Flame Retardant Mechanism of Polymer/Carbon Nanotube Nanocomposites

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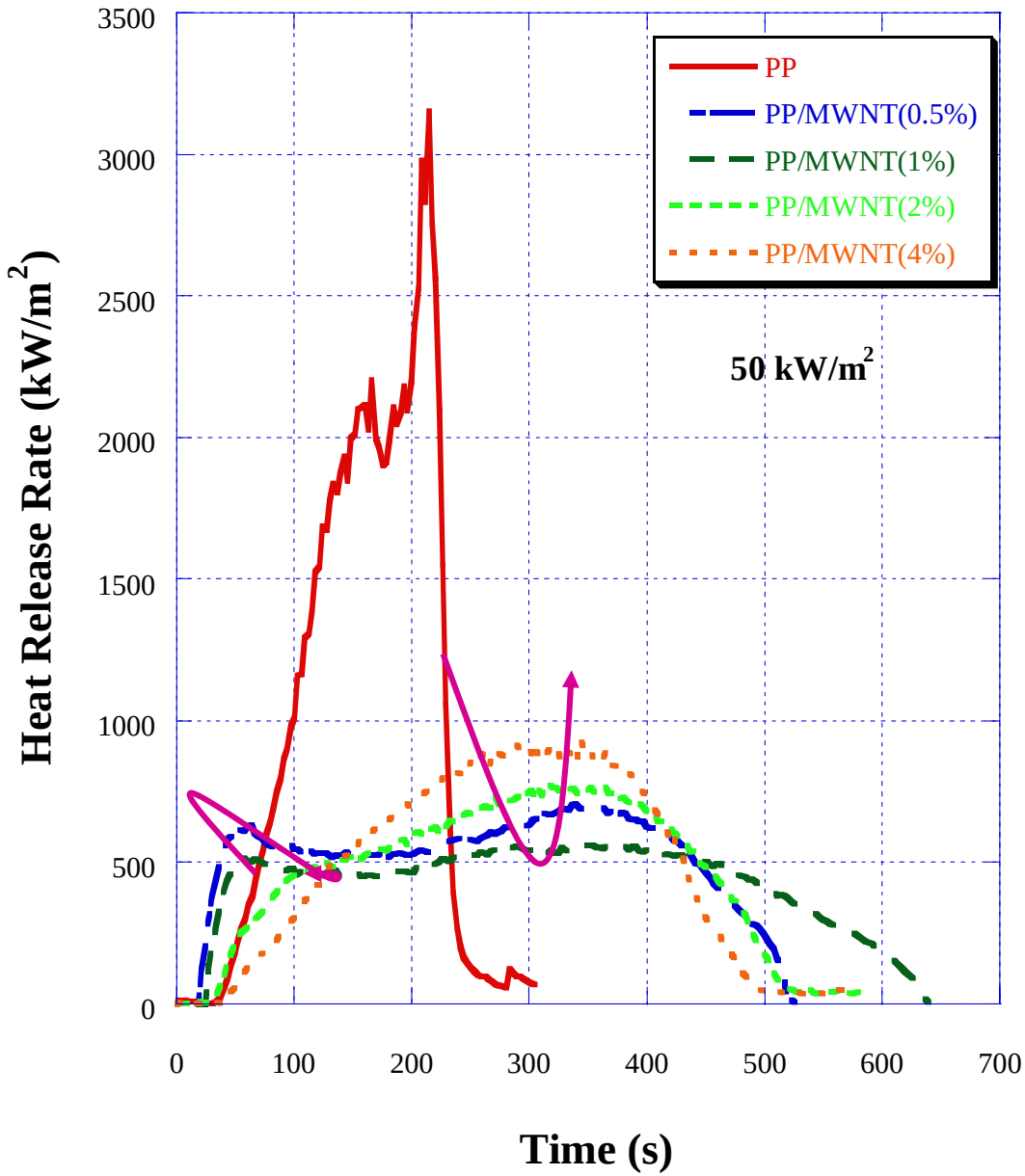
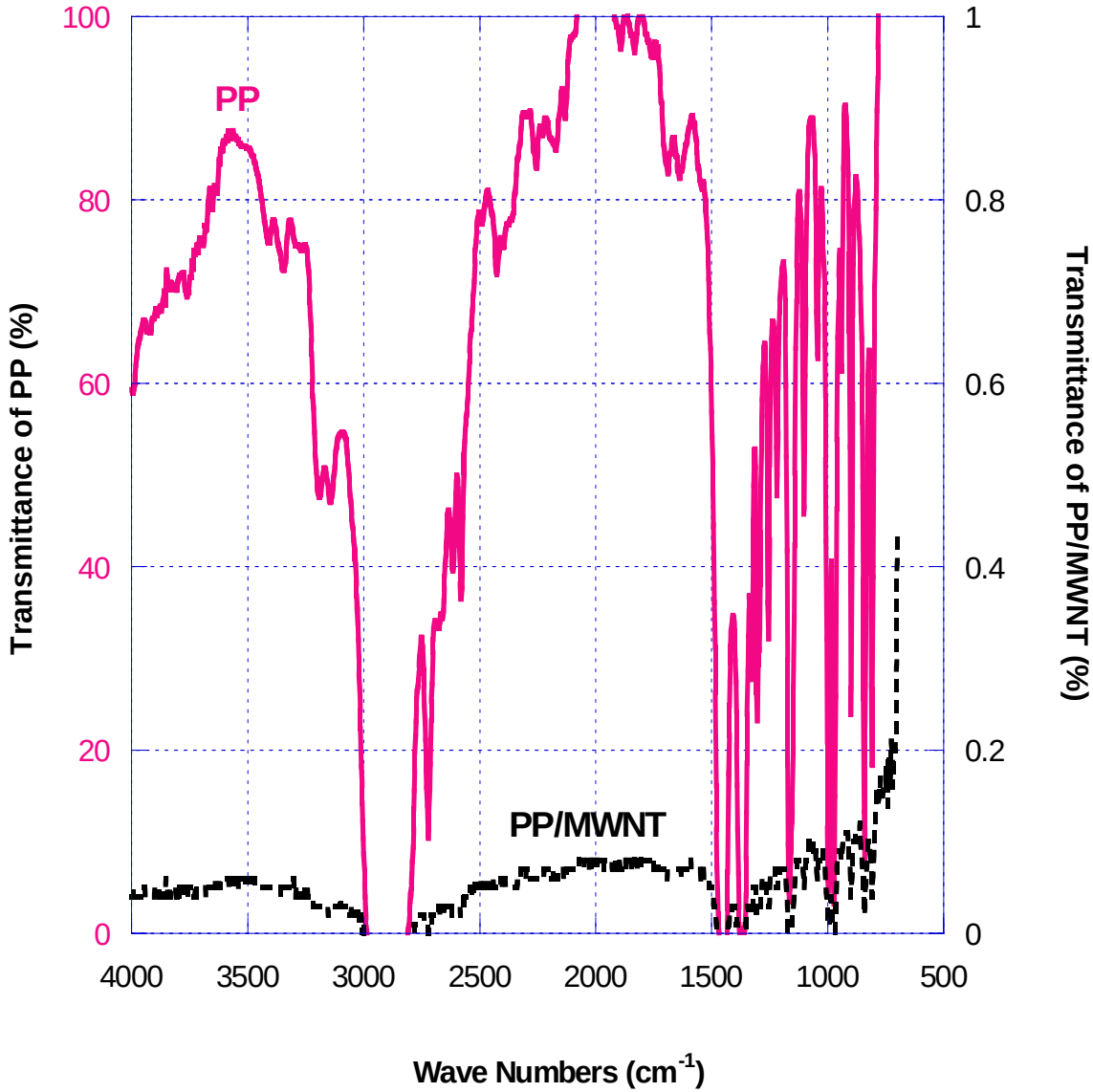
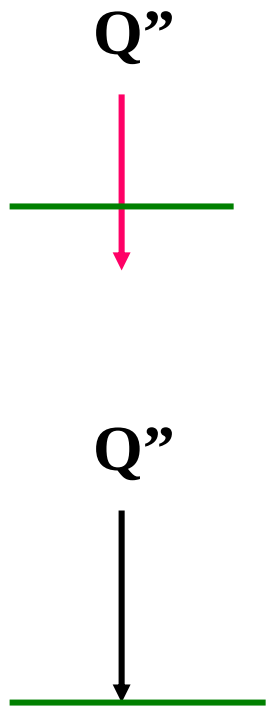
Contents of Presentation

