

# **GALVANIC CORROSION OF LIGHT METAL COUPLES**

R Balasubramaniam  
Materials and Metallurgical Engineering

REACH-2007, Timber Trail, 10 Mar 07

## **Acknowledge**

- Mr. M. Surender (PhD Student)
- Dr. N. Sathyamurthy (Laptop lender)
- Dr. C.V.R. Murthy (Internet downloader)
- Dr. Javed Malik (Internet downloader)
- Dr. Dhiren Katti (CD bringer)
- Friends and colleagues

## **Flow (Saraswati)**

- Fundamentals of Corrosion
- Forms of Corrosion
- Galvanic Corrosion
- Application: Light Metal Couples
- Future Light Weight Automobiles (GM, USA)
- What do we have in Corrosion Laboratory?

## **DEFINE**

- Corrosion is the **degradation** of **engineering material** due to **electrochemical reaction** with the **environment**

## **Degradation**

- Loss in useful property
- Cosmetic damage to complete wastage

## **Engineering Materials**

- **Metals**
- Ceramics
- Polymers
- Composites
- Semiconducting materials

## Electrochemical Reaction

- Any reaction that involves loss or gain of electrons
- Oxidation :  $M \rightarrow M^{n+} + ne^{-}$
- Reduction:  $2H^{+} + 2e^{-} \rightarrow H_2$   
 $O_2 + 2H_2O + 4e^{-} \rightarrow 4OH^{-}$
- All corrosion reactions are **oxidation** reactions
- Remember: without reduction reaction, there will be no corrosion reaction

## Environment

- Atmosphere
- Soil
- Aqueous Environment
- Human Body
- High Temperatures
- Biological
- Space

## Why study corrosion?

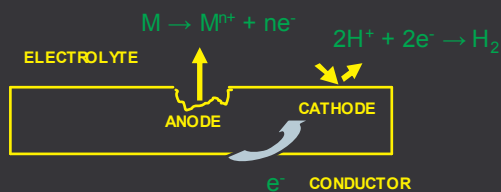
- Corrosion costs society
- Annual loss due to corrosion in India about 5 % of the GDP
- Example: Replacement of corroded rails costs Railways Rs. 440 Crores every year
- Direct cost (part cost, maintenance, etc)
- Indirect cost (human lives, production loss, market value, etc)

## Good applications of corrosion

- Etching to reveal microstructures
- Batteries
- Anodizing
- Electrochemical machining

## Corrosion Basics

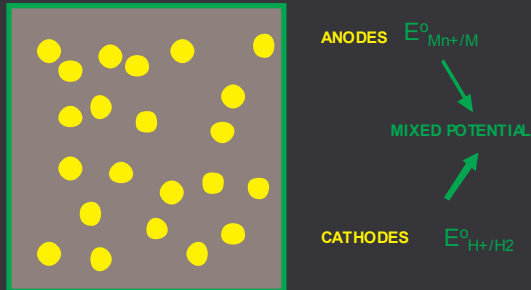
- Wet electrochemical cell (four components)



## Mantra of Prevention

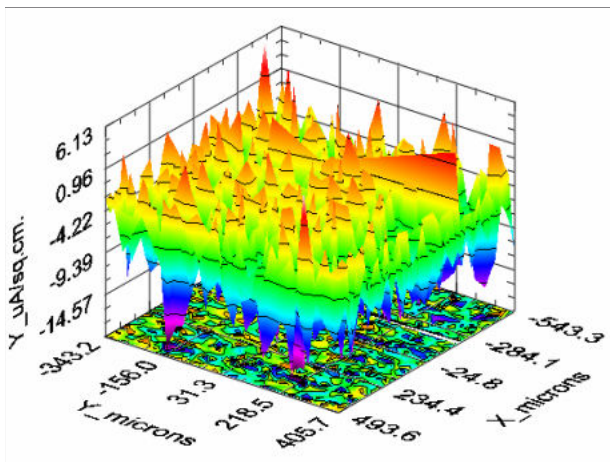
- Remove any one components of the wet electrochemical cell and corrosion will STOP
- Remember: Prevention better than control

