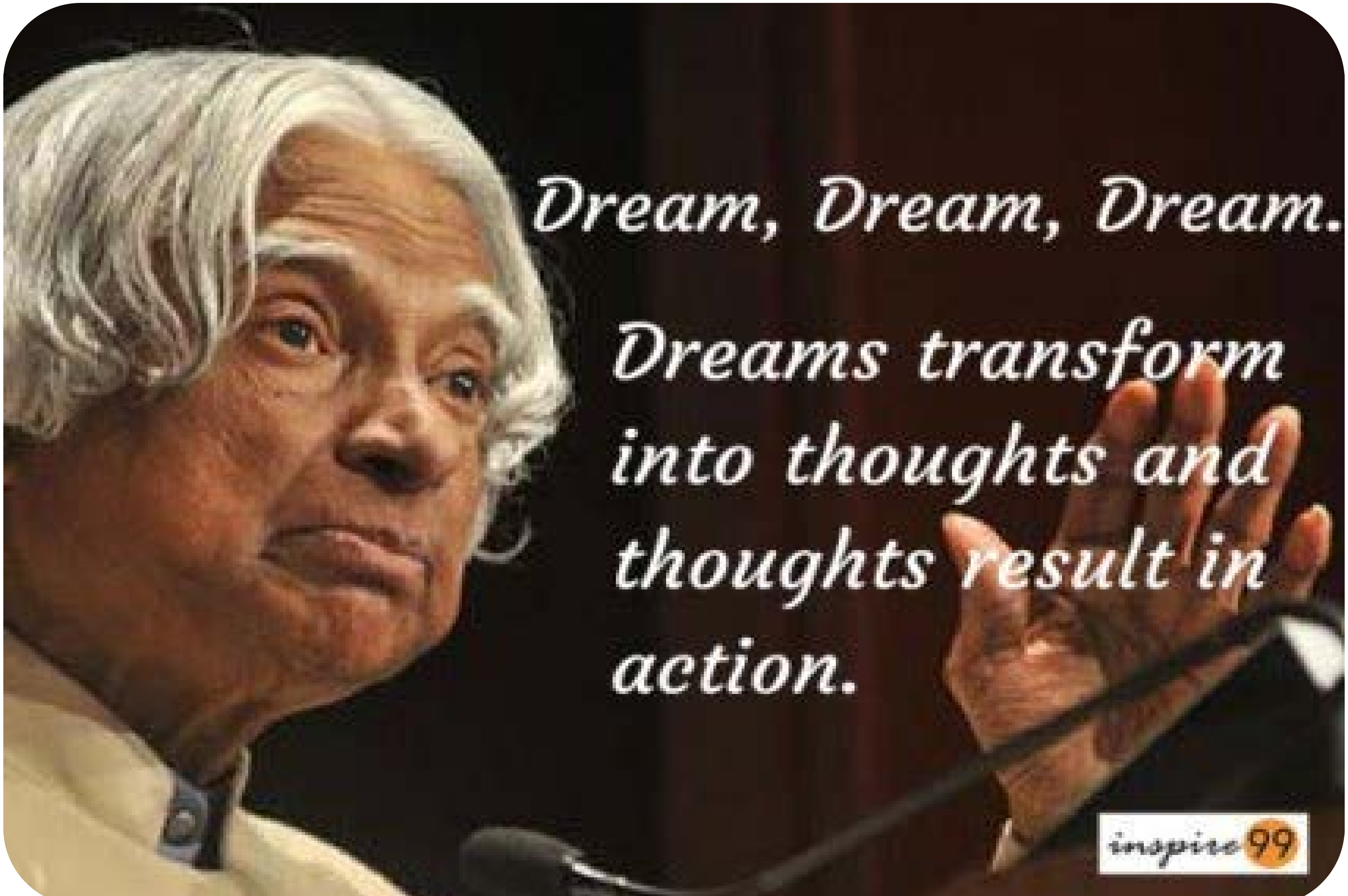


Solar cells

LATEST APPLICATION OF THIN FILMS

IoT, MEMS, CMOS memories, Medical implantable	Smart cards, Skin patch, RFID	Wearables, E-textile, Medical device	Smartphone, Tablet, Power tool, Toy	Transport	Large-scale energy storage
Capacity range →					
1 mAh	10 mAh	100 mAh	1 Ah	100 Ah	> 1 kAh
Important features					
• Rechargeable • Small footprint, many micro-batteries • Long life time • Rapid discharge • Tend to incorporate with energy harvesting	• Can be both disposable and rechargeable • Laminar and thin, some with special form factor • Relatively low power • Cost sensitive	• High energy density for small volume • Long working hours • Flexible, stretchable or thin, some with special form factor	• Light-weight and small volume • Long working hours • Some with special form factors • High power	• Safe • Reliable • High power • High capacity	• Cost advantage • Long life time • Reliable • High capacity
					
Technology Status					
Small volume production	Available, mostly customized	Prototypes available	Research to prototype	Research	Very early stage

Motivation


Dream, Dream, Dream.
Dreams transform into thoughts and thoughts result in action.
inspire99





Here are a few steps you can take to improve your Self-Esteem:

1. Forgive yourself for past mistakes.
2. Focus on your positive attributes.
3. Follow the example of successful people.
4. Become a self-talker.
5. Exhibit a good attitude.
6. Get plenty of rest.
7. Make your work/study skills your own.
8. Practice your talents.
9. Become physically fit.
10. Learn new things.
11. Improve your personal relationships.
12. Dress well!!!!


Q&A

Sky is not your limit !!!

All the best !

Thank you