Si_3N_4 Ceramic Composite with the addition of MWCNTs and ML-Graphene

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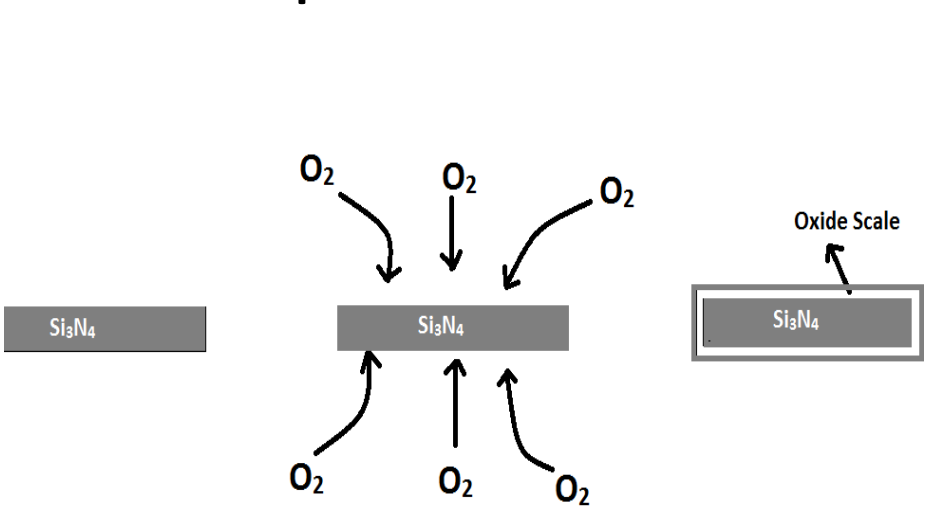
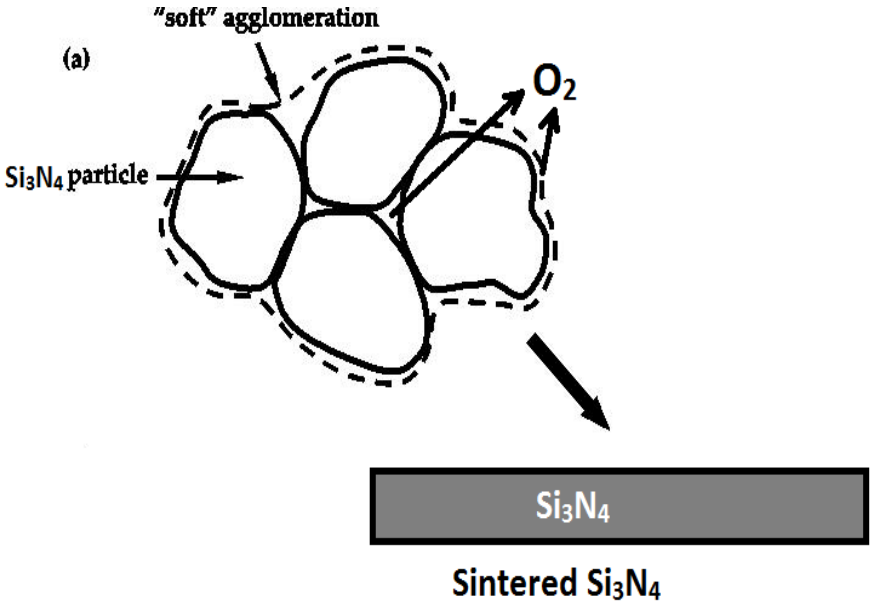
Aim of work

- To study the effect of oxidized Si_3N_4 powder particles on the mechanical properties of hot isostatic pressed Si_3N_4–CNTs/Grpahene composite material.





Plans Accomplished

1st Semester

Si_3N_4	
1434	Si_3N_4 (Ref.)
1435	Si_3N_4 (10 hrs Oxidized)
1436	Si_3N_4 (20 hrs Oxidized)

2nd Semester

Addition of 1% CNTs and 2% Graphene	
1459	Si_3N_4 - 1% CNTs – 2% Graphene (Ref.)
1460	Si_3N_4 (10 hrs oxidized) – 1% CNTs – 2% Graphene
1461	Si_3N_4 (20 hrs oxidized) – 1% CNTs – 2% Graphene
Addition of 3% CNTs	
1462	Si_3N_4 – 3% CNTs (Ref.)
1463	Si_3N_4 (10 hrs oxidized) – 3% CNTs
1464	Si_3N_4 (20 hrs Oxidized) – 3% CNTs
Addition of 3 wt.% Graphene	
1468	Si_3N_4 – 3% Graphene (Ref.)
1469	Si_3N_4 (10 hrs Oxidized) – 3% Graphene
1470	Si_3N_4 (20 hrs oxidized) – 3% Graphene

Progress Report 2017-2018

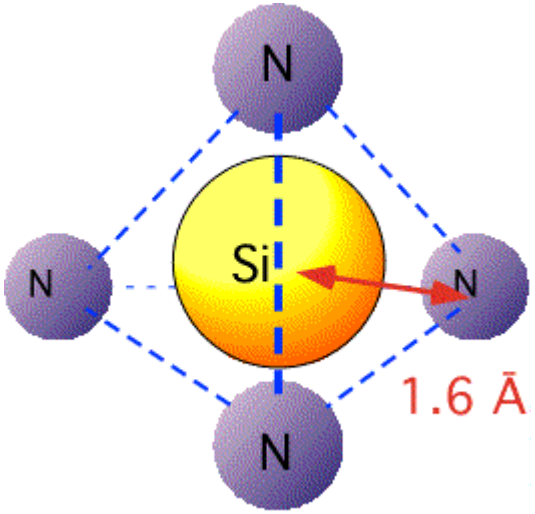
- Paper has been submitted in the Journal of European Ceramic Society (Impact Factor 3.411) (Submitted)

Participation in Conferences 2017-2018

- Attended Hungarian Microscopic Conference 2017 in Siofok, Hungary
- Poster Presentation in ECerS 2017, 15th Conference & Exhibition of the European Ceramic Society, 2017
- Poster Presentation International Conference Deformation and Fracture in PM Materials, High Tatras, 2017. Oct.22-25.
- Poster Presentation in Joint ICTP-IAEA Workshop on Fundamentals of Vitrification and Vitreous Materials for Nuclear Waste Immobilization, The Abdus Salam Centre for Theoritical Physics (ICTP), Trieste Italy. Nov. 06 -10, 2017.
- Oral Presentation "17th PhD Students Materials Science Day", University of Pannon, Veszprem, Hungary, Dec. 4. 2017
- Doctoral Summer School at Károly Róbert University, August 2017

Silicon nitride

- Silicon nitride (Si_3N_4) based ceramics are gaining more attention due to their promising high-temperature thermal and mechanical properties.
- Three crystallographic structures of silicon nitride (Si_3N_4), α, β and γ phases.



