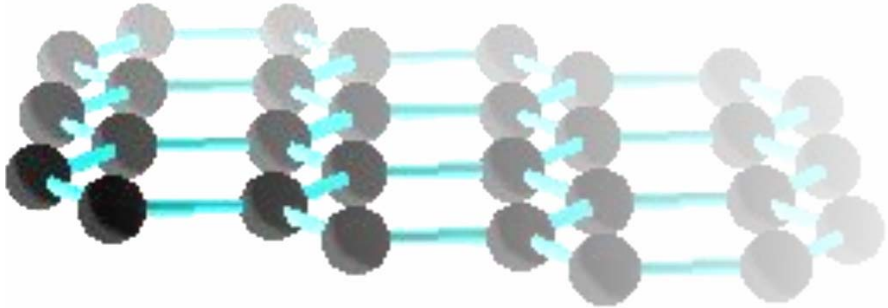
Cathode wear in aluminium electrolysis



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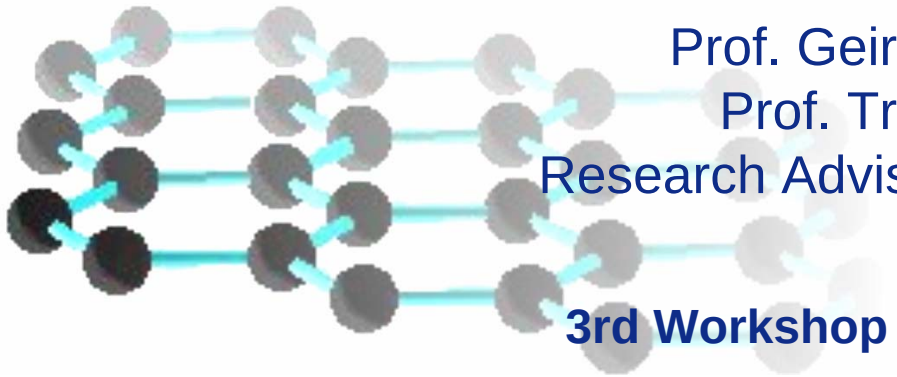


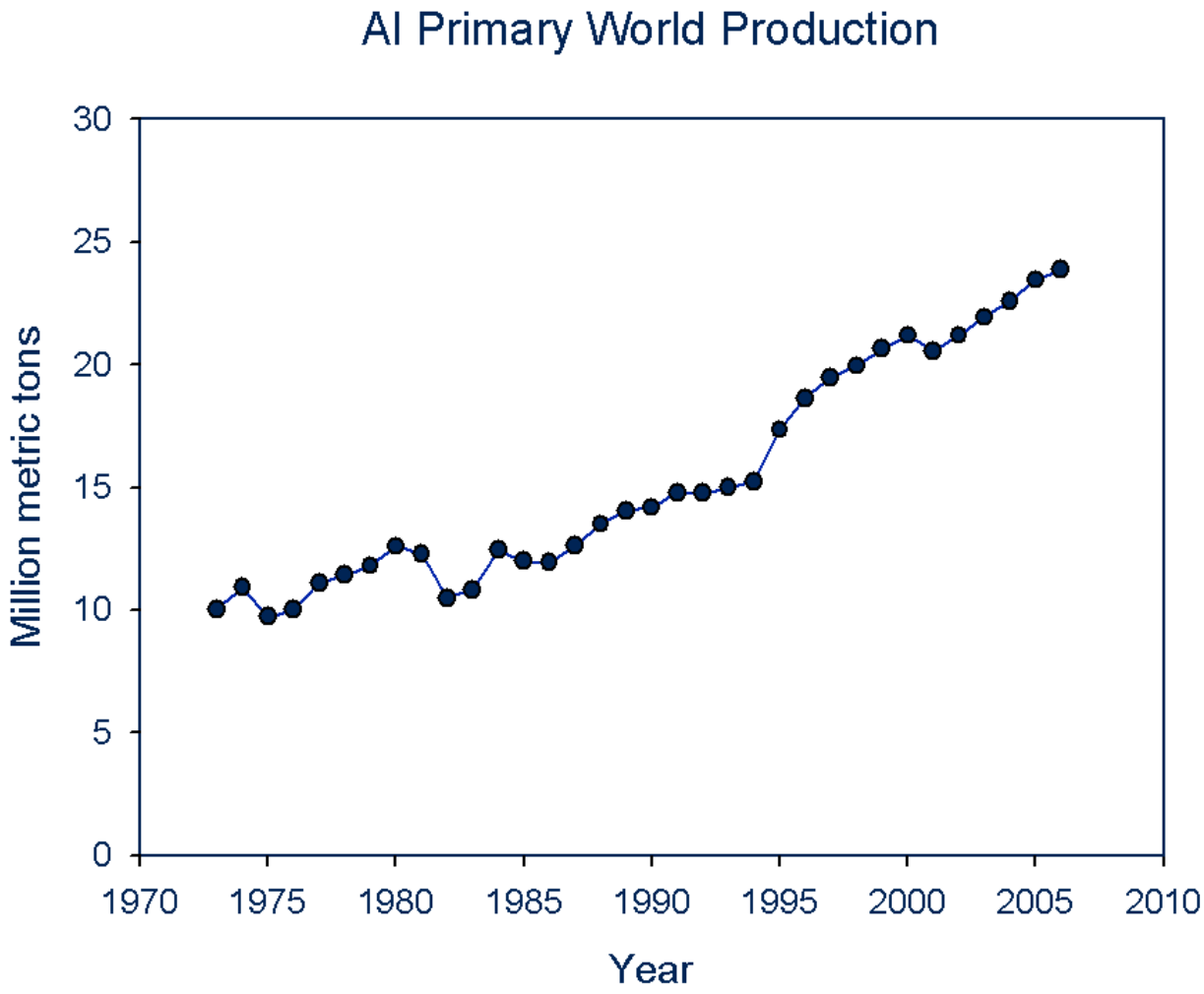
3rd Workshop on Reactive Metal Processing
MIT, Boston
3 March 2007