- **Flame retardant mechanism of polymer-carbon nanotube nanocomposites**
- **Effects of dispersion of the tubes on flammability properties**

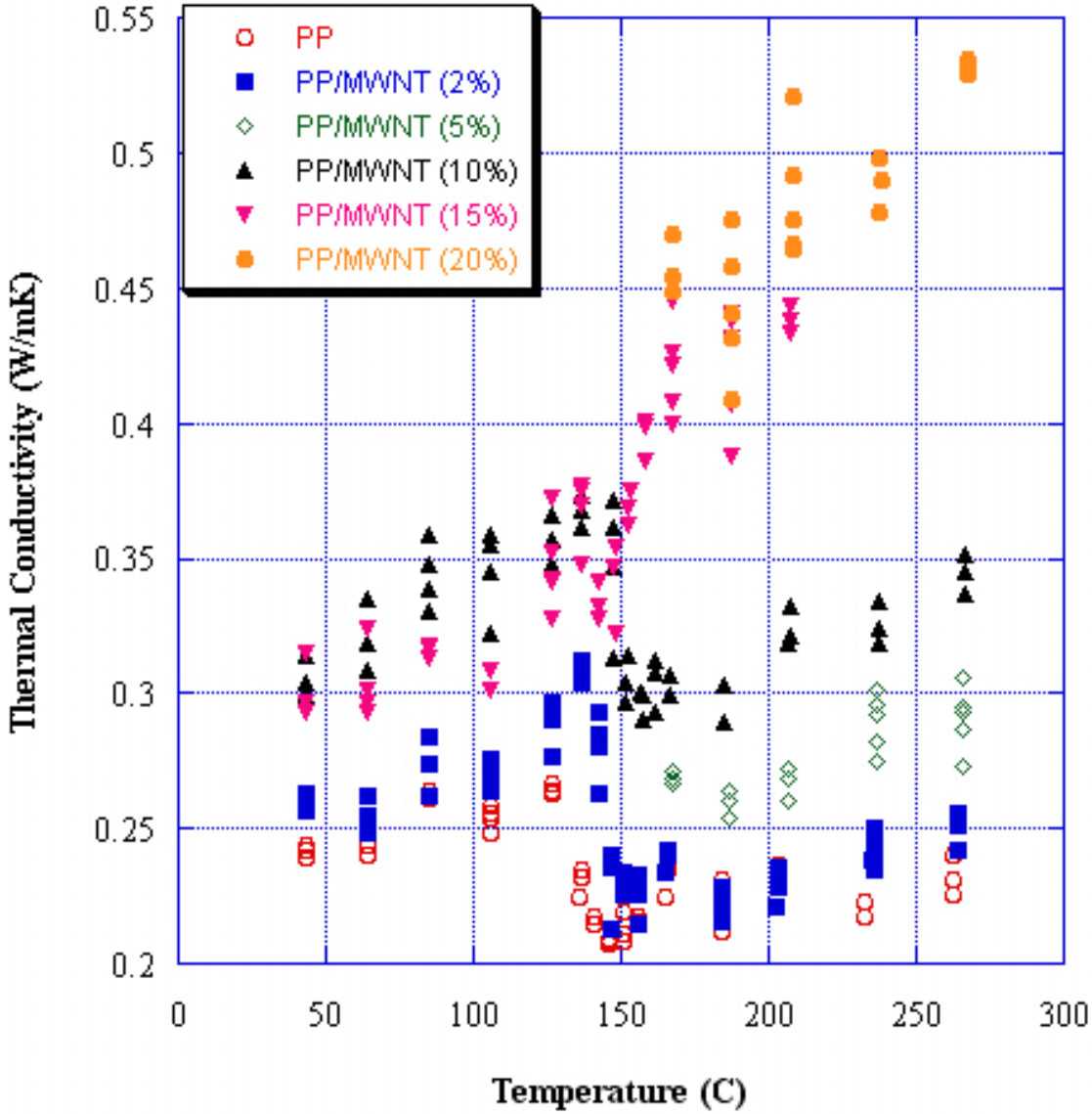

PP
PP/MWNT(0.5%)
PP/MWNT(1%)
PP/MWNT(2%)
PP/MWNT(4%)
50 kW/m2
Heat Release Rate (kW/m2)
Time (s)
0
500
1000
1500
2000
2500
3000
3500
0
100
200
300
400
500
600
700

Comparison of transmission spectra between PP and PP/MWNT (1%) through 200 μm thick film