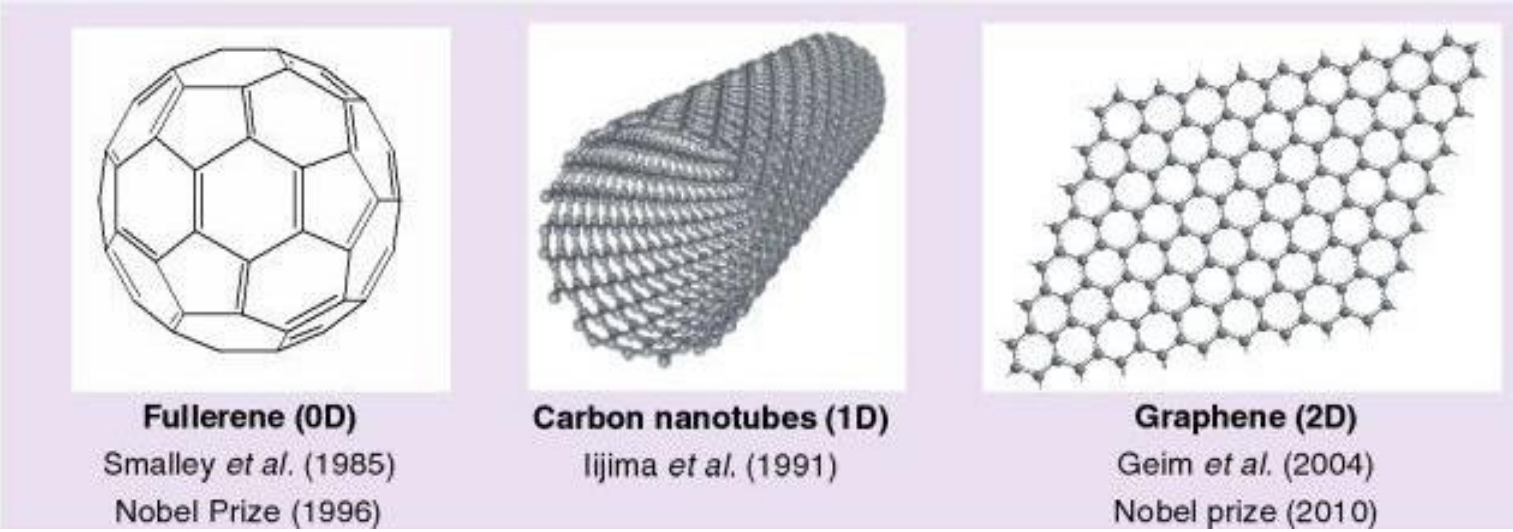
CNTs vs Graphene

Carbon Nanotubes (CNTs)

- Allotrope of carbon
- hollow, cylindrical structures, a sheet of graphene rolled into a cylinder.
- high thermal conductivity, electron mobility, and chemical reactivity

Graphene

- Allotrope of carbon
- 2D material, a single layer of graphite, with carbon atoms arranged in a hexagonal, honeycomb lattice.
- high thermal conductivity, electron mobility, and chemical reactivity



Fullerene (0D)
Smalley *et al.* (1985)
Nobel Prize (1996)

Carbon nanotubes (1D)
Iijima *et al.* (1991)

Graphene (2D)
Geim *et al.* (2004)
Nobel prize (2010)