Outline

- **Introduction**
  - **The Hall-Héroult Process**
  - **Cathode Materials**
  - **Cathode Wear**

- **Cathode wear research at NTNU/SINTEF**
  - **Carbide Chemistry in Bath**
  - **Additives and Coating**
  - **Porosity Manipulations**
  - **Nano Carbon Formation**

Aluminium production

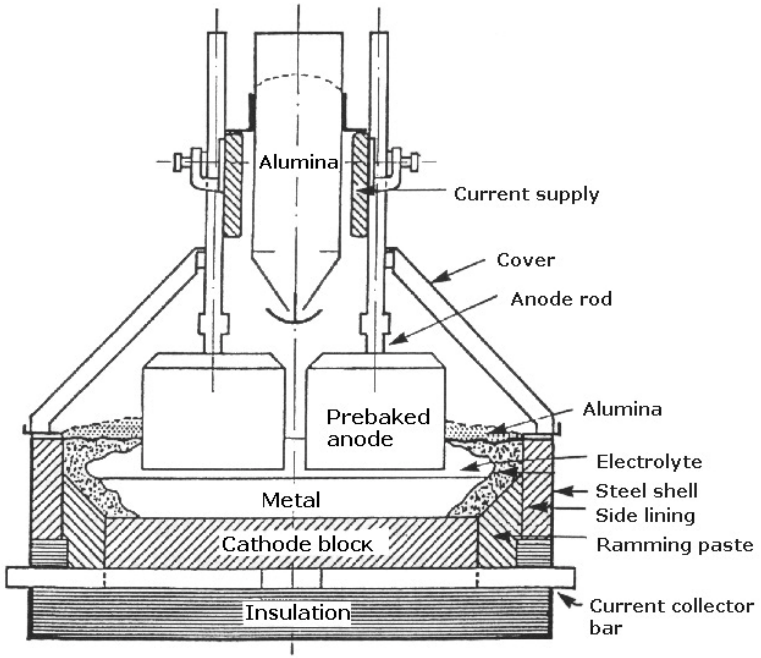


Applications

- Transport
  - Cars
  - Planes
  - Rails
  - Ships
- Packaging
  - Foil
  - Cans
  - Cooking
- Electrical
- Construction
- Medicine

The Hall-Héroult Process

Patented by Charles Hall and Paul Héroult in 1886.



