PLASMA CHEMISTRY IN MTA TTK

Results and applications

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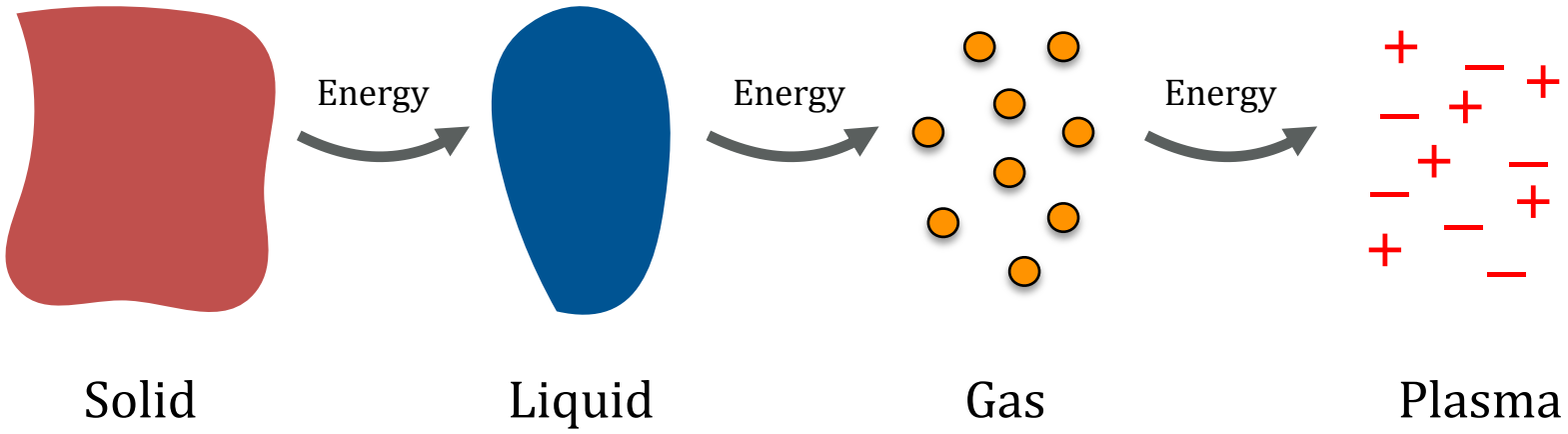
The plasma state



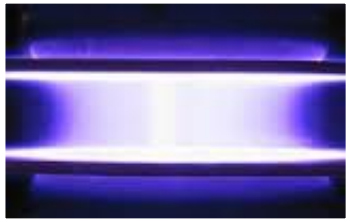
The plasma state

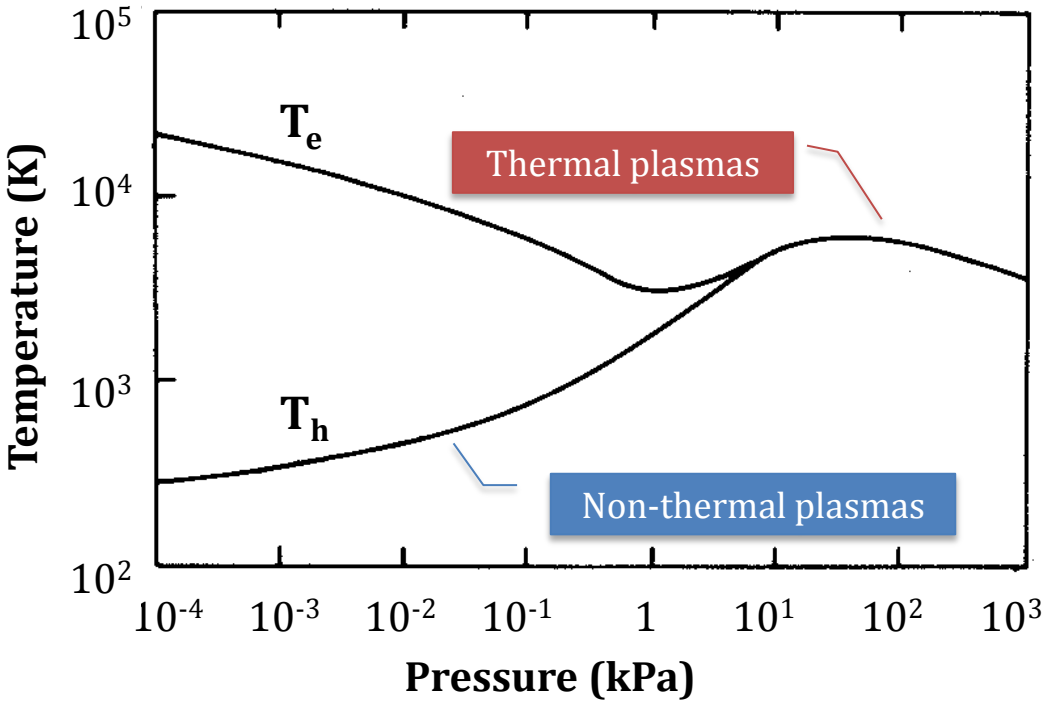
Gas of high energy content

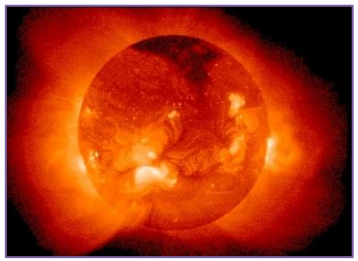
Excited atoms, positive ions and electrons