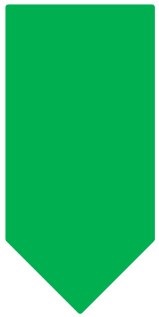
Base Powders

1

α-Si_3N_4 Powder

2

α-Si_3N_4 Powder



Oxidation at 1000 ˚ C for 10 hrs

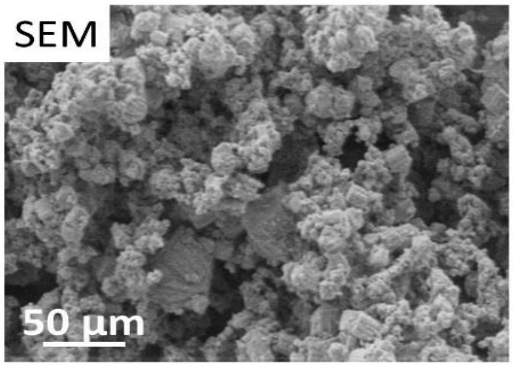
3

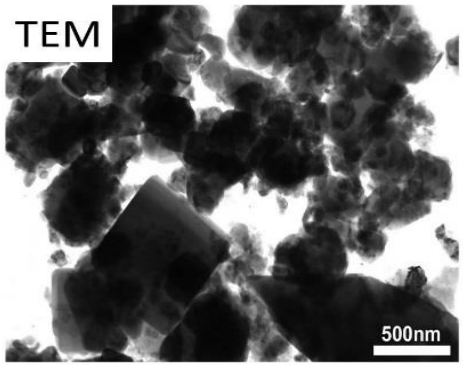
α-Si_3N_4 Powder

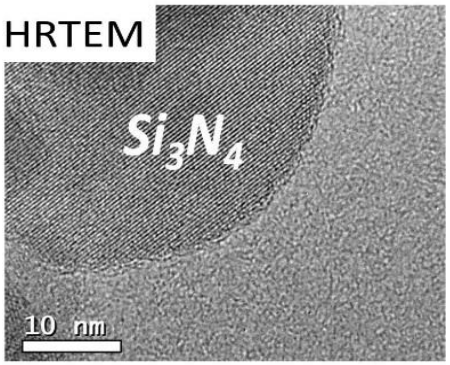
Oxidation at 1000 ˚ C for 20 hrs

Structure of Base powders

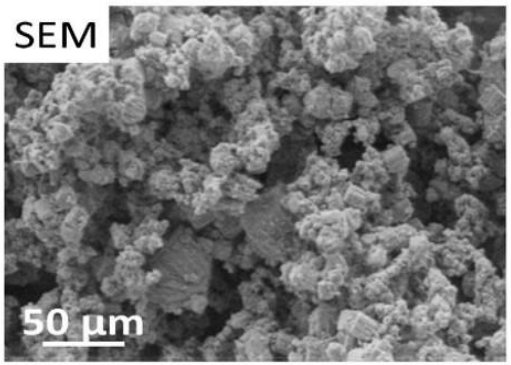
α-Si_3N_4 Powder

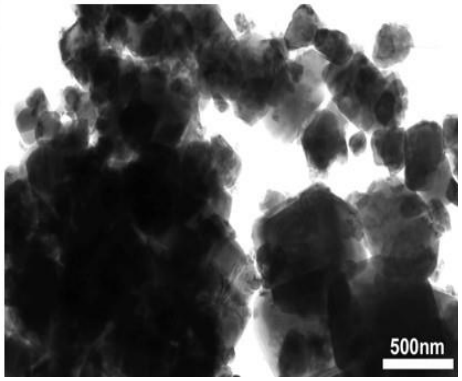


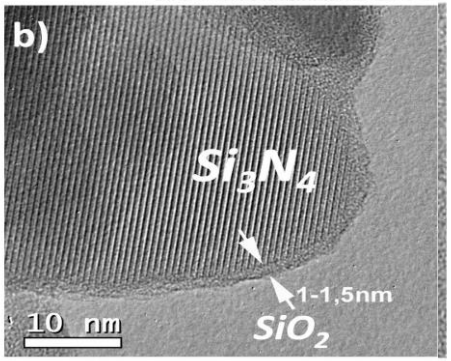