- **Cathode Reaction**

  $Al^{3+} + 3e^- = Al(l)$

- **Anode Reaction**

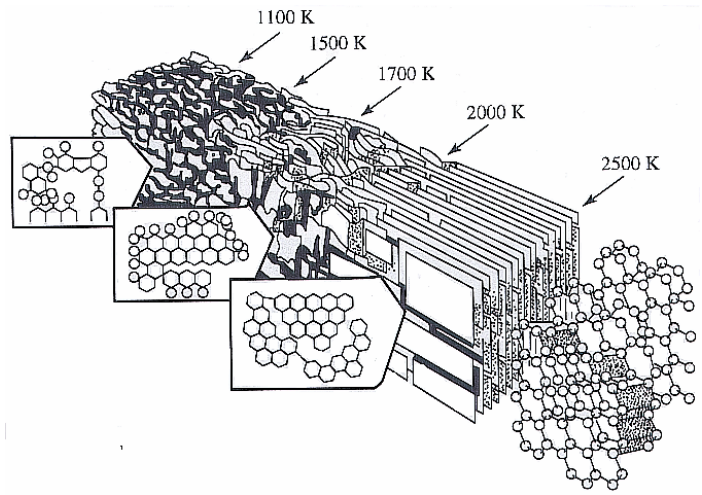
  $3/2O^{2-} + 3/4C(s) = 3/4CO_2 + 3e^-$

- **Cell reaction**

  $1/2Al_2O_3(diss) + 3/4C(s) = Al(l) + 3/4CO_2(g)$

Electrolyte:	**Cryolite (Na_3AlF_6) + ~10 wt% excess AlF_3 + Al_2O_3**
Temperature:	**~960 °C**
Voltage:	**4,2 V**
Current:	**100 – 325 kA**
Current efficiency:	**~95 %**

Cathode Materials

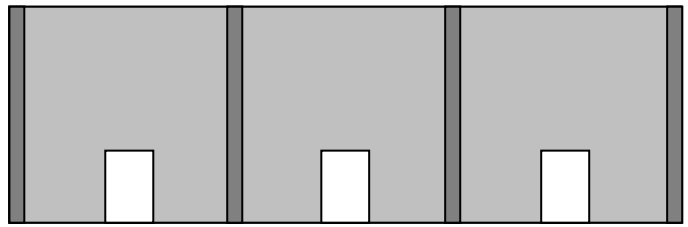


Three main categories:

- **Anthracitic**
- **Semigraphitic**
- **Semi or fully graphitized**

During the past two decades changes from using only anthracitic to graphitic or graphitized materials has taken place.

Cathodes are made from prebaked carbon blocks with paste rammed into joints and seams between and around them.

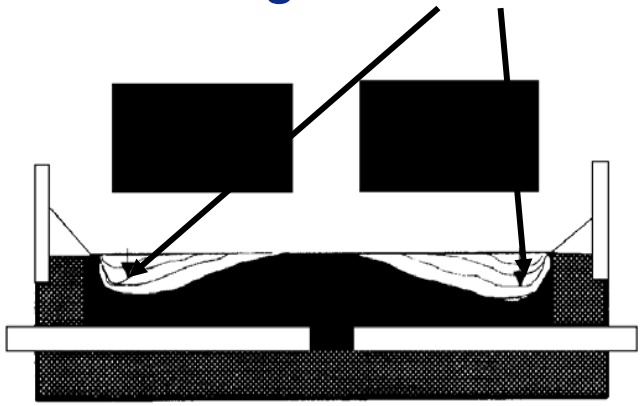


Cathode wear

- **Lifetime of aluminium electrolysis cell limited by cathode carbon failure.**
- **Anthracitic to graphitic:**
  - **Improved thermal and electrical properties**
  - **Reduced tendency towards sodium penetration**
  - **Higher wear**
- **Wear mechanisms:**
  - **Physical abrasion: solid alumina particles**
  - **Chemical wear: formation and dissolution of Al_4C_3**
  - **Particulate detachement**