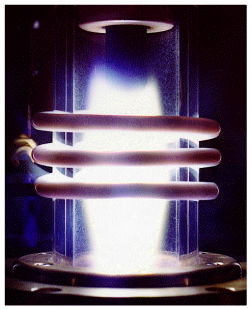
Special properties

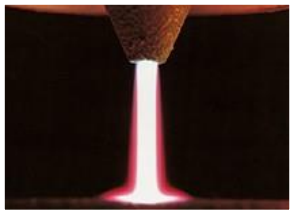
Types of plasmas











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Why plasma chemistry?

- High energy density & temperature (>3000 K)
- Intensive heat and mass transfer
- Efficient decomposition of precursors
- Very rapid reactions (0,001 – 1 s)
- High cooling rate (1000 K/ms)
- Special products: nanopowders, nanomaterials …

- Application in materials & environmental science

Facilities and models

Plasma	System	Typical models
Thermal	RF, 30 kW	MS: nanopowders (oxides, nitrides, carbides, fullerenes)
		ES: halogenated hydrocarbons …
	Arc, 100 kW	MS: metals, silicates, ceramics …
		ES: solid and liquid wastes (muds, slags, flying dusts …)
	SPS, 10 kW	MS: nanostructured ceramics (monolithic, composite ...)
	APS, 40 kW	MS: ceramic & metallic layers (monolithic, composite ...)
Cold (non-thermal)	RF, 100 W	MS: carbon nanostructures, graphite-oxide …
	DBD, 300 W	MS: polymers, textiles …
	PI^3, 300 W	MS: surface modification (polymers, metals, ceramics ...)

MS - materials science, ES – environmental science

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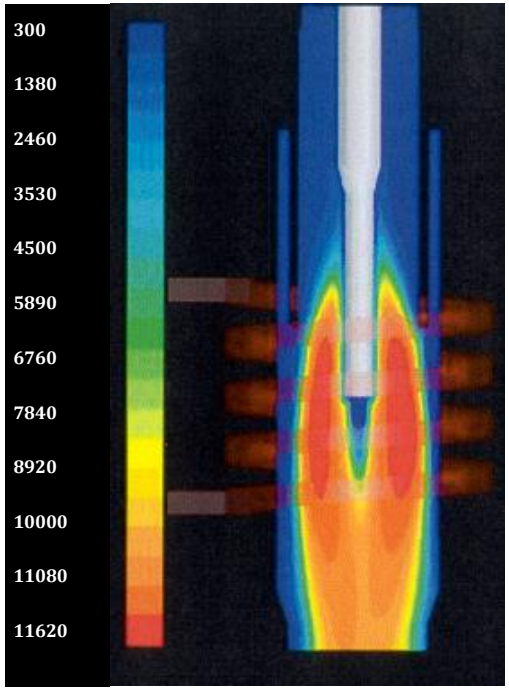
RF thermal plasma reactor

3-5 MHz, 30 kW, TEKNA PL-35 torch



Typical T-distribution

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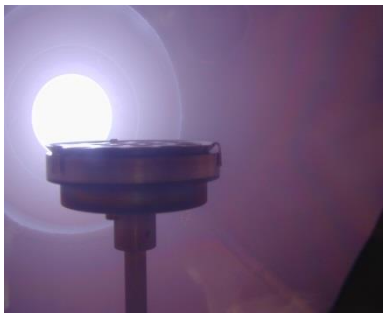
The PIII (PI^3) system