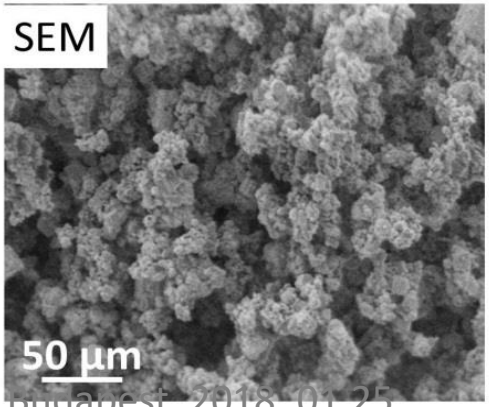
10 hrs oxidized α-Si_3N_4

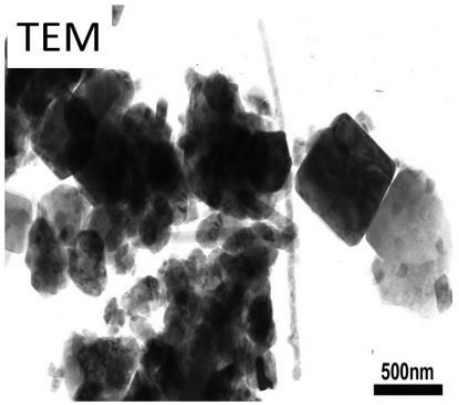


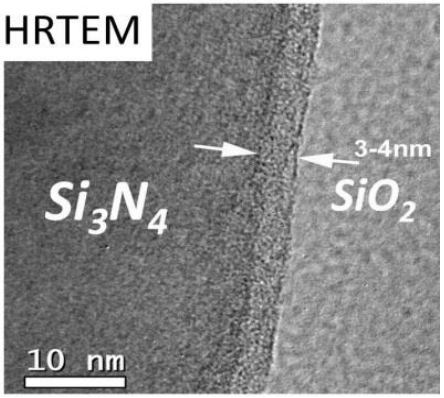




20 hrs oxidized α-Si_3N_4

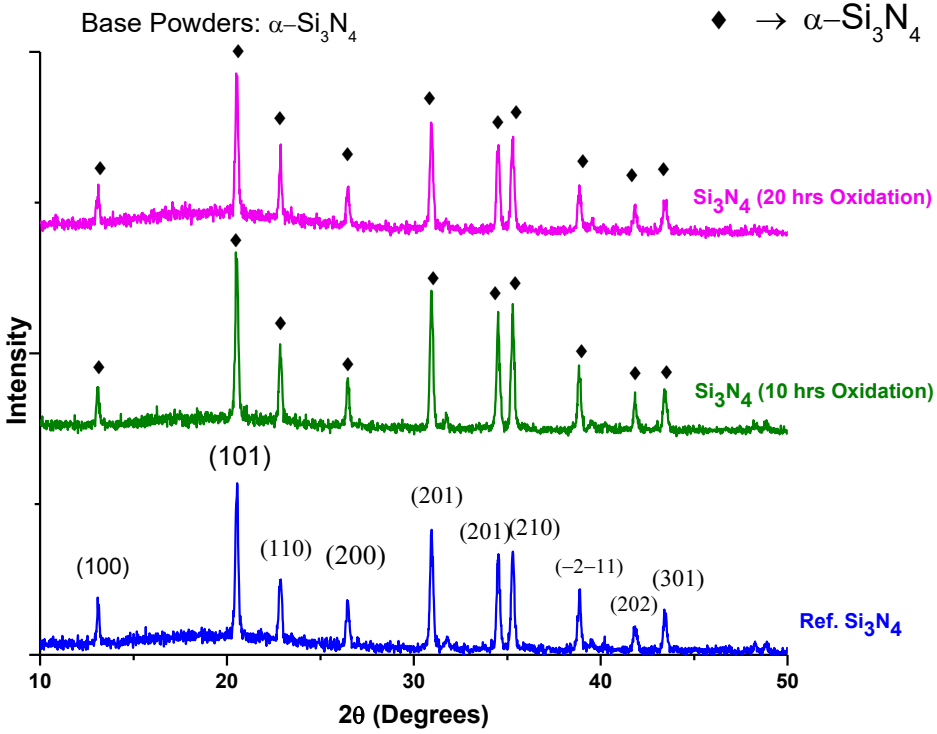




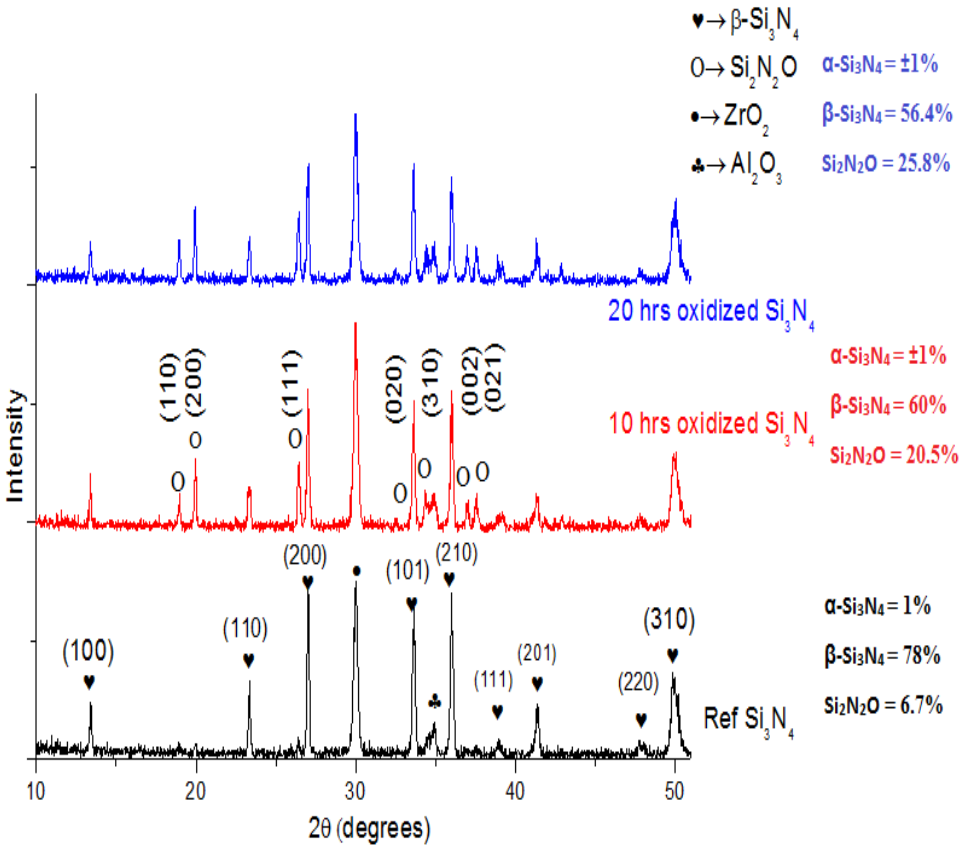


Characterization of powder and sintered sample

Base Powder



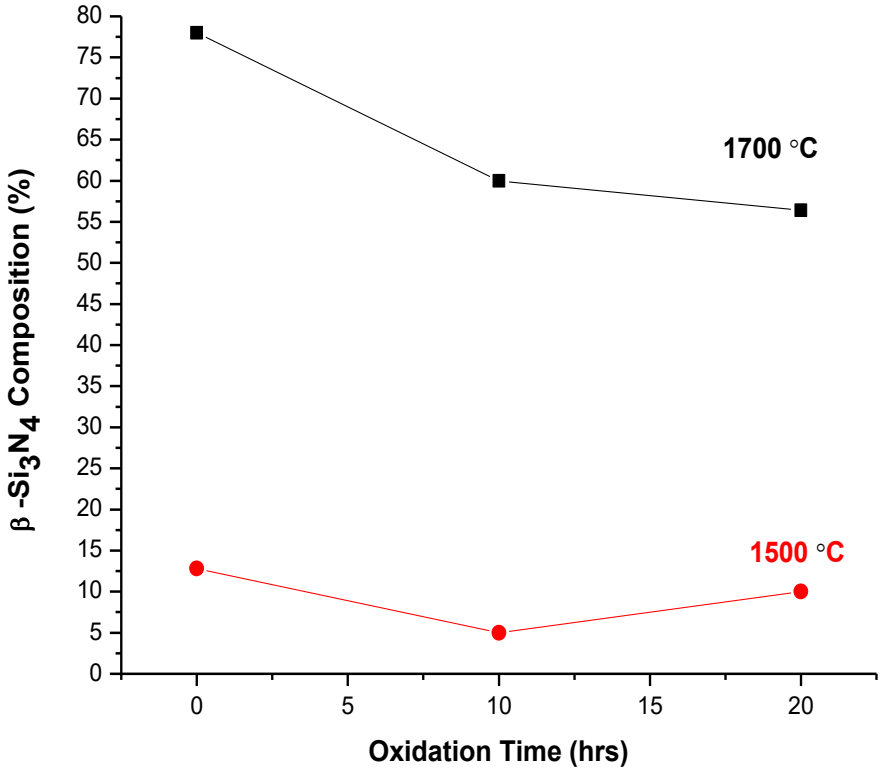
Sintered at 1700 ˚C



JCPDS PDF (01-076-1407), (00-33-1160), (00-47-1627) and (00-83-0944)