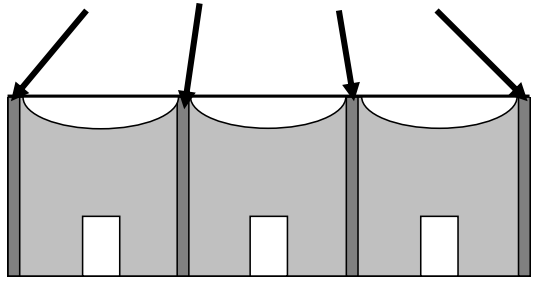
Industrial wear patterns

High current density zones



W pattern

Amorphous ramming paste

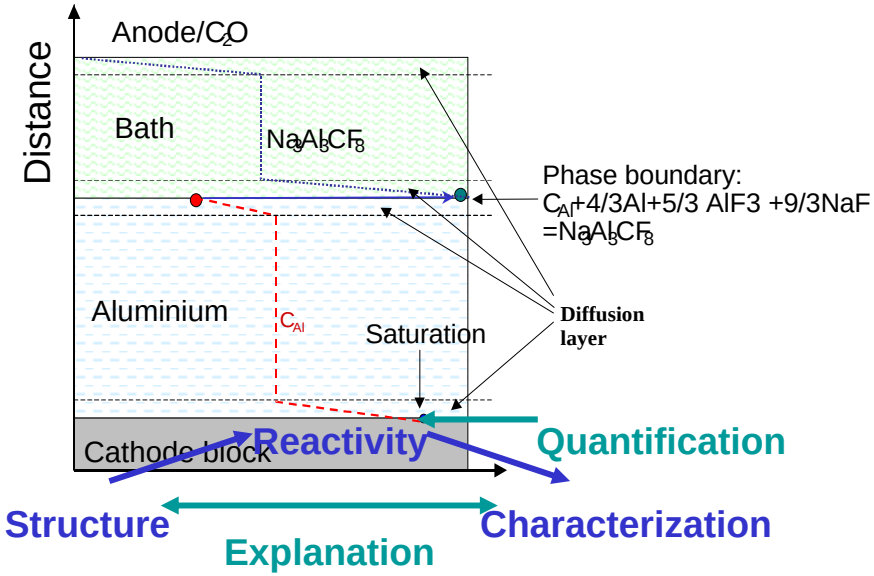


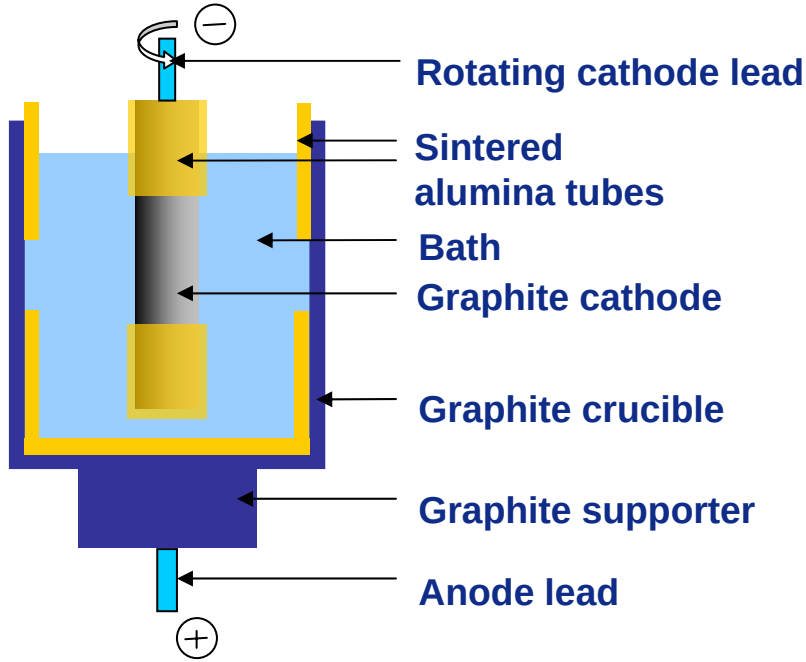
U pattern

- **Wear rates :**
  - 10-30 mm/year
  - Graphitic materials shows the highest wear rate
- **Wear mechanisms:**
  - Physical abrasion: solid alumina particles
  - Chemical wear: formation and dissolution of Al_4C_3
  - Particulate detachment

Carbide Chemistry

- **Mechanism of formation and dissolution of Al_4C_3**
  - **Electrochemical wear as function of experimental parameters**
  - **Microstructure studies to study carbide formation and dissolution inside or at surfaces of cathode material**

