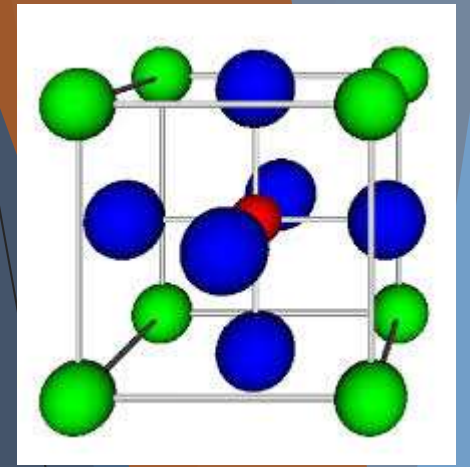


# Metal Carbides - Solid State Chemistry

By Sean Kasprisin

# Solid State Chemistry and Metal Carbides - a Definition

- ▶ Solid State Chemistry - Focusing on the Synthesis, structure, and Properties of Solid phase materials particularly non-molecular solids
- ▶ Metal Carbides - A solid state compound composed of a metal and carbon in various ratios. Bimetallic possible
- ▶ MAX Phase Metal Carbide - a Metal Carbide that includes an additional element such as Silicon or Aluminum to change the structure of the compound



# Metal Carbides

1. Strange bonding structure. Carbon gets pushed into a small center space to form “bonds” with all of the surrounding Metals (does not follow the octet rule)
2. Multiple ratios possible for most Metal Carbides
3. Multiple phases even with the same ratios due to changes in the lattice structure.
4. Metal Carbides can be bimetallic containing two different metals
5. MAX Phases cause a layered structure alternating the other element with the Metal Carbide.
6. If MAX Phases can selectively etch out the other element it can create a 2D layered structure with an increased surface area

# Why are they Important

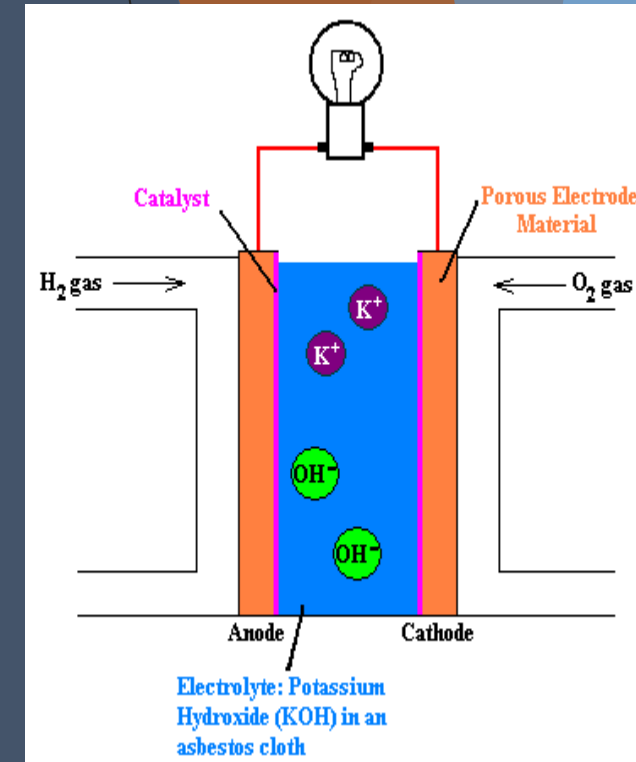
The research in the area of metal carbides has multiple applications:

1. Large Thermal Capacity and a good conductor
2. A Catalyst in the HER (Hydrogen evolution reaction) and OER (Oxygen evolution reaction)
3. Strong a light material similar to graphene due to structure

Overall there are a lot of applications for Metal Carbides, but the one of the most interesting is the catalytic capabilities for Hydrogen Fuel Cells as an alternative energy source

# Hydrogen Fuel Cells - Metal Carbides

- ▶ Fossil Fuels will not last forever: Better and cleaner energy
- ▶ The reaction is a REDOX reaction of Hydrogen and Oxygen:
- ▶ There are many catalysts for the Hydrogen Half, but not as many useful ones for the Oxygen
- ▶ Platinum is the best catalyst, but is not very common and very expensive for the use in cars, electronics, etc....
- ▶ Metal Carbides are an alternate catalyst source that could replace Platinum