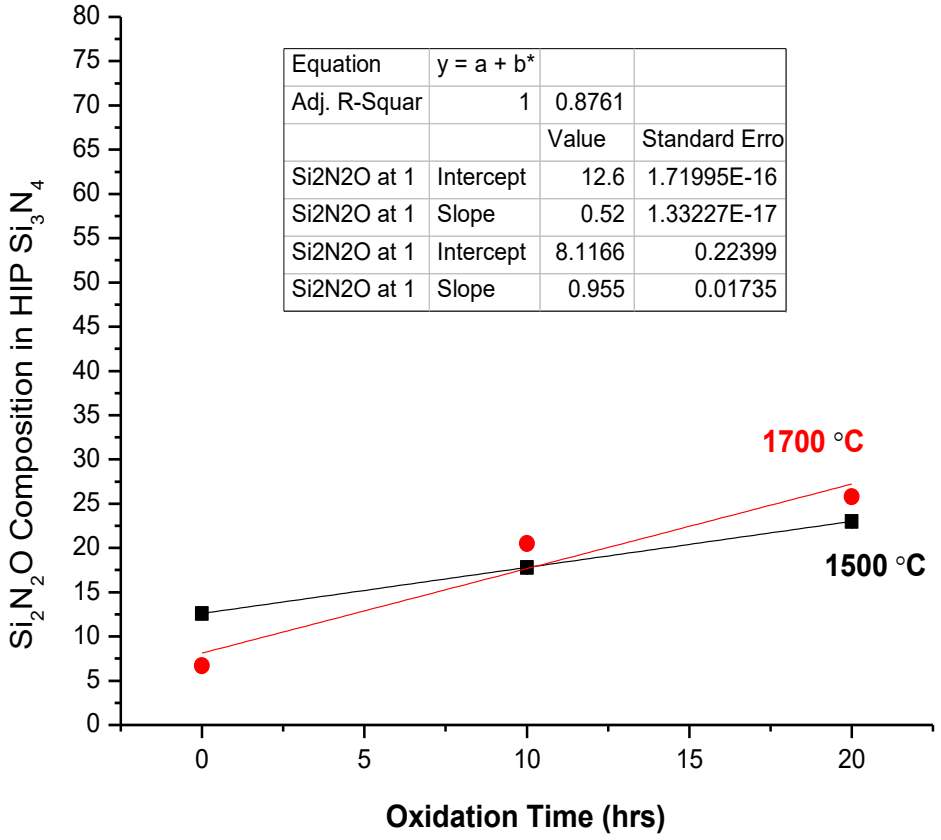
Characterization Sintered Samples

β-Si_3N_4 Content in HIP Si_3N_4

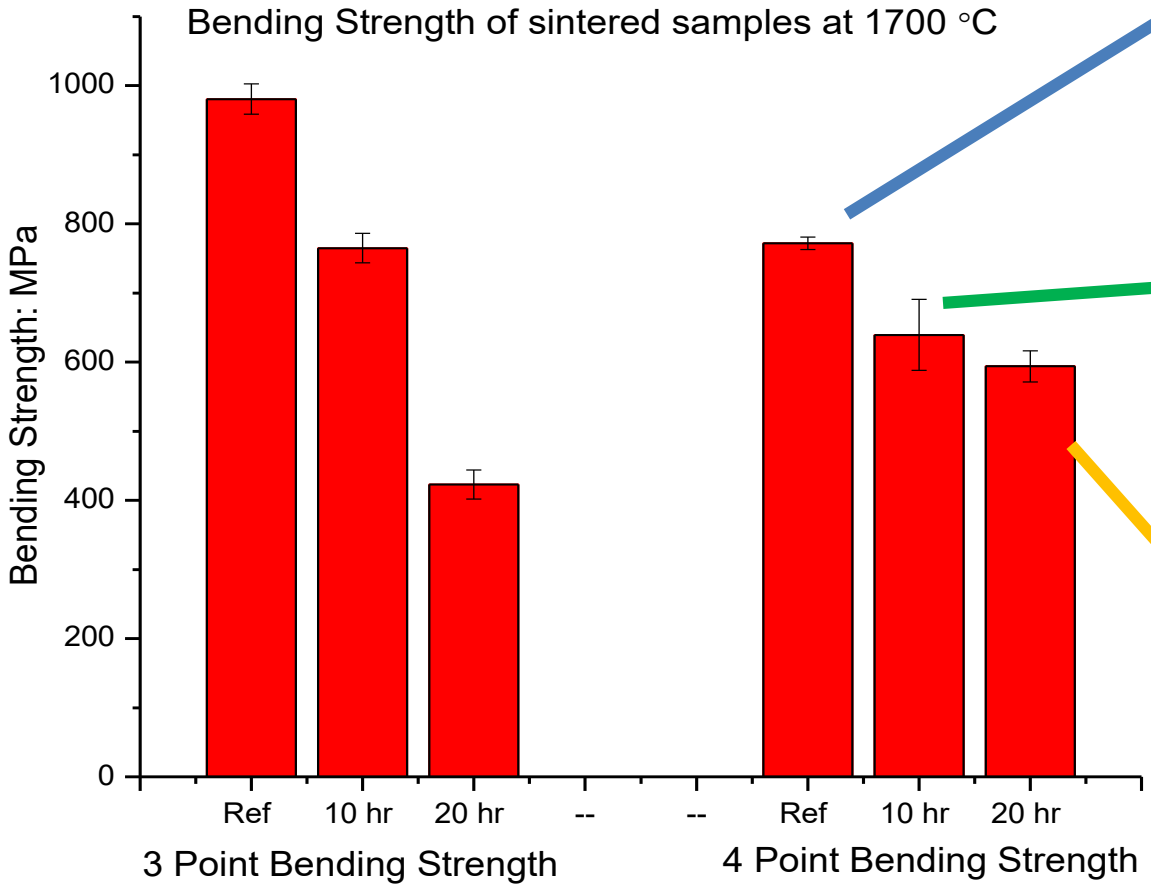


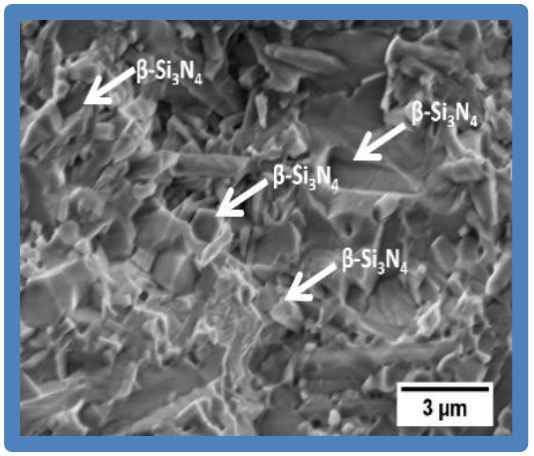
Si_2N_2O Content in HIP Si_3N_4

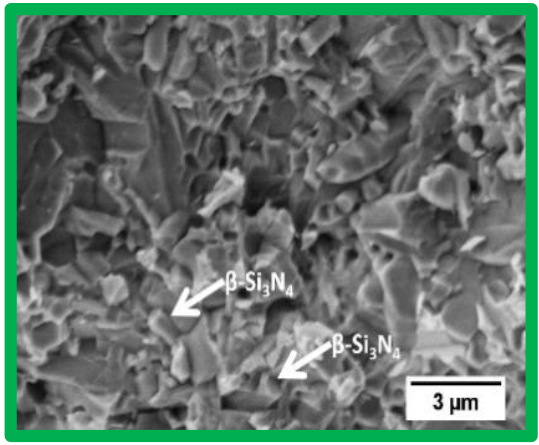
Equation	y = a + b*		
Adj. R-Squar	1	0.8761	
		Value	Standard Erro
Si2N2O at 1	Intercept	12.6	1.71995E-16
Si2N2O at 1	Slope	0.52	1.33227E-17
Si2N2O at 1	Intercept	8.1166	0.22399
Si2N2O at 1	Slope	0.955	0.01735