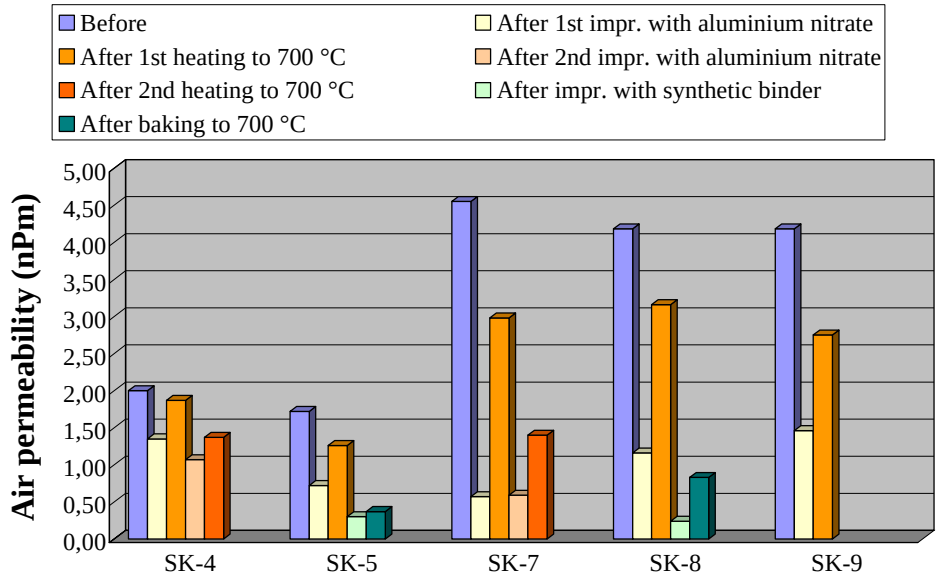


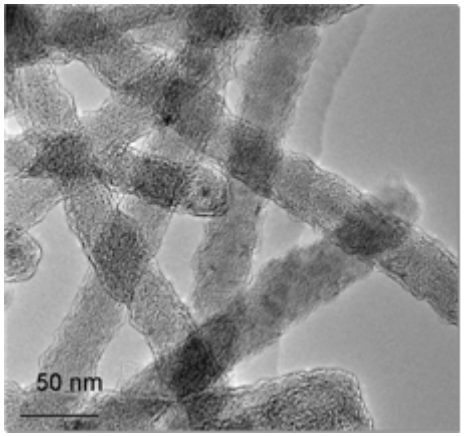


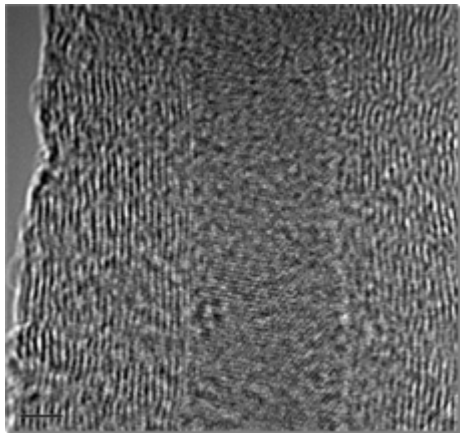
Additives and Nano Carbon

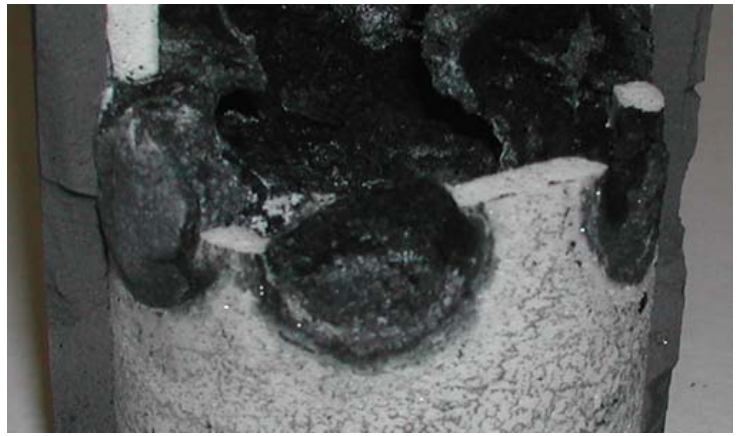
- **Soaking with Synthetic Binder**
- **Soaking with Inorganic Compounds**
- **Combinations**