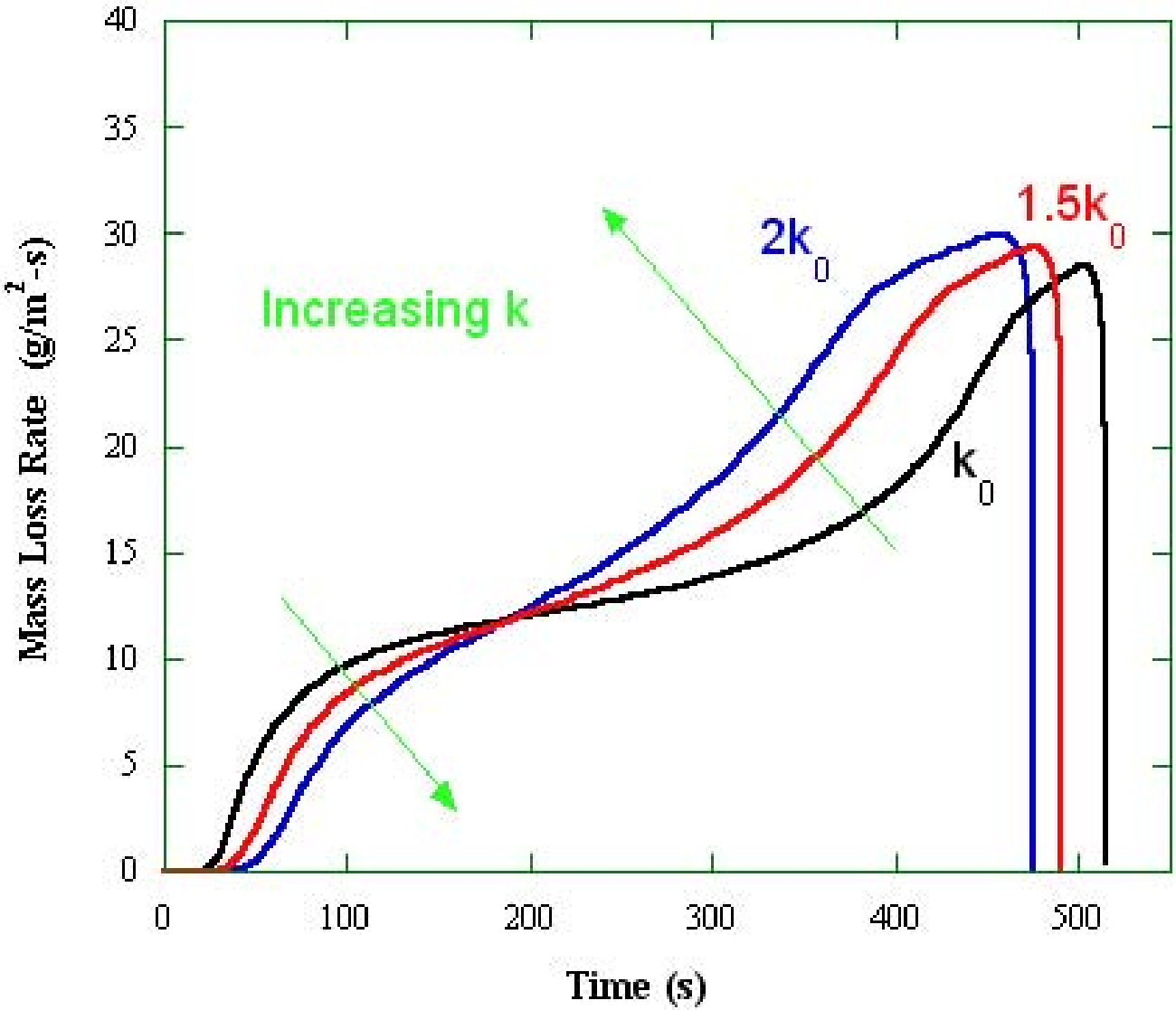


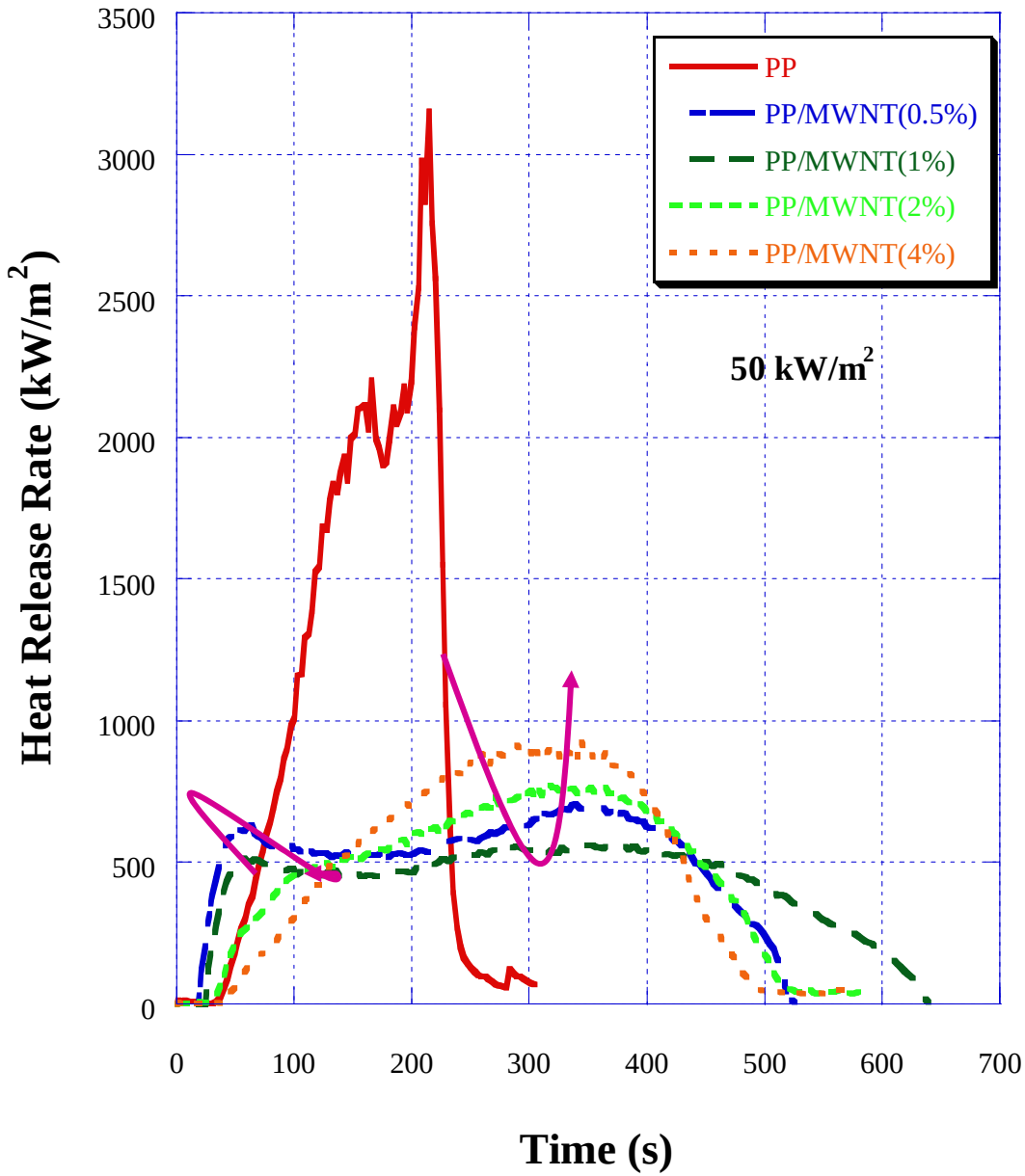


Effects of concentration of MWNT and temperature on thermal conductivity of PP/MWNT nanocomposites