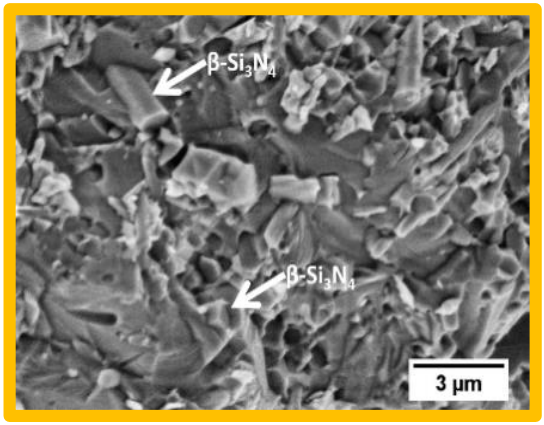


Bending Strength

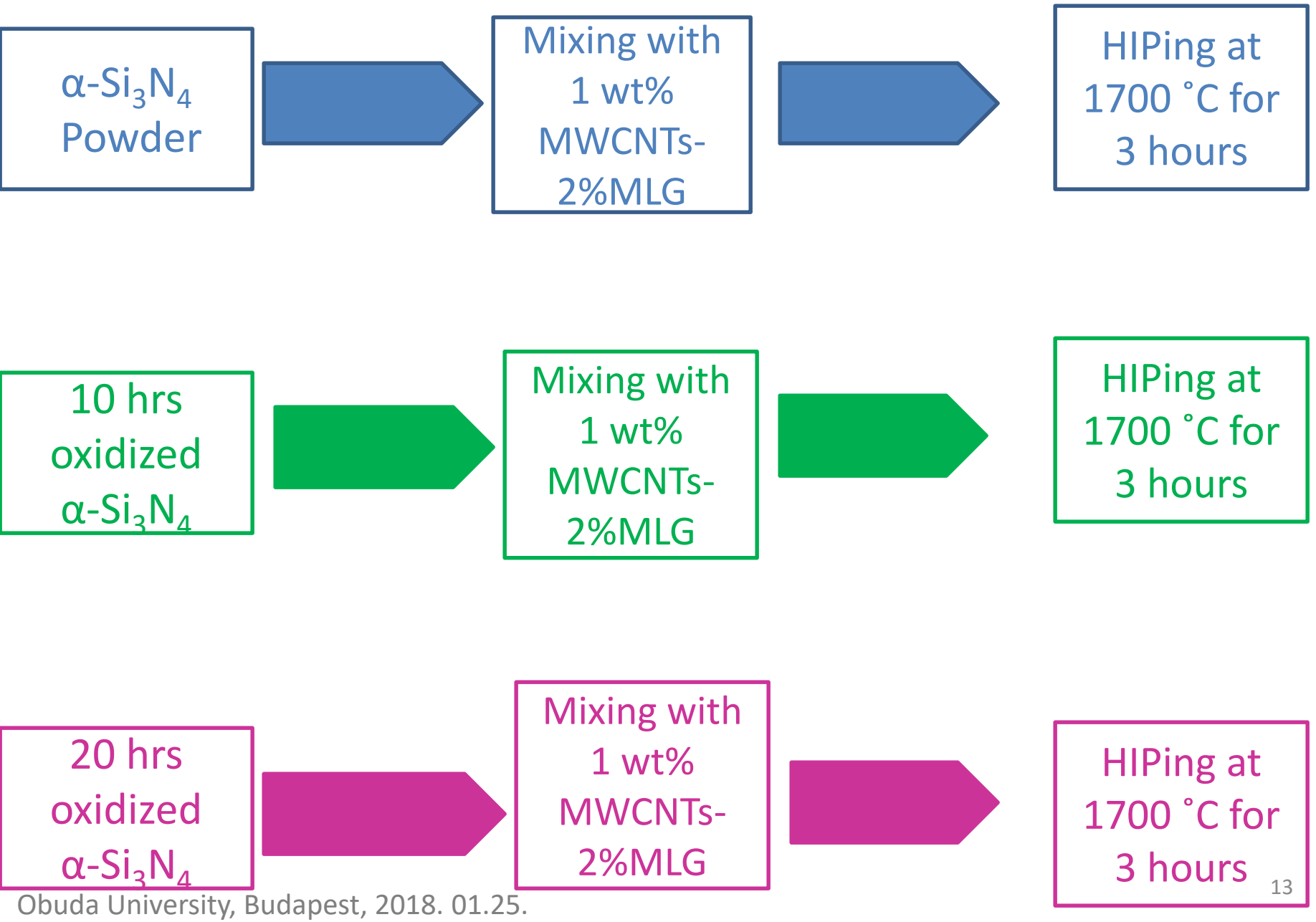




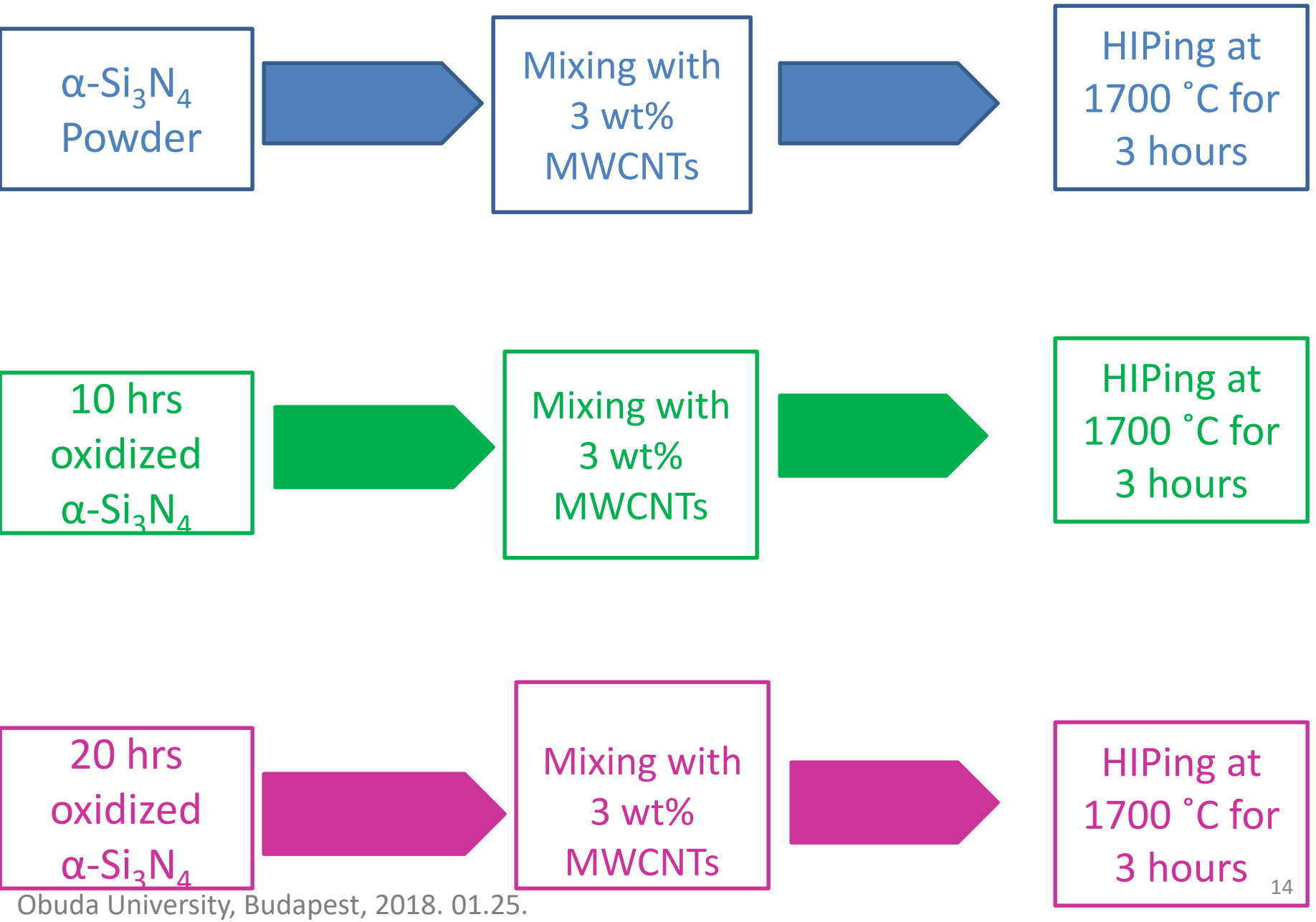




Materials Preparation

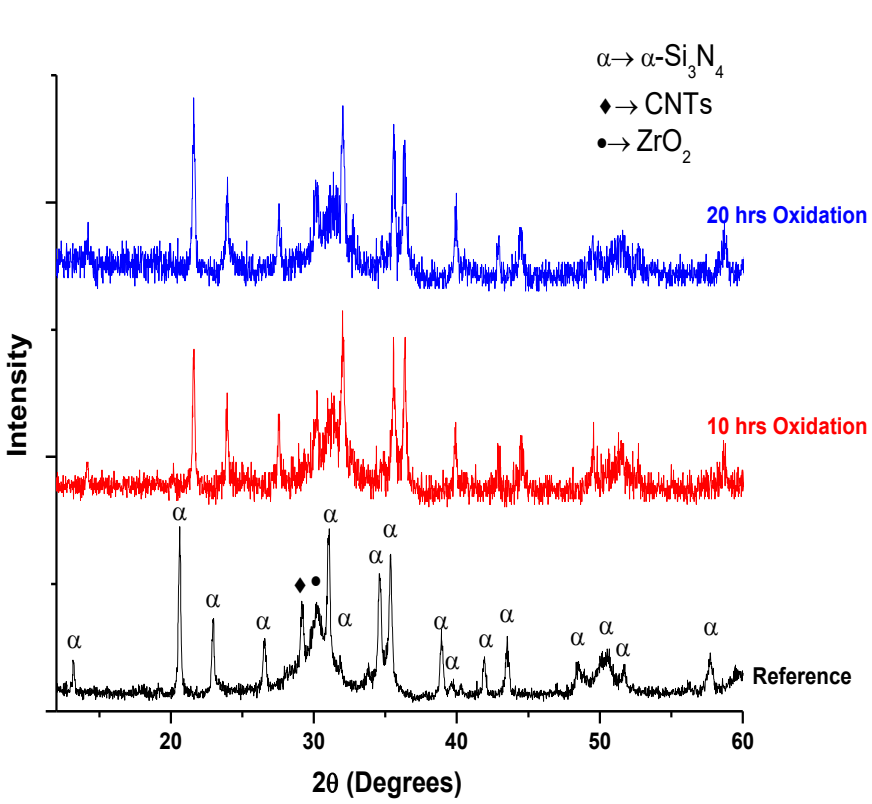


Materials Preparation

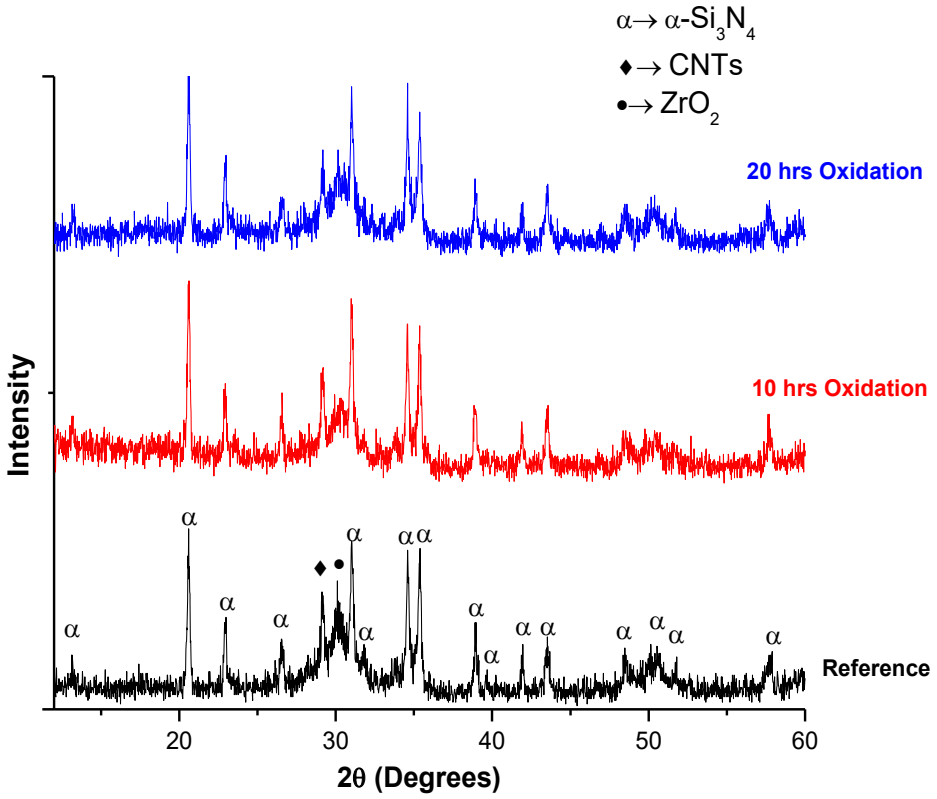


Characterization of samples