SELECTED EXAMPLES

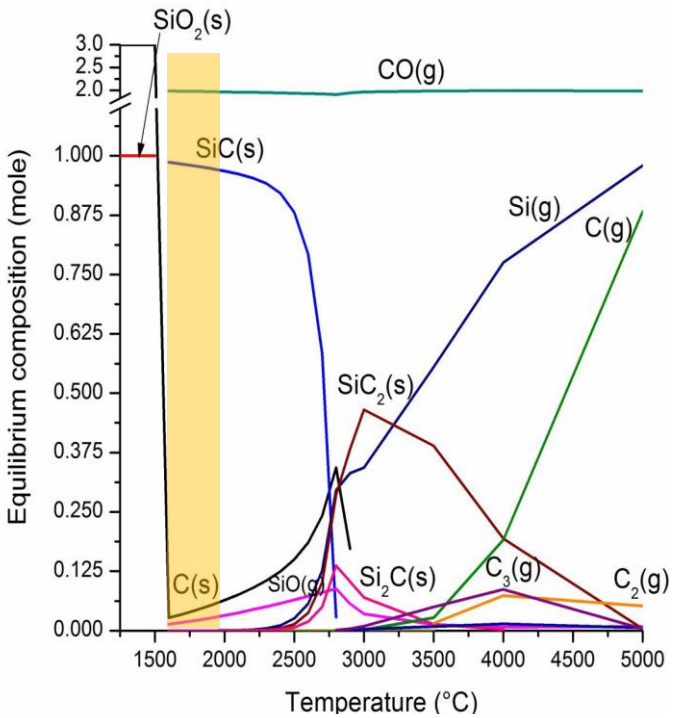
Thermal plasmas for MS

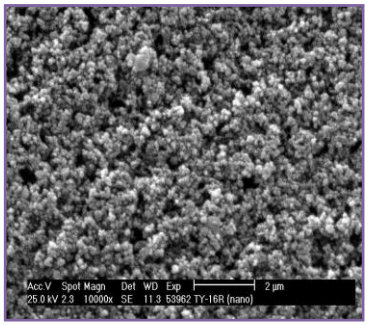
- Synthesis of silicon carbide in RF-TP
- Synthesis of fullerenes in RF-TP
- SPS of graphene reinforced HAP composites
- SiC coatings by APS

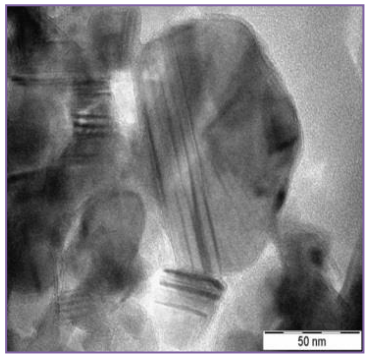
Synthesis of SiC nanopowder

$SiO_2 + C \Rightarrow SiO(g) + CO$

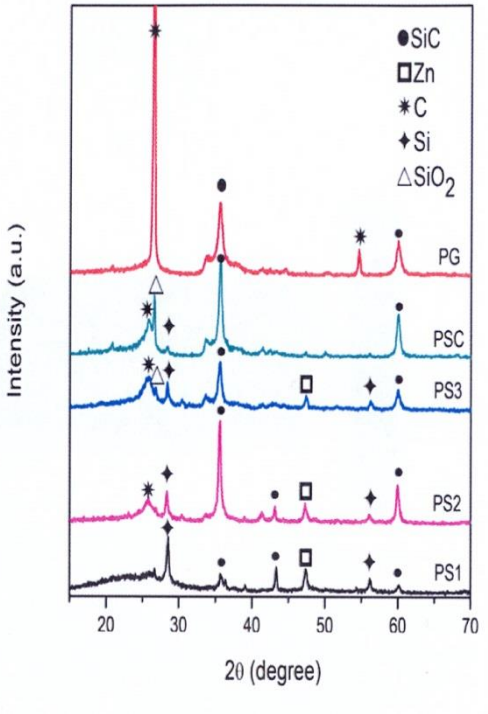
$SiO(g) + C \Rightarrow SiC + CO$







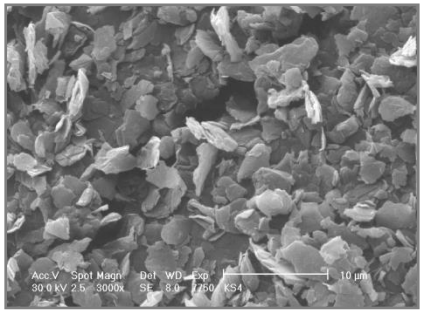
Mean PS 100 nm



Mainly β-crystallites
Some α SiC

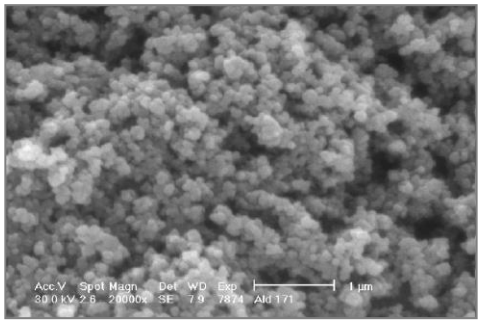
J . Szépvölgyi et al: Powder Technology **214 ,** 300 (2011)

Synthesis of fullerenes



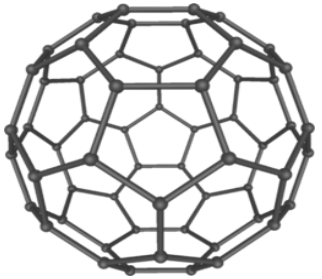
KS4 graphite powder
(D50 = 3,7 µm)