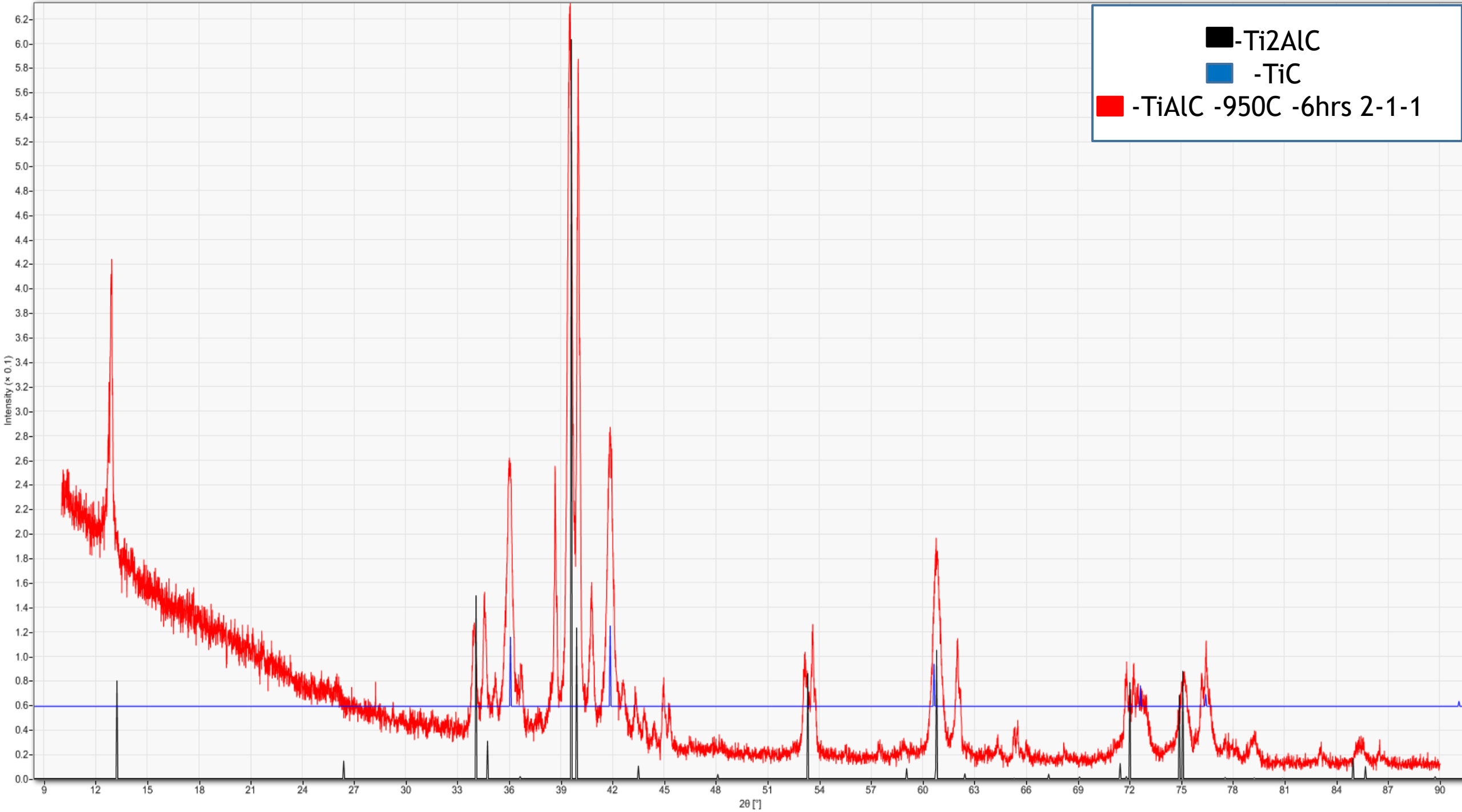


# Synthesis of Metal Carbides

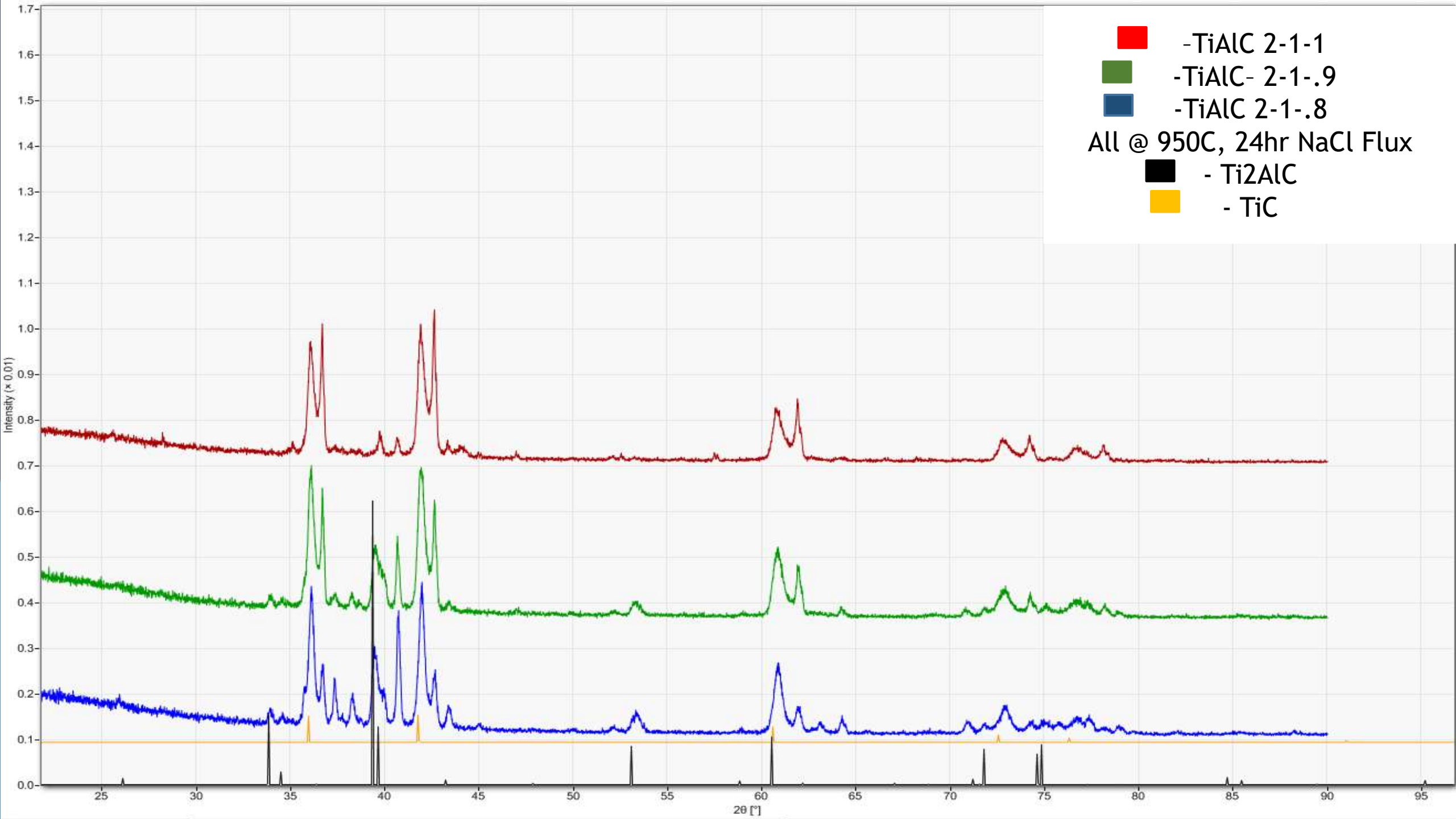
- ▶ There are multiple ways of synthesizing Metal Carbides
  1. Annealing a well blended mixture of the Metal and Carbon to high temps such as 1400 Celsius, usually followed by washing and compressing with high Pressures (1MPa)
  2. Annealing a well blended mixture of Metal and Carbon with a salt flux with a low eutectic point (under 800°C) to create a solvent for the reaction to place, then it is annealed under Argon, and then is washed and centrifuged
  3. Synthesis by using a ammonium heptamolybdate and phenylenediamine which has its pH adjusted and is then heated to create a precipitate which is collected through the use of a centrifuge. Then annealed
  4. Etching of MAX Phase Metal Carbides has so far successfully been achieved by using Hydrofluoric Acid at concentrations of 1M