## Real life



## Mixed Potential

- Free Corrosion Potential
- Both anodic and cathodic reaction rates are equal at FCP
- This is the potential a sample achieves on immersing in solution



## Polarization

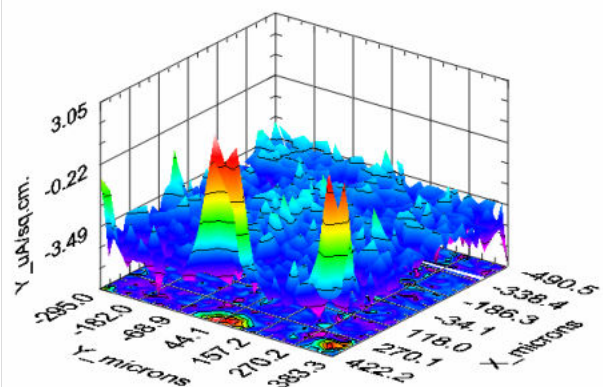
- Deviation of potential away from equilibrium
- Anodic polarization : take sample to more positive potentials (anodic/corrosion reaction becomes faster)
- Cathodic polarization : take sample to more negative potentials (cathodic reactions become faster)

## What causes polarization?

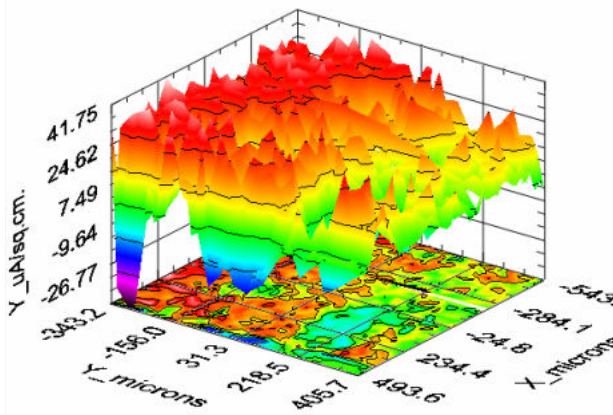
- Indian elections: caste, cash, co-ercion
- Electrochemistry: electron supply or withdrawal



## Cathodic polarization : reduction reactions faster



Anodic polarization : reduction reactions faster



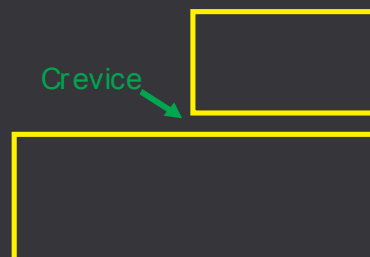
## Forms of Corrosion

- Uniform corrosion
- Localized corrosion
- Uniform corrosion is predictable and engineers can design accordingly = GOOD
- Localized corrosion = DISASTER

## Localized Corrosion

- Intergranular Corrosion
- Weldment Corrosion
- Dealloying
- Erosion Corrosion
- Corrosion-Mechanical Interactions (SCC / HE / CFC)
- Galvanic Corrosion
- Crevice Corrosion

## Crevice Corrosion



## Crevice Corrosion



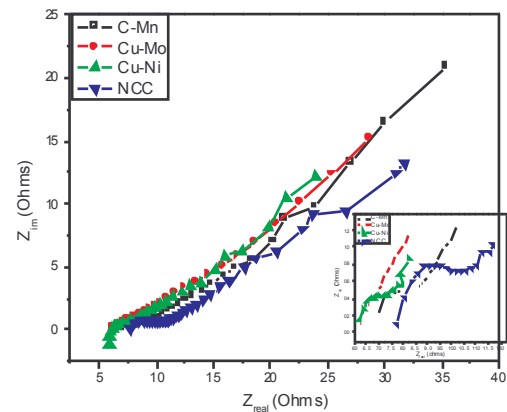
## Indian Railways Example



## Problems due to corrosion



Thinning of rail foot



49 days of salt fog exposure

## Future Plans

- Work from Feb 2005
- **Important : Structure Property Correlation**
- Mega meeting with BSP/RDSO/IITK – 16 April 07
- First heat (300 tons) – May 07
- Second heat (300 tons) – Dec 07
- Field trail, begin – June 07
- First analysis of field samples – Dec 07
- Final analysis of field samples – June 08
- Final recommendation