TP processing

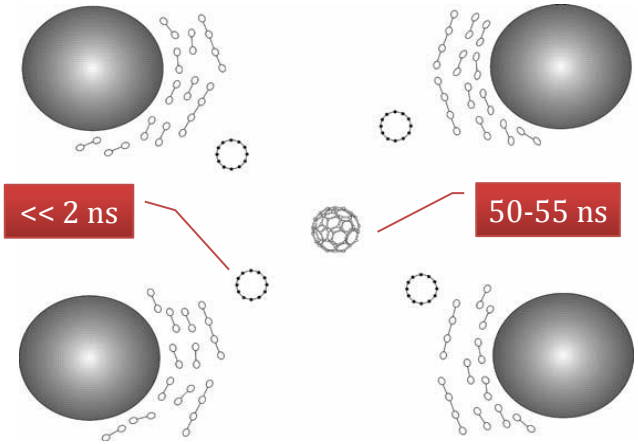


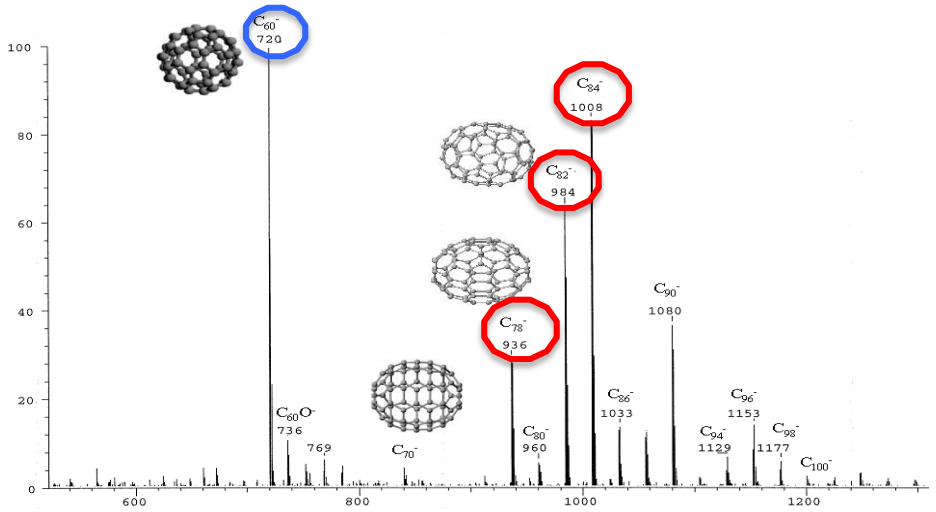
Fullerene soot
(D50 = 25 nm)

Extraction



C60





Z. Markovic et al: J. Nanoscience Nanotechnology **7**, 1357 (2007)

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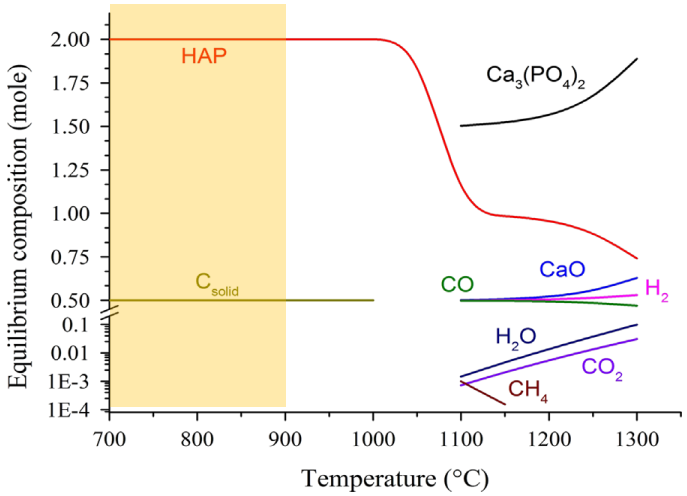
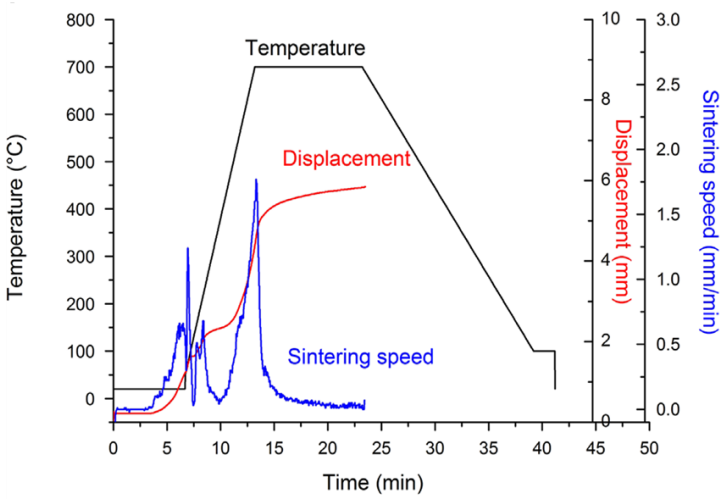
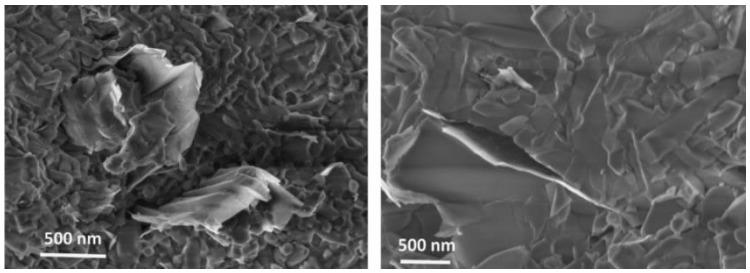
SPS of graphene reinforced HAP composites