Si_3N_4-1% MWCNTs-2%MLG



Si_3N_4-3% MWCNTs



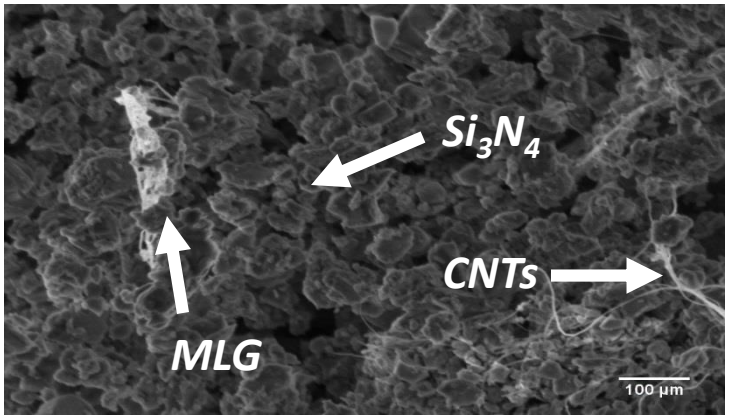
JCPDS PDF (01-076-1407), (00-33-1160), (00-47-1627) and (00-83-0944)

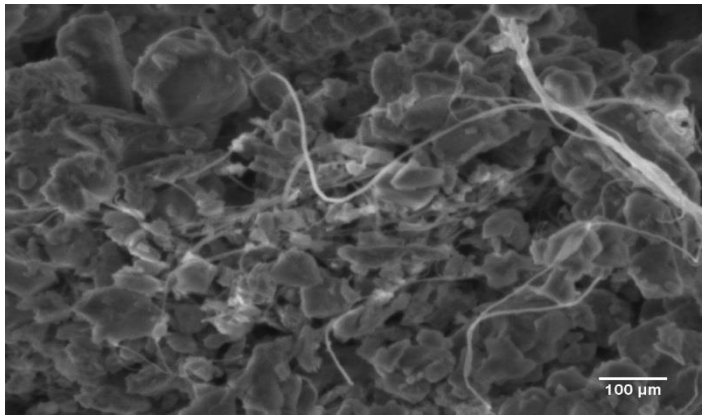
Morpholigical Study of Si_3N_4-1%MWCNTs-2%MLG

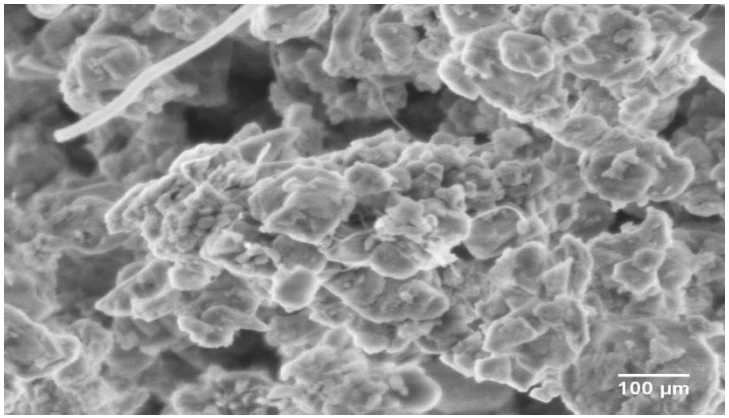
Unoxidizided (Ref.)