## Galvanic Corrosion

- One of the famous forms of corrosion
- Also called dissimilar metal corrosion and contact corrosion
- When two dissimilar metals are in contact, the **active member** of the couple corrodes more severely and the **noble member** is protected

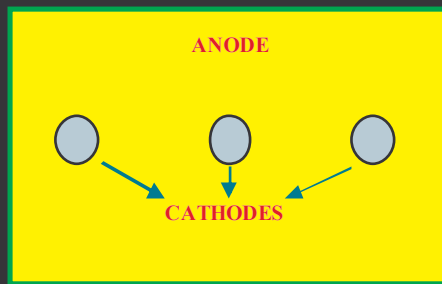
## GALVANIC SERIES IN SEA WATER

Graphite	
Platinum	Noble
Titanium	
SS 316, 317 (passive)	
Cu-Ni alloys	
SS 304 (passive)	
Silver	
Nickel	
Lead	
Bronzes	
Cu	
Sn	
brasses	
SS 316, 317 (active)	
mild steel	
cast iron	
Al alloys	
Zn	Active
Mg alloys	



## Area effect

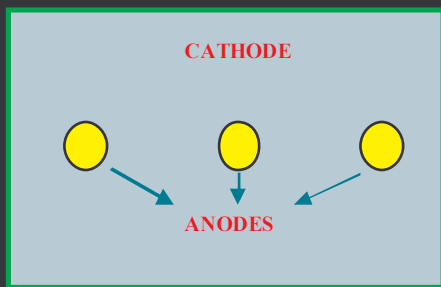
A large cathode demands more electrons and hence attack on anode intensified



ANODE IS NOT ATTACKED INTENSELY



COPPER RIVETS IN STEEL SHEET



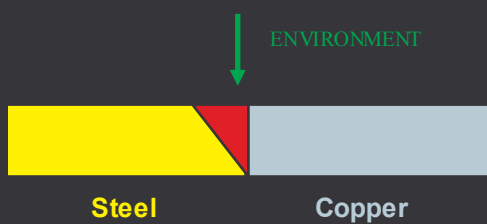
ANODE IS ATTACKED INTENSELY



STEEL RIVETS IN COPPER SHEET

## Distance Effect

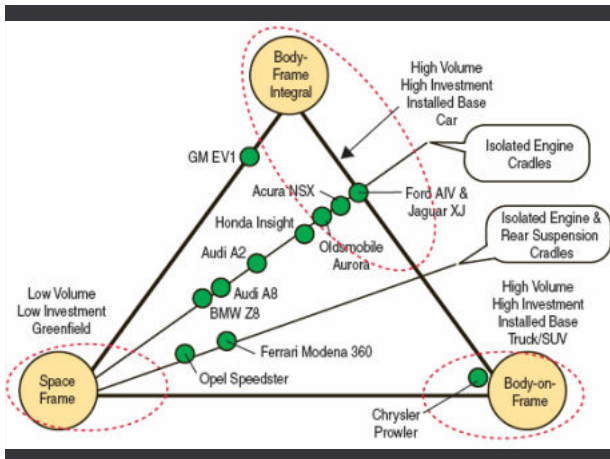
Galvanic corrosion concentrated near contact joints