98 % HAP + 2 % GNP

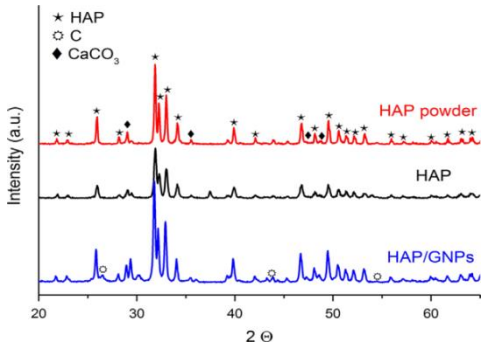


SPS conditions at 700°C





HV 3.5-4.5 GPa; 3P BS 100-120 MPa



Sz. Klébert et al: Ceramics Intntl. **41**(3), 3647 (2015)

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SiC coatings by APS

Synthesis of SiC nanopowder

↓

Mixing with Al_2O_3+TiO_2

↓

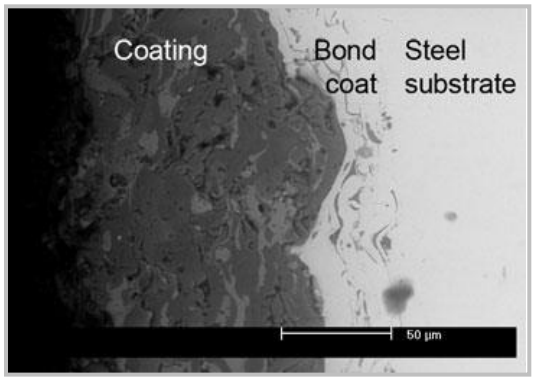
Granulation EtOH+TES

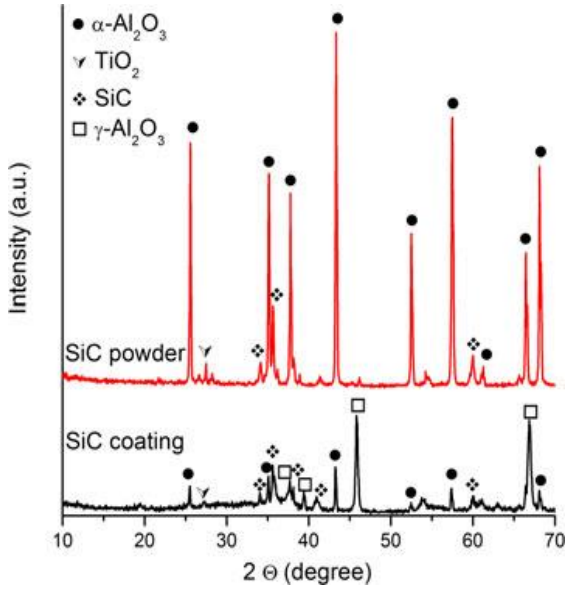
↓

Drying 120°C, 4 h

↓

Calcination 400°C, 0.5 h





Z. Károly et al: Intntl. J. Appl. Ceram. Tech. **10** (1), 72 (2013)

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Cold plasmas for MS

- Nitrogen implantation of Polyamide-6
- Surface modification of n-C materials

Nitrogen implantation of Polyamide-6

Preparation of PA6 dics

↓

PI^3 treatment (150 W) in N_2

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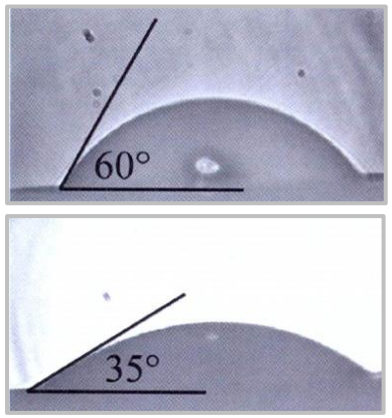
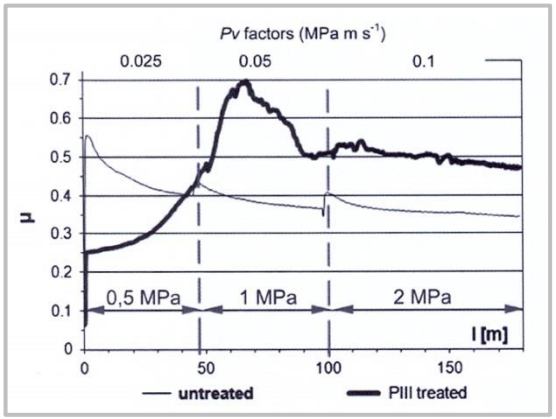
Analysis by XPS