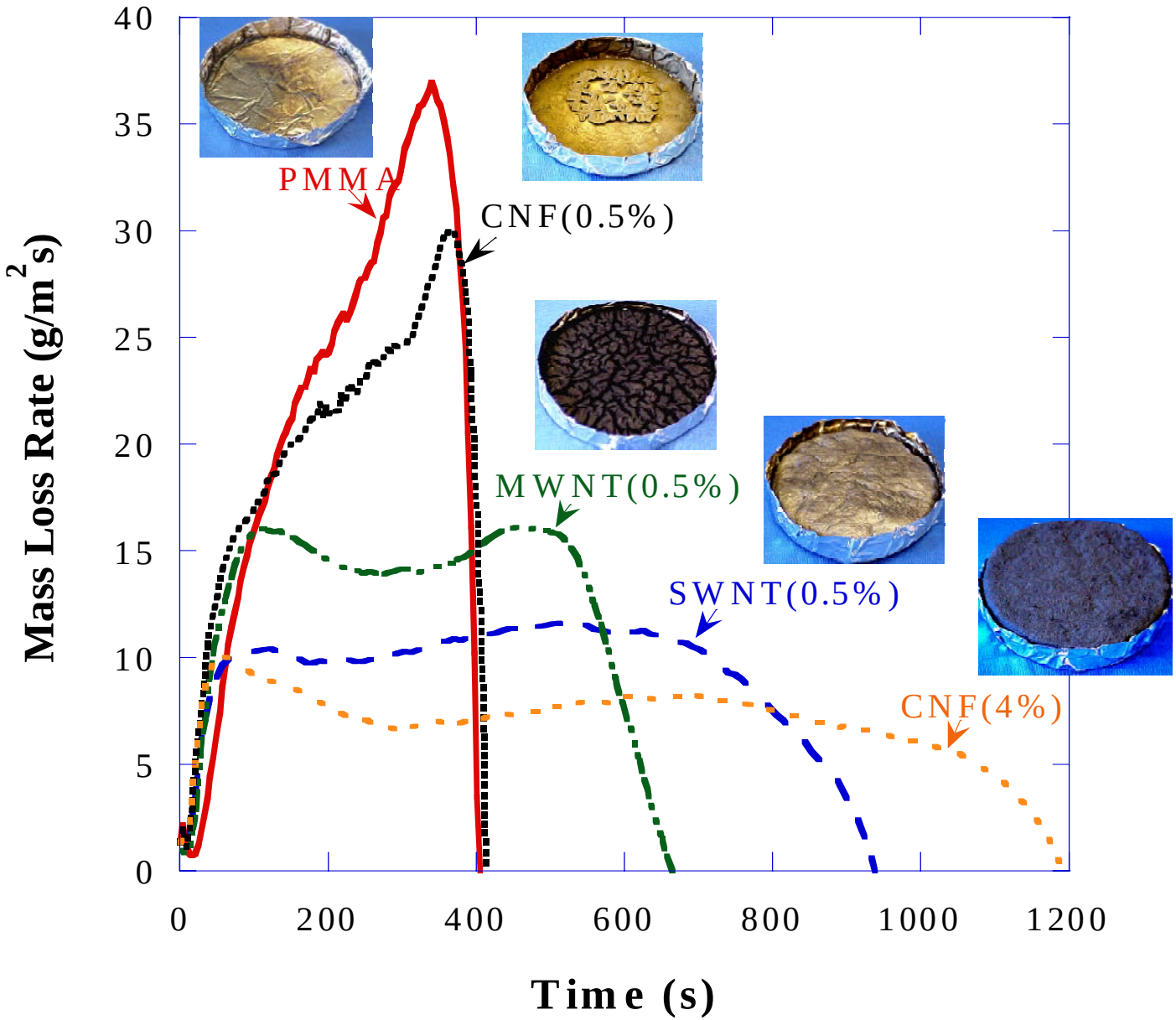


Calculated effects of an increase in thermal conductivity on mass loss rate of PP at 50 kW/m2 in nitrogen




PP
PP/MWNT(0.5%)
PP/MWNT(1%)
PP/MWNT(2%)
PP/MWNT(4%)
50 kW/m2
Heat Release Rate (kW/m2)
Time (s)
0
500
1000
1500
2000
2500
3000
3500
0
100
200
300
400
500
600
700

Effects of addition of nanotubes on mass loss rate of PMMA at 50 kW/m^2 in Nitrogen