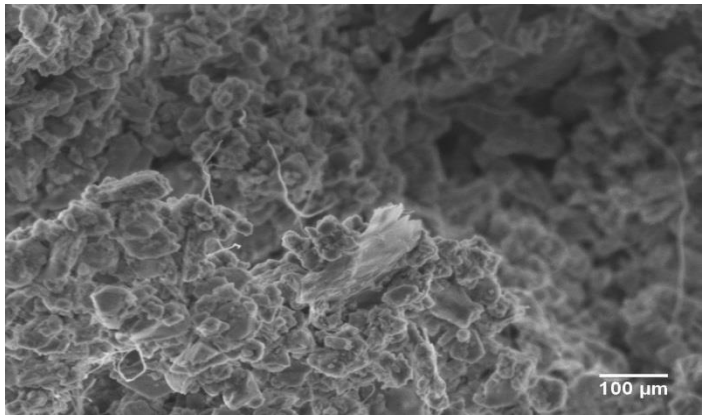
10 hrs oxidized

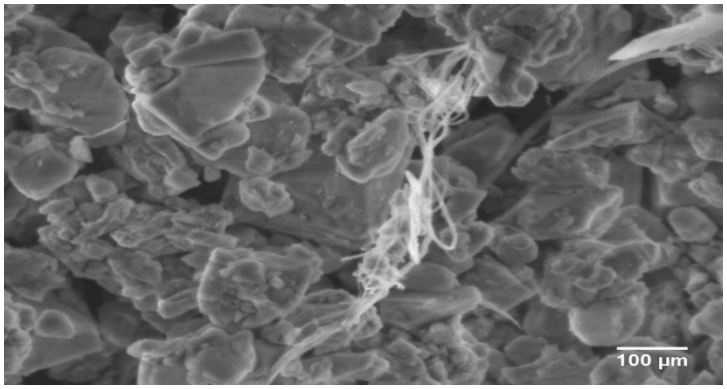
20 hrs oxidized

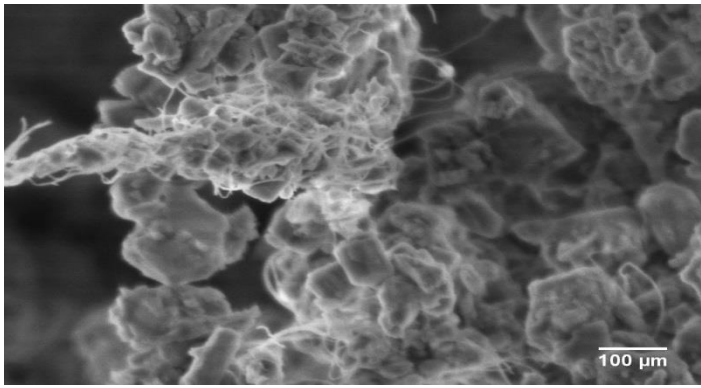










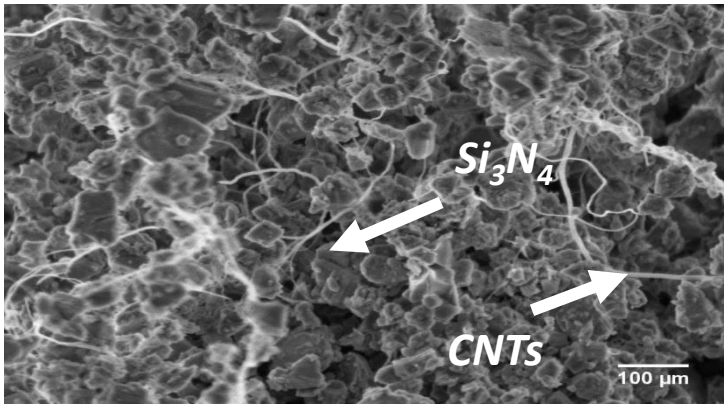


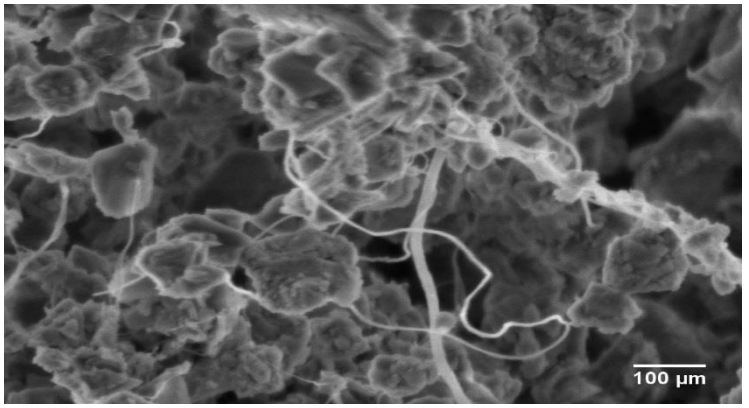
Morpholigical Study of Si_3N_4-3% MWCNTs

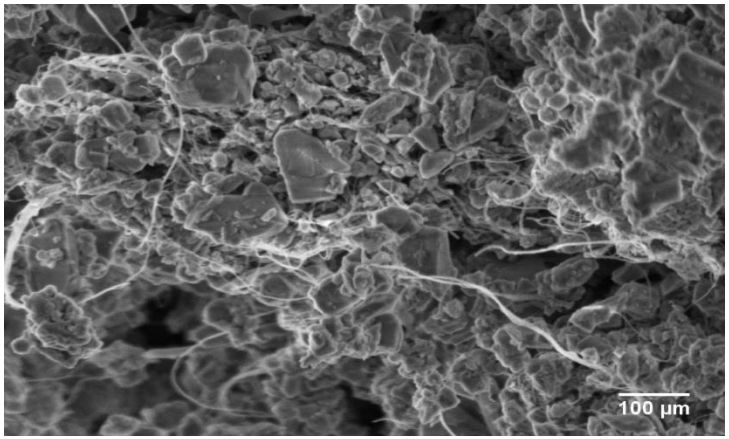
Unoxidizided (Ref.)

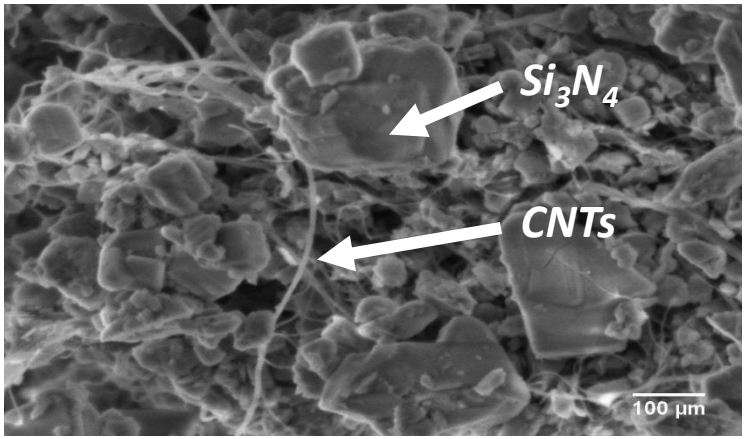
10 hrs oxidized

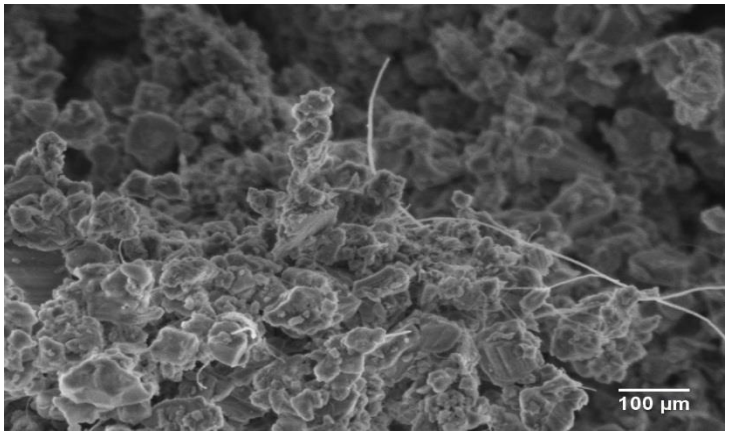
20 hrs oxidized

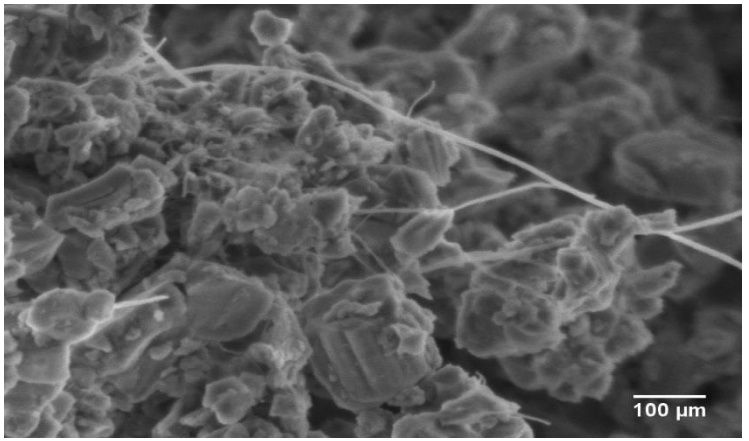












Conclusion

- Powders were milled successfully by attrition milling
- Particles size in between 50 nm to 500 nm
- Oxidation of base powder was done successfully and confirmed by EDX, HRTEM.
- MWCNTs and MLG mixed with the base powder successfully without its deformation.
- Uniform distribution of MWCNTs and Graphene in the powder.
- Further investigation are needed for the CNTs interaction with the matrix (Si3N4).

Future Plans

- Sintering by HIP
- Characterization of Sintered Samples by TEM, HRTEM, SEM, EDX.
- Mechanical Testing (HV, 3 pt. & 4pt. Bending st., toughness, Young's Modulus and surface wear testing)
- Paper Publication in International Journal

Future Plans for Conferences

- Junior EURO-MAT 2018 (Abstract Submitted).

Acknowledgement

- Dr. Zsolt Fogarassy for TEM & HRTEM and Dr. Zsolt E. Horvath for XRD.
- Thanks to supervisors for their support
- Special Thanks to the technical Staff Viktor Varga and Sandor Gurban

Thank you for your attention