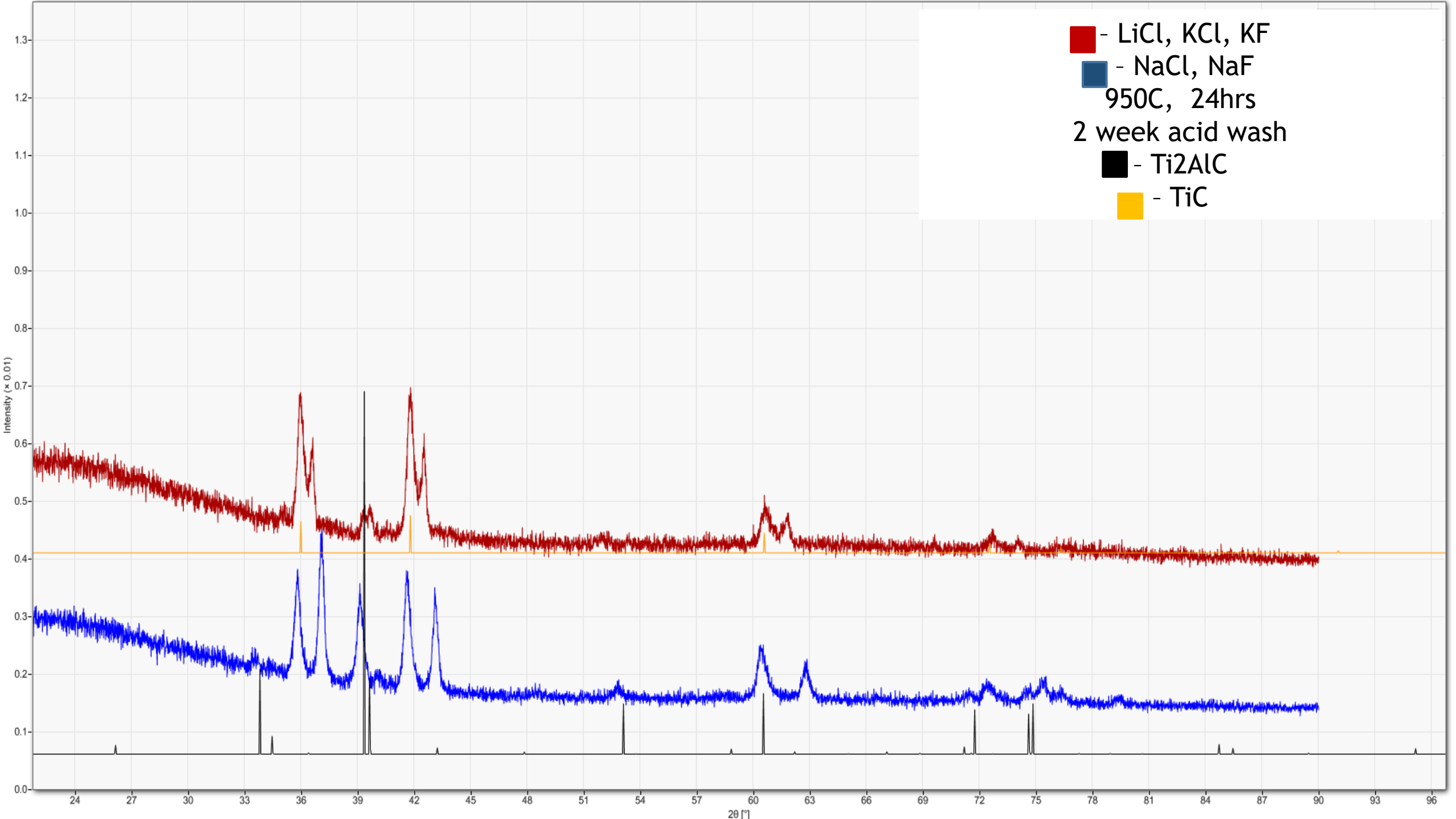
# Determining Metal Carbides

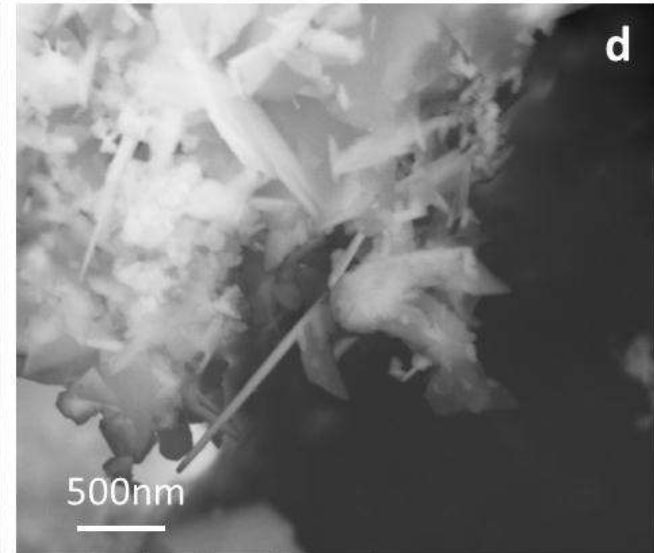
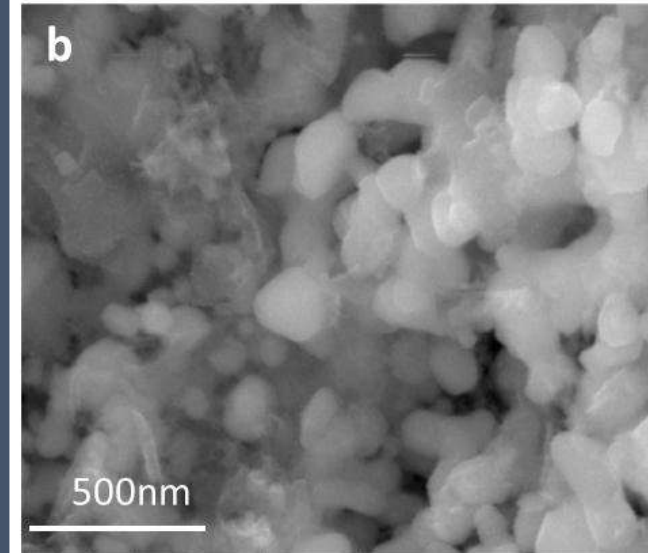
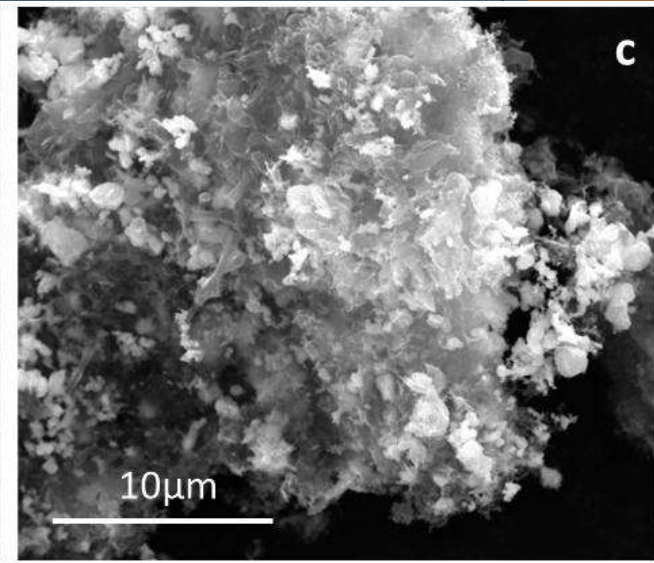
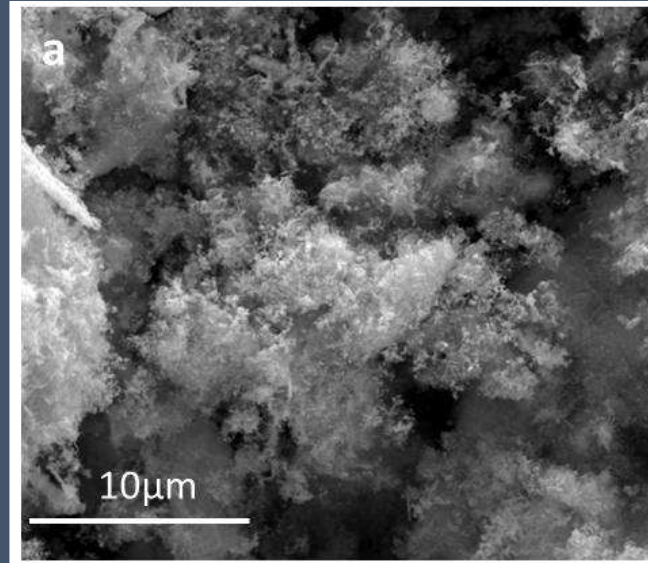
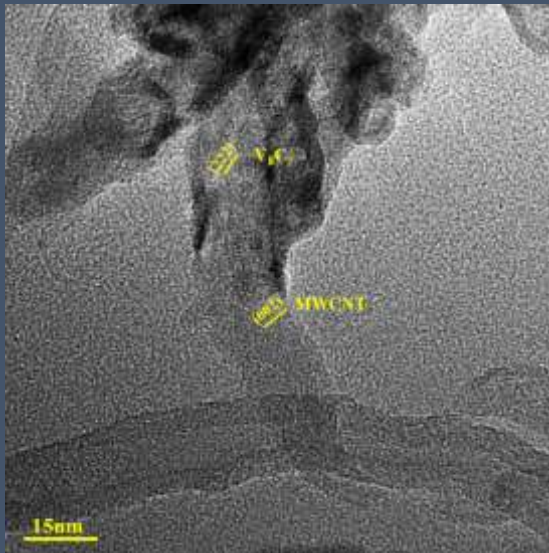
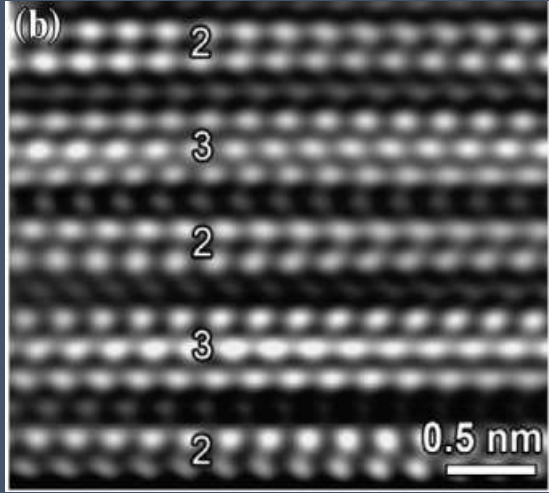
- ▶ The use of an X-Ray diffractometer to see whether or not the diffraction patterns match the Metal Carbides and also if there are other compounds or unreacted reagents in the product
- ▶ SEM(scanning electron microscope) & TEM(transmitting electron Microscope) are used to be able to identify the morphology of the product as well as being able to see unreacted Carbon or other elements











# Testing of Metal Carbides

- ▶ There are several ways of testing the Metal Carbides:
  - ▶ 1. There are E-Chem tests done to determine capabilities
  - ▶ 2. Heating tests can be done to determine thermal conductivity and heat resistance
  - ▶ 3. Pressure/tensile strength can also be tested
  - ▶ 4. Magnets can be used to test whether or not it is magnetic

# Conclusion

The Study of Solid State Chemistry - Especially Metal Carbides is a fascinating field that has multiple applications possible

There are several synthesis methods to create metal carbides which can be used to synthesize single, multiple or MAX Phase Metal Carbides

The determination of Metal Carbides is done by X-Ray Diffraction and the use of SEM or TEM

Other tests can then be conducted to determine other attributes that Metal Carbides can contain

# References

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Questions ??