Sample	Surface composition (at%)		
	O	N	C
Untreated PA6	39	16	45
PI^3–treated PA6	30	30	40



Contact angles in water (untreated, treated)



PI^3 treatment modifies the friction coefficient

G. Kalácska et al: Wear **290-291,** 66 (2012)

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Surface modification of n-C materials

Models

Graphene powder (GR)

Single layer
graphite oxide (SLGO)

Highly oriented pyrolytic
graphite (HOPG – reference)

Deposition of graphite layer

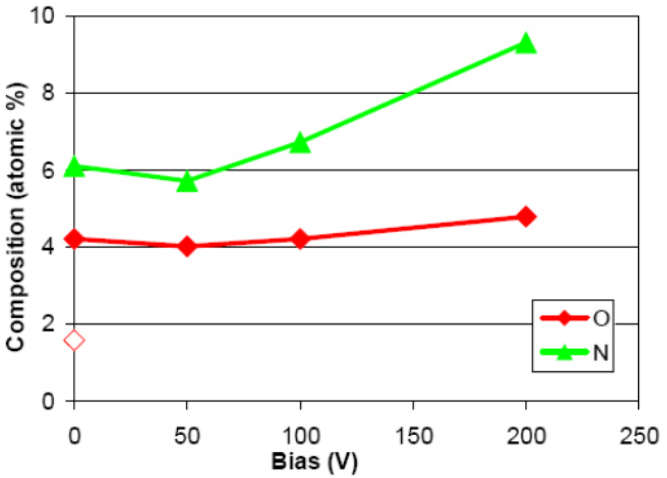
↓

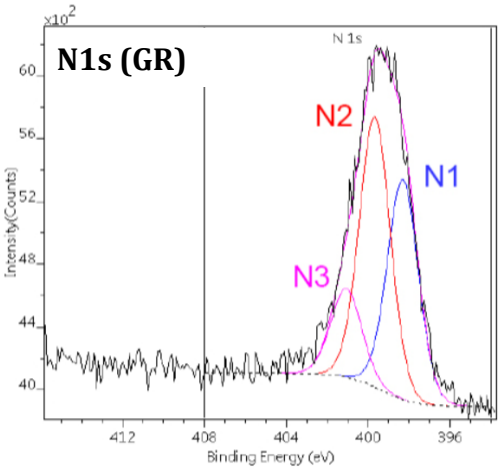
CP treatment (100 W) in N_2

↓

Analysis by XPS

Surface composition of the GR layer





Component	Energy *(eV)*	Assignment
N1	398.3 ± 0.3	sp^2 N in pyridine type ring
N2	399.7 ± 0.3	sp^2 N in diazine/triazine type ring structure
N3	400.9 ± 0.3	N substituting C in graphite plane

I. Bertóti et al: Open Chem. **13**, 451 (2015)

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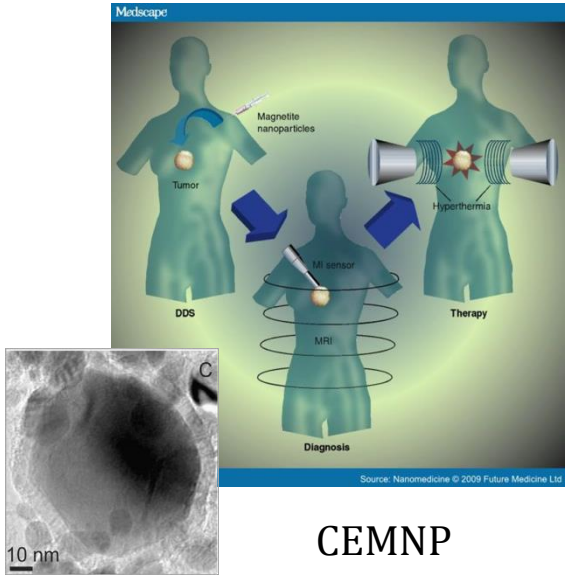
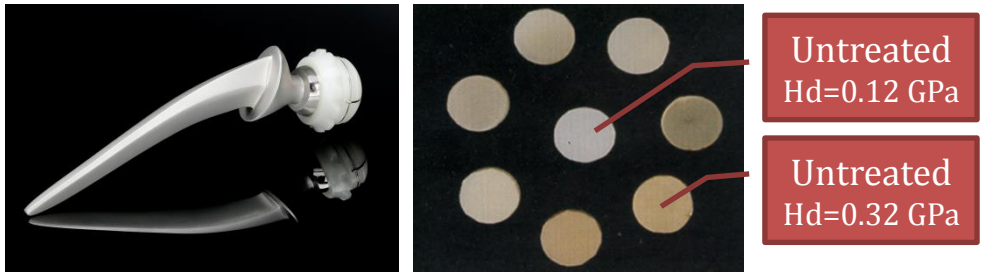
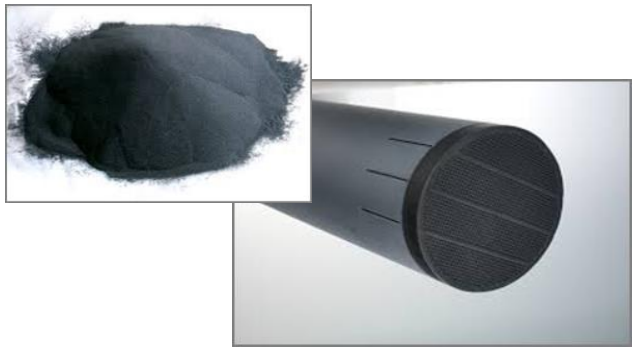
Some applications