## Practical Example

Automobile Industry

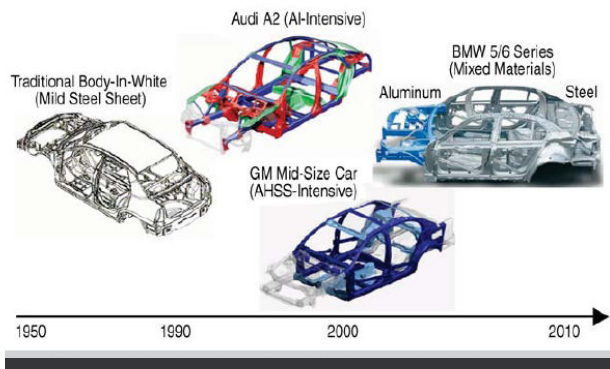
Acknowledge: General Motors, USA



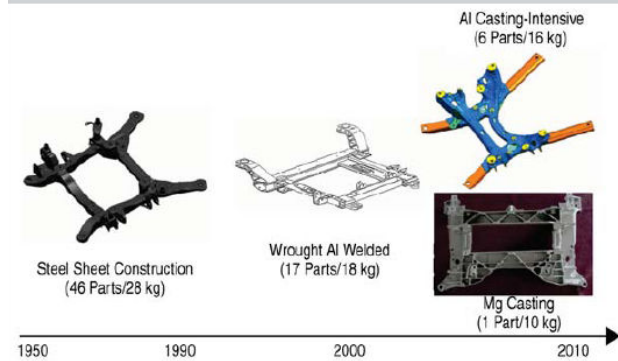
## Evolution of materials in automobiles

Lighter and stronger  
Reduce weight

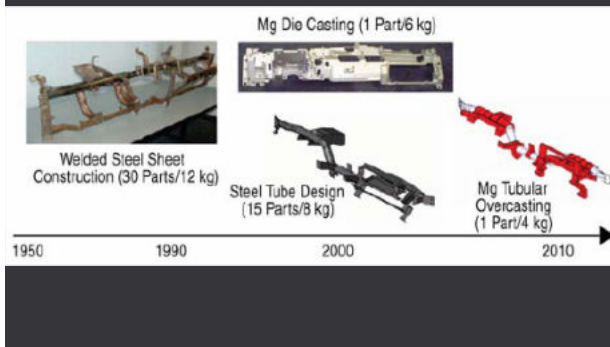
### Material and manufacturing evolution



### Front cradle structure



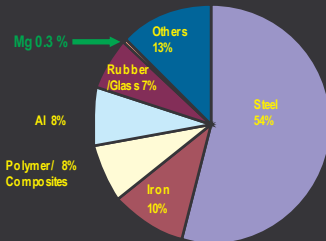
### Instrument panel front structure



### Why Light Metals?

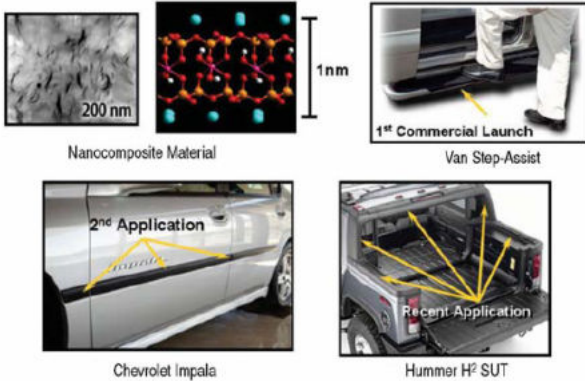
- Magnesium and aluminum in transportation
- Increases fuel economy
- High strength to weight ratio
- Good castability and formability enables high production rate





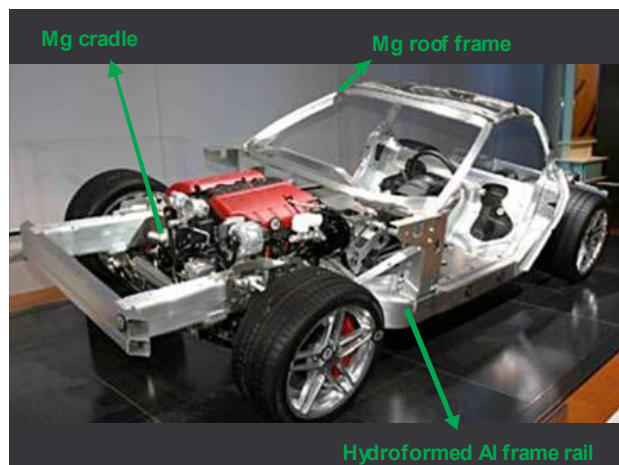
How can we ignore nanotechnology?