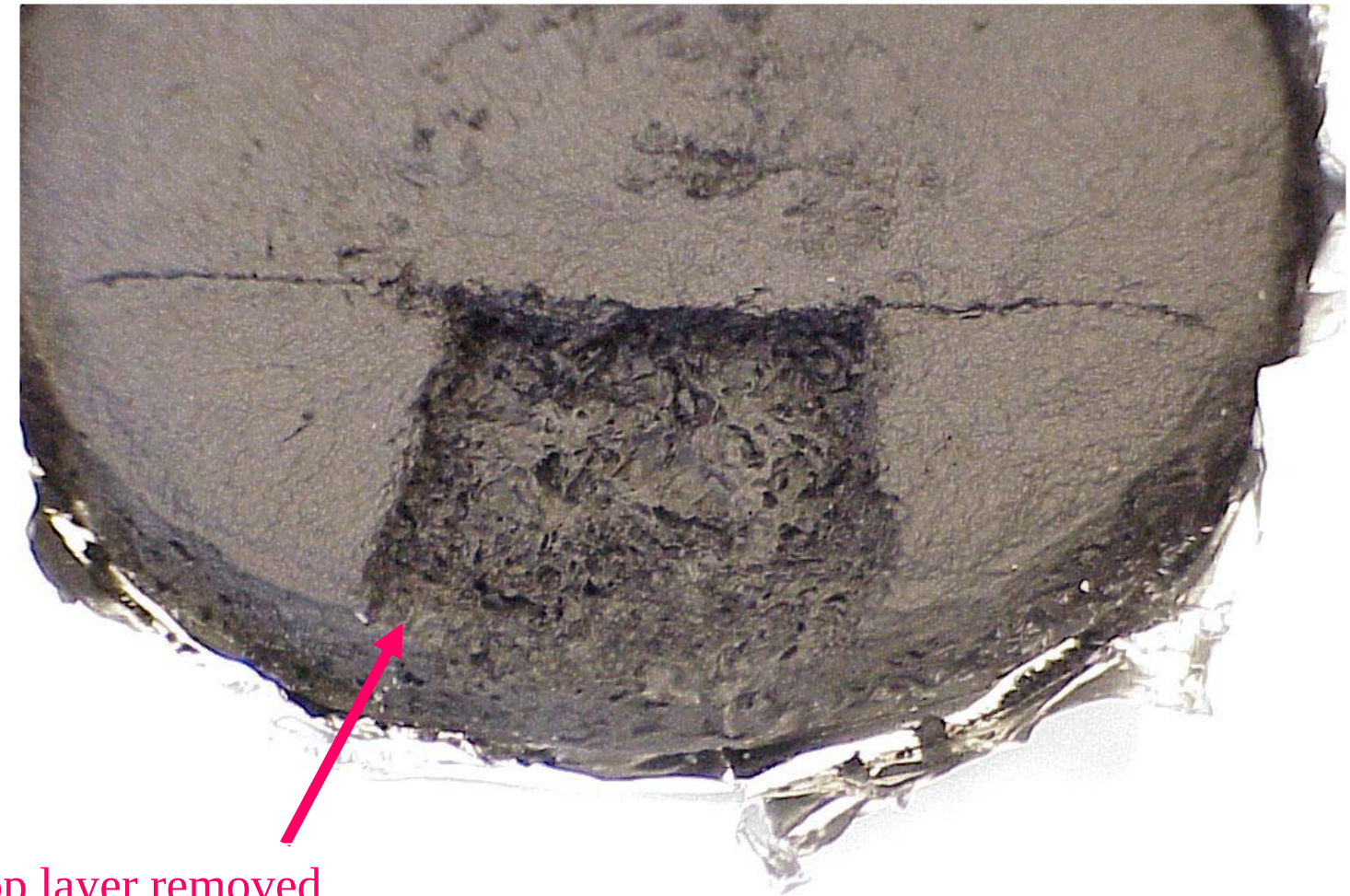


Residue of PP/MWNT(2%) collected after gasification test at 50 kW/^{2} in nitrogen