CEMNP



PI^3 of HDPE femoral head

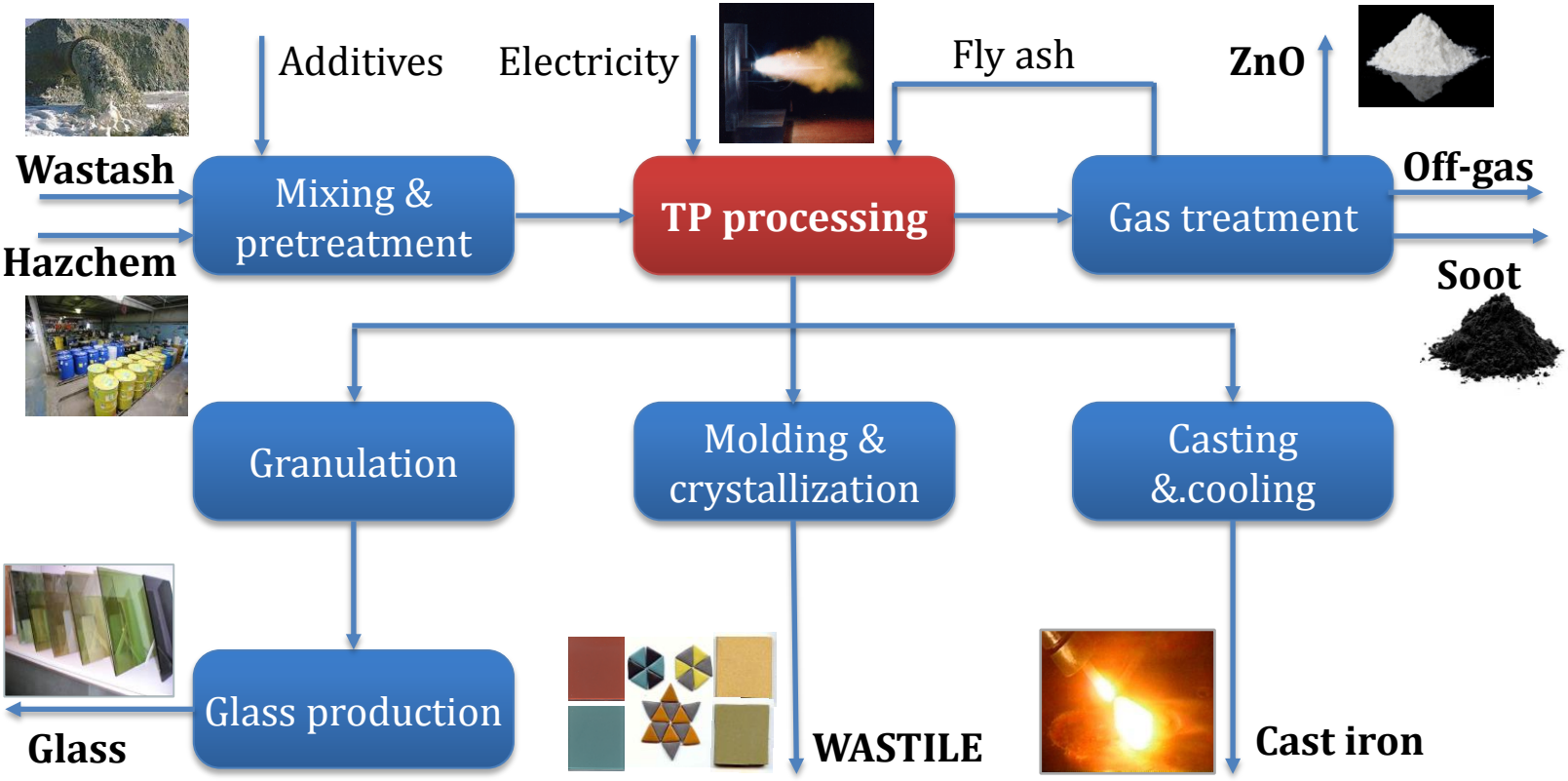


SiC nanomembranes

Thermal plasmas for ES

- The WASTILE project
- The TYGRE project
- Biomass processing

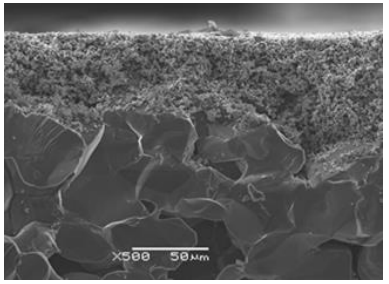
The WASTILE project



The TYGRE project

Pyrolysis carbon
+ quartz sand

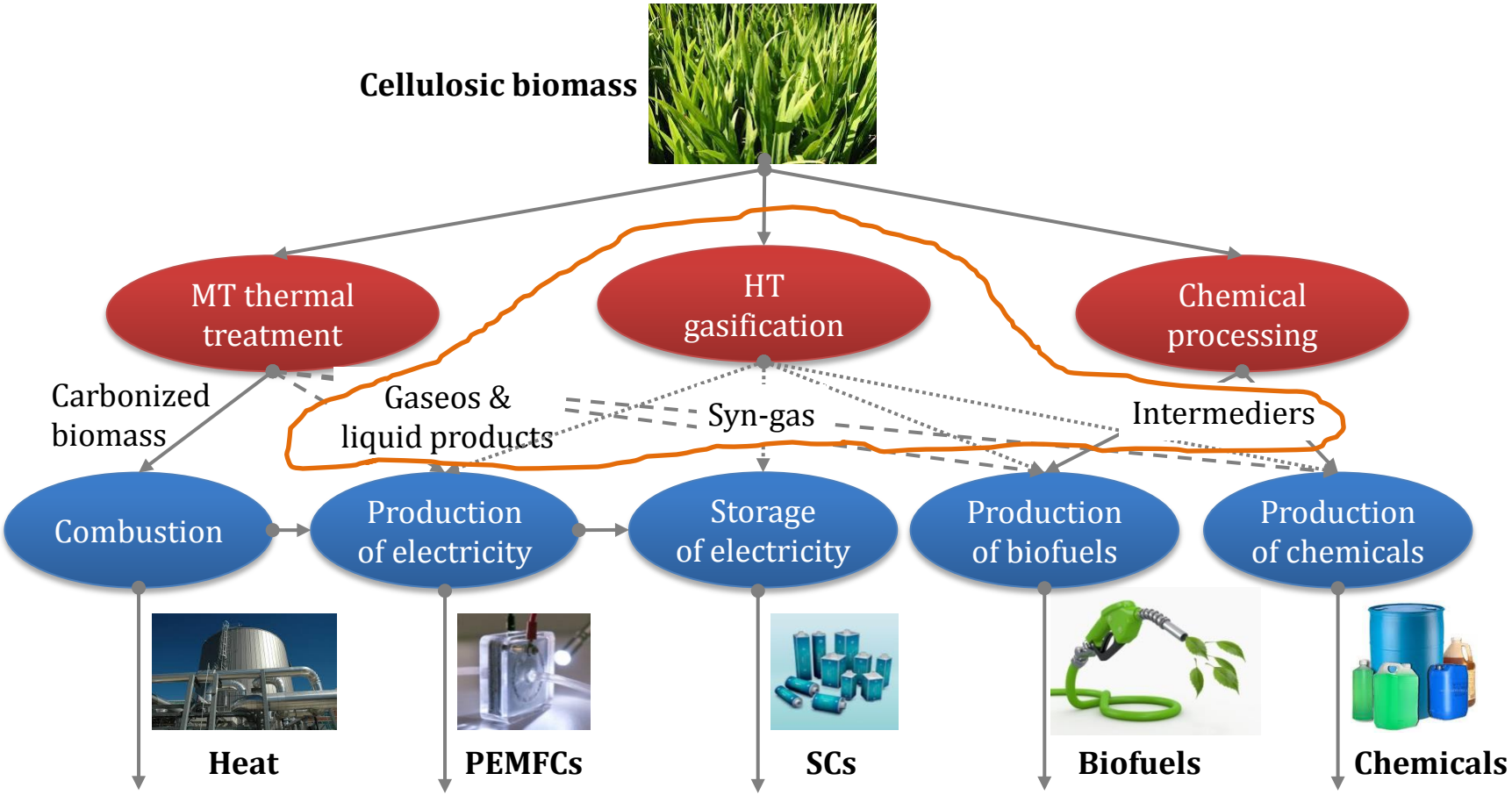
TP technology



Ceramic membranes

Constructed in Policoro (Italy); capacity: 10 kg/h

Processing of biomass



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Concluding remarks

- **Plasma chemistry**
  - Interesting field of chemical research
  - Special conditions, special reactions, special products
  - Broad applications in materials science & environmental protection
- **Related research in MTA TTK**
  - Specialty ceramic powders
  - Micro- and nanostructured bulk ceramics and composites
  - Micro- and nanostructured ceramic layers and coatings
  - Surface modification of polymers, ceramics and metals
  - Processing of different hazardous materials

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