### Nanocomposites in recent GM vehicles



Lets come back to "solid" engineering materials - metals

### 2006 Corvette Z06





## THE PROBLEM

- Connect Al and Mg
- Form galvanic couple
- Mg will corrode much more rapidly (already poor corrosion resistance!)
- Joining technology (other materials)
  - Riveting (zinc coated steel rivets)
  - Adhesive bonding

## Dhammapada 191

Dukkham dukkhasamppadam, dukkha ssa  
ca atikkamam

Ariyam c'athangikam maggam,  
dukkhupasamgāminam

“Suffering, the origin of suffering, the  
cessation of suffering and the noble  
eightfold path which leads to the cessation  
of suffering”

“Corrosion, the origin of corrosion,  
the cessation of corrosion and the  
practical paths that leads to  
cessation of corrosion”

## What do we have?

- Potentiostats for studying various kinds of corrosion behaviour
- TGA for high temperature oxidation
- Corrosion chamber for simulation
- Salt fog chamber
- Electrodeposition units
- Optical microscope with image analyzer
- Scanning electron microscope(s)

Thank you, Alexander von Humboldt  
Foundation, IIT Kanpur  
and MHRD/SAIL/Railways

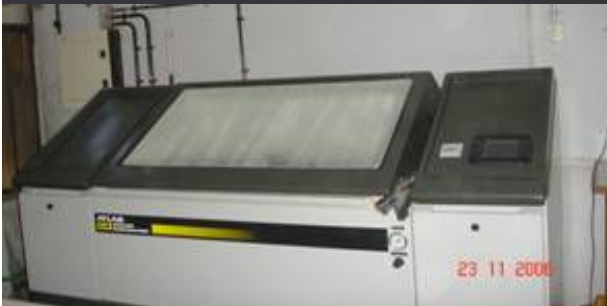


Thank you, MHRD  
SAIL  
Railways



Netzsh TGA/DSC

Thank you, MHRD/SAIL/Railways



Atlas Corrosion Chamber

Electrodeposition units



Thank you, IIT Kanpur and GM (USA)

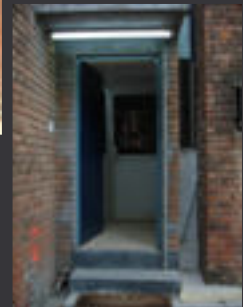
Microscope with image analyzer



Thank you, MRHD / SAIL /  
Railways



Room with easy 24-  
hour access

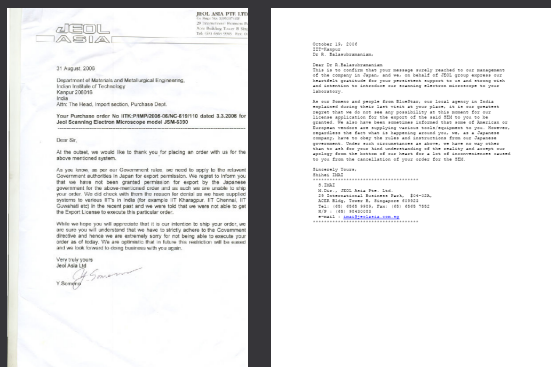


Thank you, IIT Kanpur

JEOL T330A SEM (1990 model)



Thank you, GM (USA)



Japanese ban on exporting to MME  
Department, IIT Kanpur

Good news!!!

## ZEISS EVO – 50 HV SEM



Thank you, MHRD / SAIL / Railways

All welcome to use any facility

Please also help with repair and  
maintenance

# Questions?

Thank you  
Parvanoo, 10 Mar 07

## Dhammapada 183

Sabbapāpassa akaranam  
kusalassa upasamapadā  
Sacittapariyodapanam  
etam buddhāna sāsanaṃ

The eschewing of all evil, the perfecting of  
good deeds, the purifying of one's mind,  
this is the teaching of the Buddhas (the  
awakened)