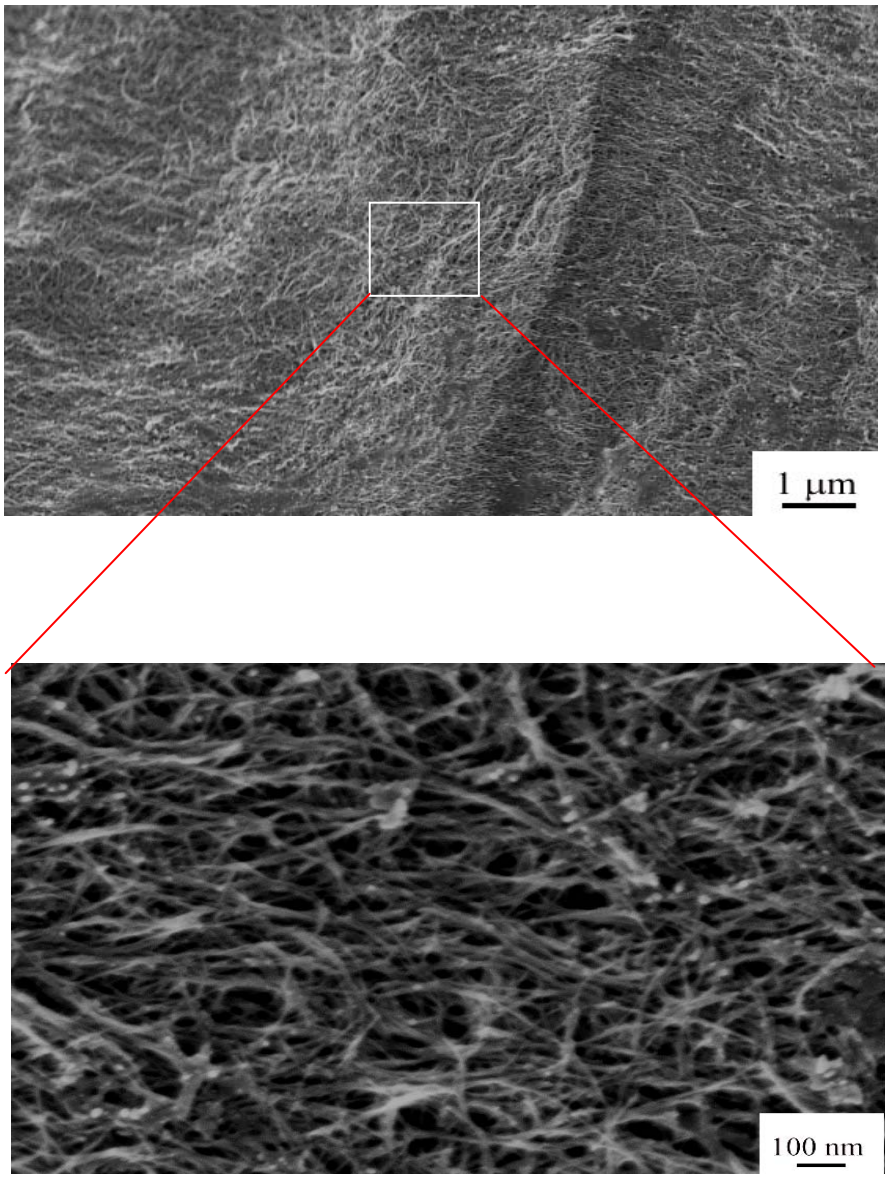
Top view

Cross section

Residue collected at 50% weight loss at 50 kW/m^2 in nitrogen

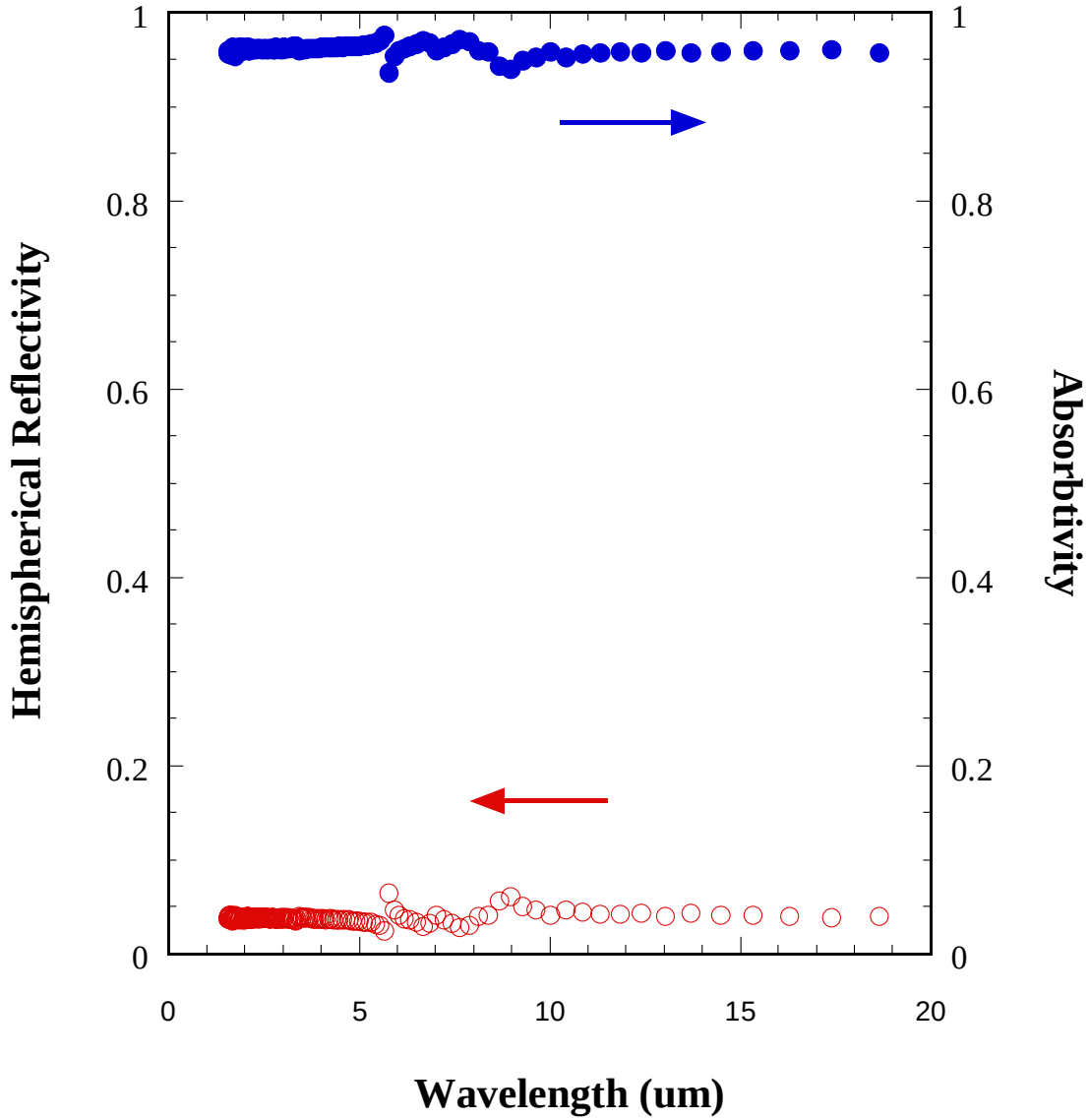


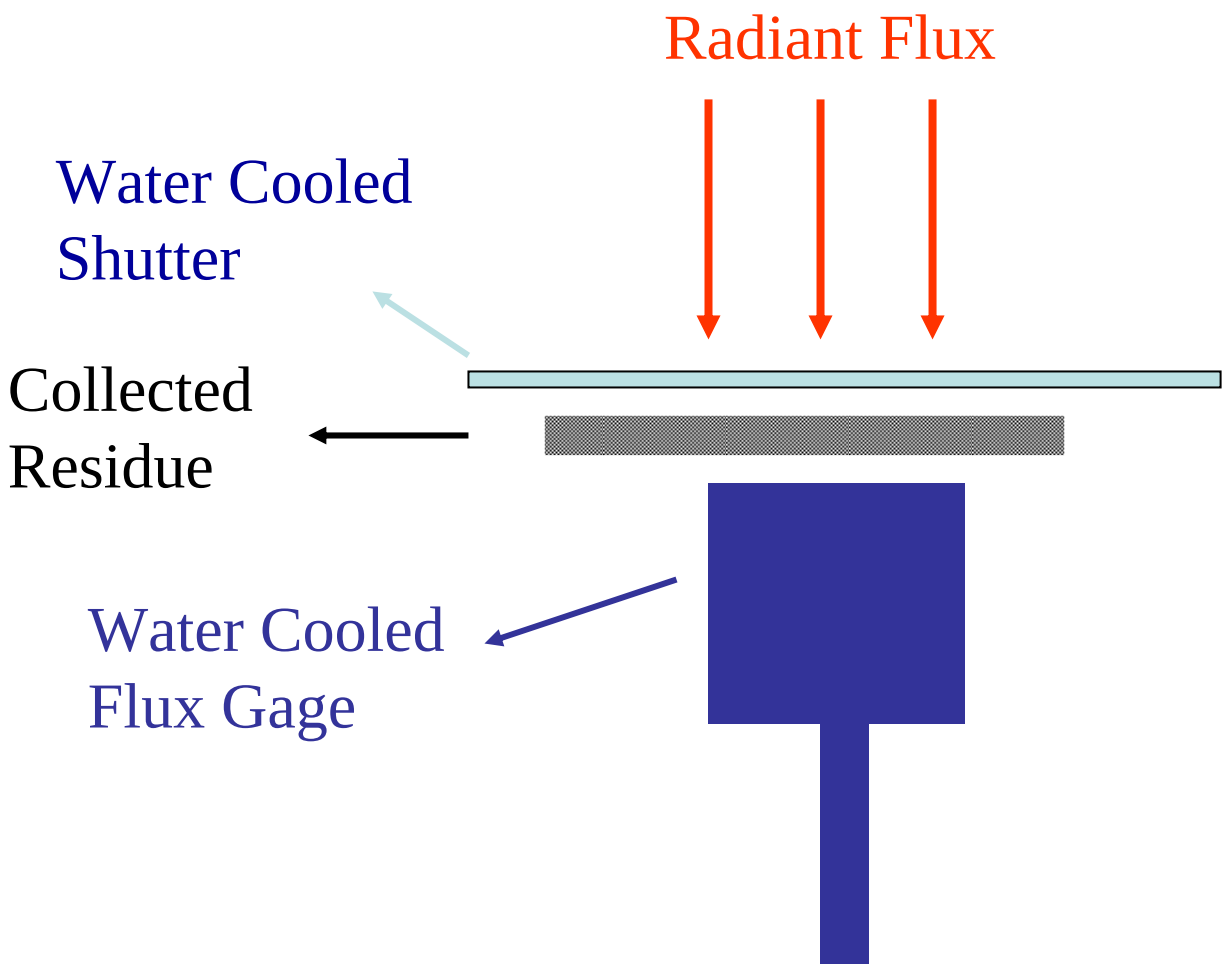