- **Anodic Formation of C from $Al_3CF_8^{3-}$**



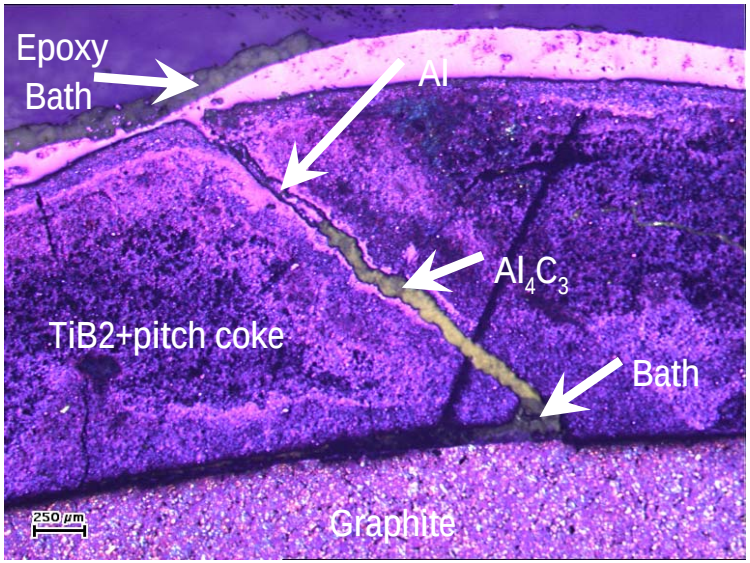




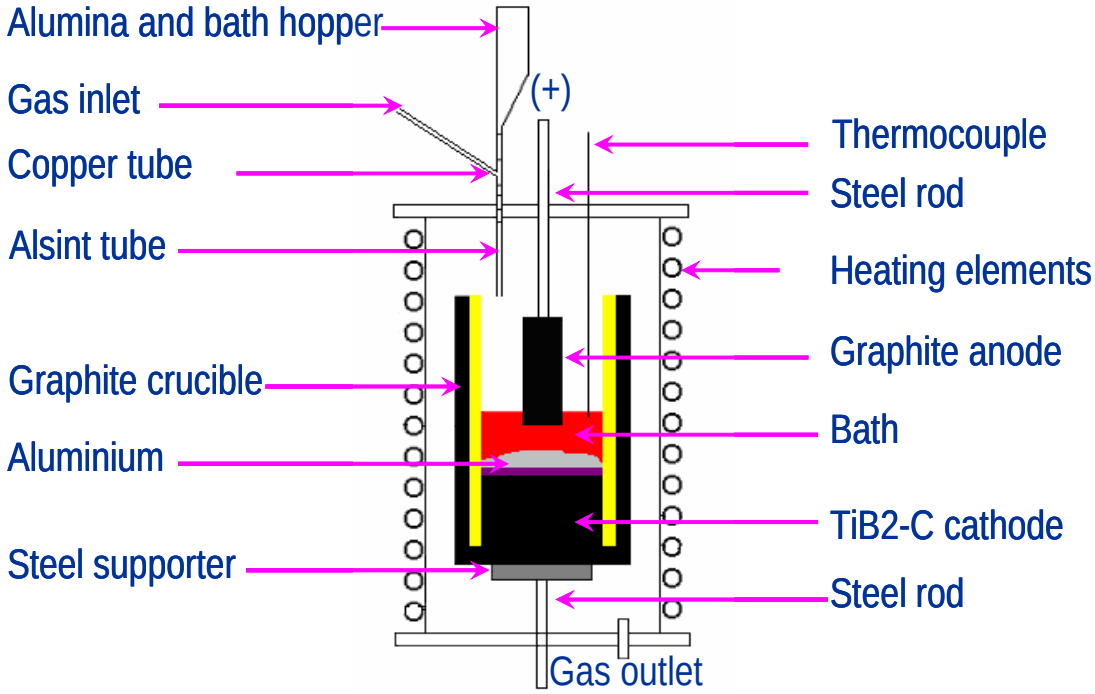


TiB_2

- **Coating and Compositions**
  - **Characterization of Coated Samples**
- **Electrolysis Test**
  - **Formation of Al_4C_3 on the TiB_2 – C interface**



8 hrs



Thank You for Your Attention

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