top layer removed

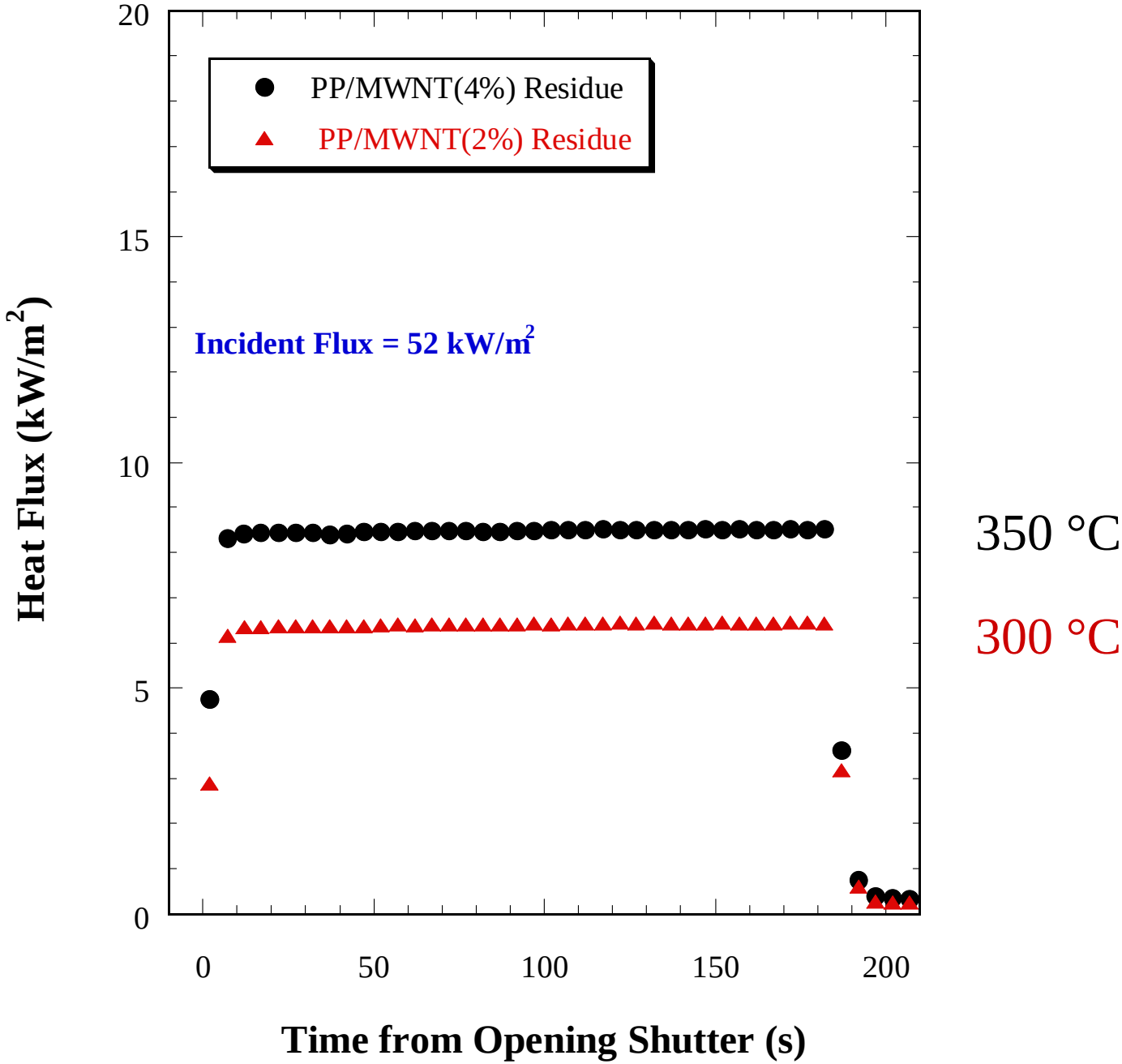


SEM image of the residue of PMMA/SWNT(1%) collected after nitrogen gasification indicating a randomly interlaced network structure.

Reflectivity and Absorptivity of Residue of PMMA/SWNT(1%

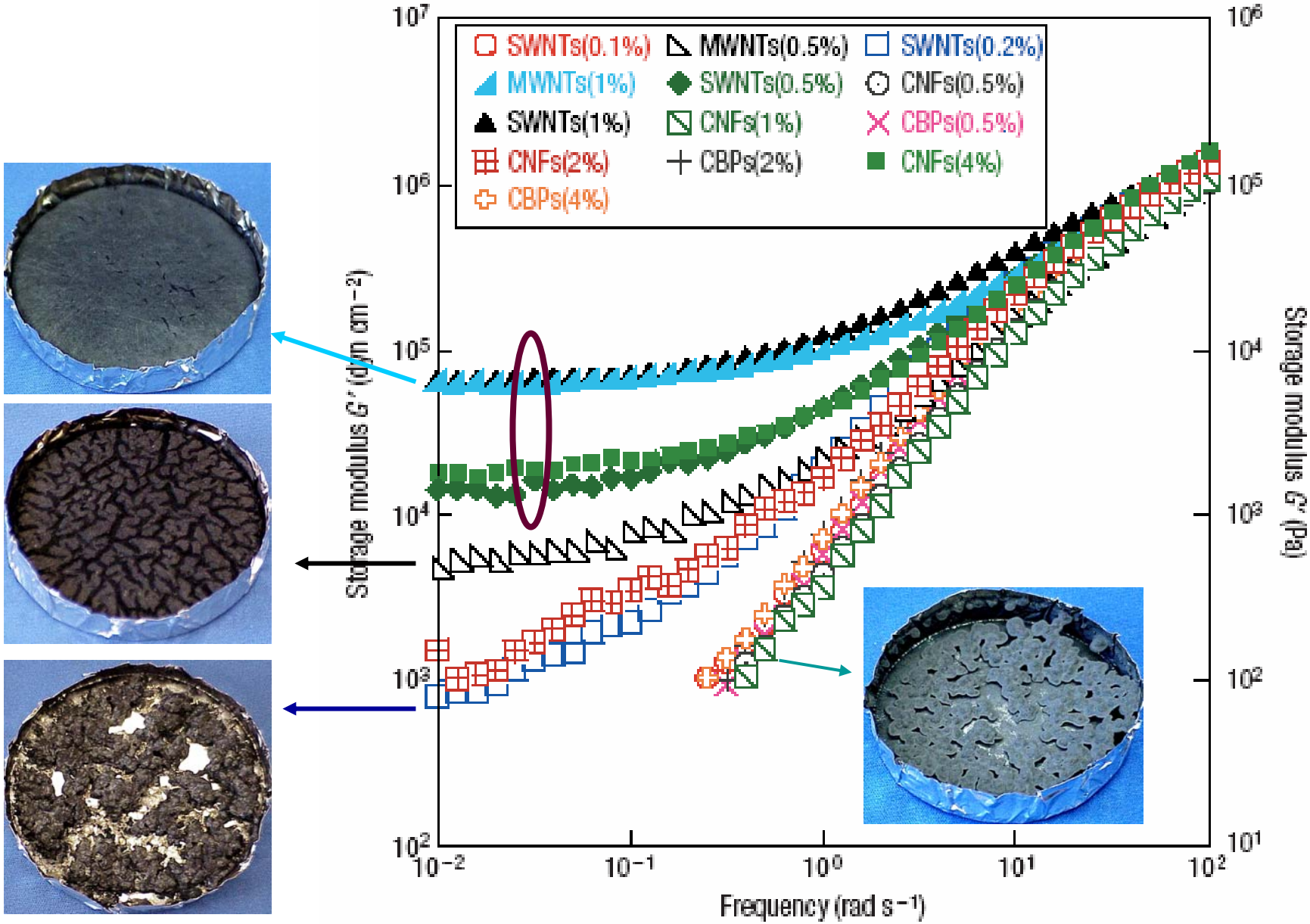



Radiant Flux
Water Cooled
Shutter
Collected
Residue
Water Cooled
Flux Gage


PP/MWNT(4%) Residue
PP/MWNT(2%) Residue
Incident Flux = 52 kW/m2
Heat Flux (kW/m2)
Time from Opening Shutter (s)
0
5
10
15
20
0
50
100
150
200
350 °C
300 °C

Formation of the Randomly Interlaced Layer which acts as a Heat Shield is Necessary for Low Heat Release Rate

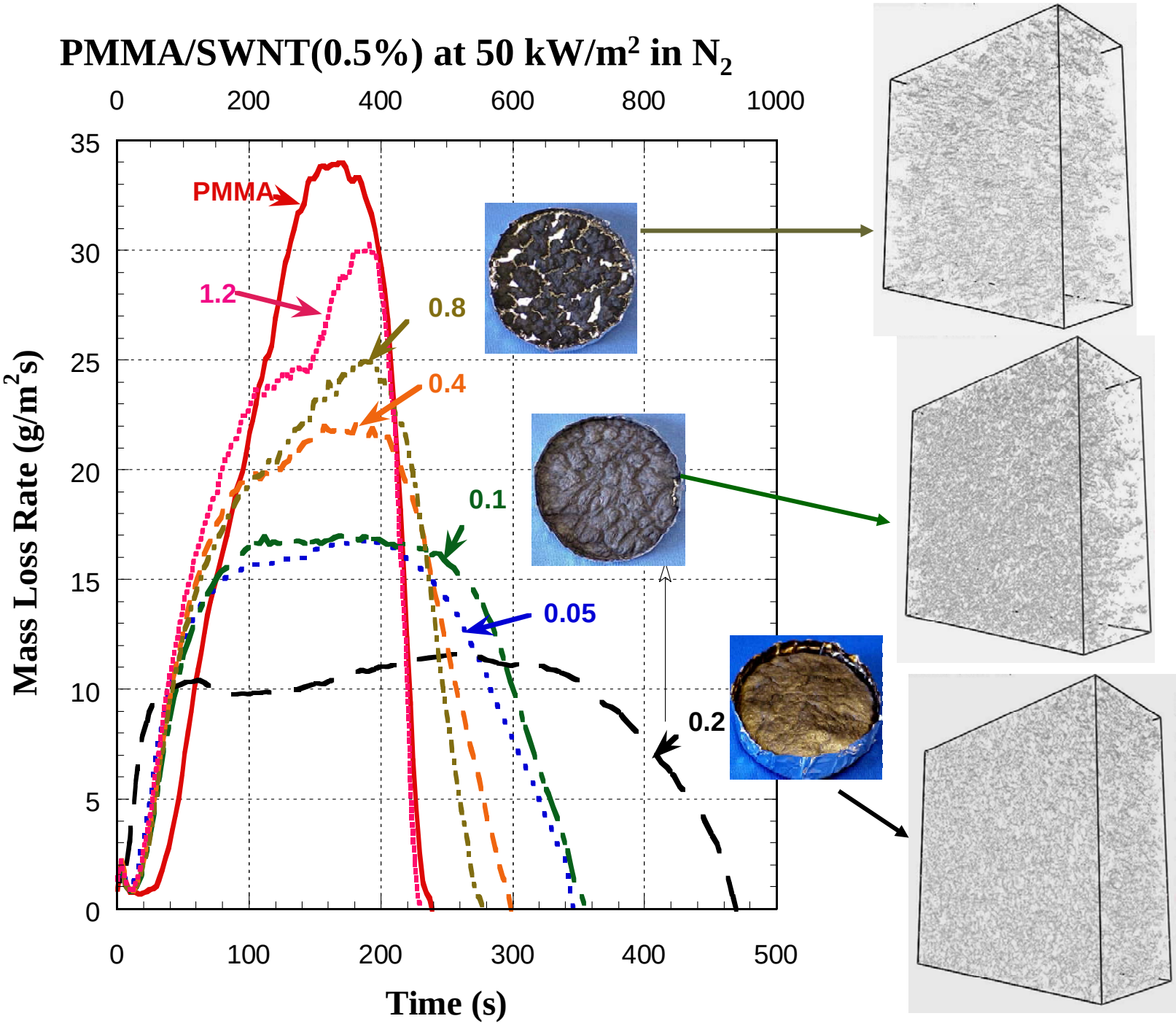
Any Screening Test Related to Rheological Properties of Initial Samples ?


SWNTs(0.1%)
MWNTs(0.5%)
SWNTs(0.2%)
MWNTs(1%)
SWNTs(0.5%)
CNFs(0.5%)
SWNTs(1%)
CNFs(1%)
CBPs(0.5%)
CNFs(2%)
CBPs(2%)
CNFs(4%)
CBPs(4%)
Storage modulus G′ (dyn cm⁻²)
Storage modulus G′ (Pa)
Frequency (rad s⁻¹)
10⁷
10⁶
10⁵
10⁴
10³
10²
10⁶
10⁵
10⁴
10³
10²
10¹
10⁻²
10⁻¹
10⁰
10¹
10²

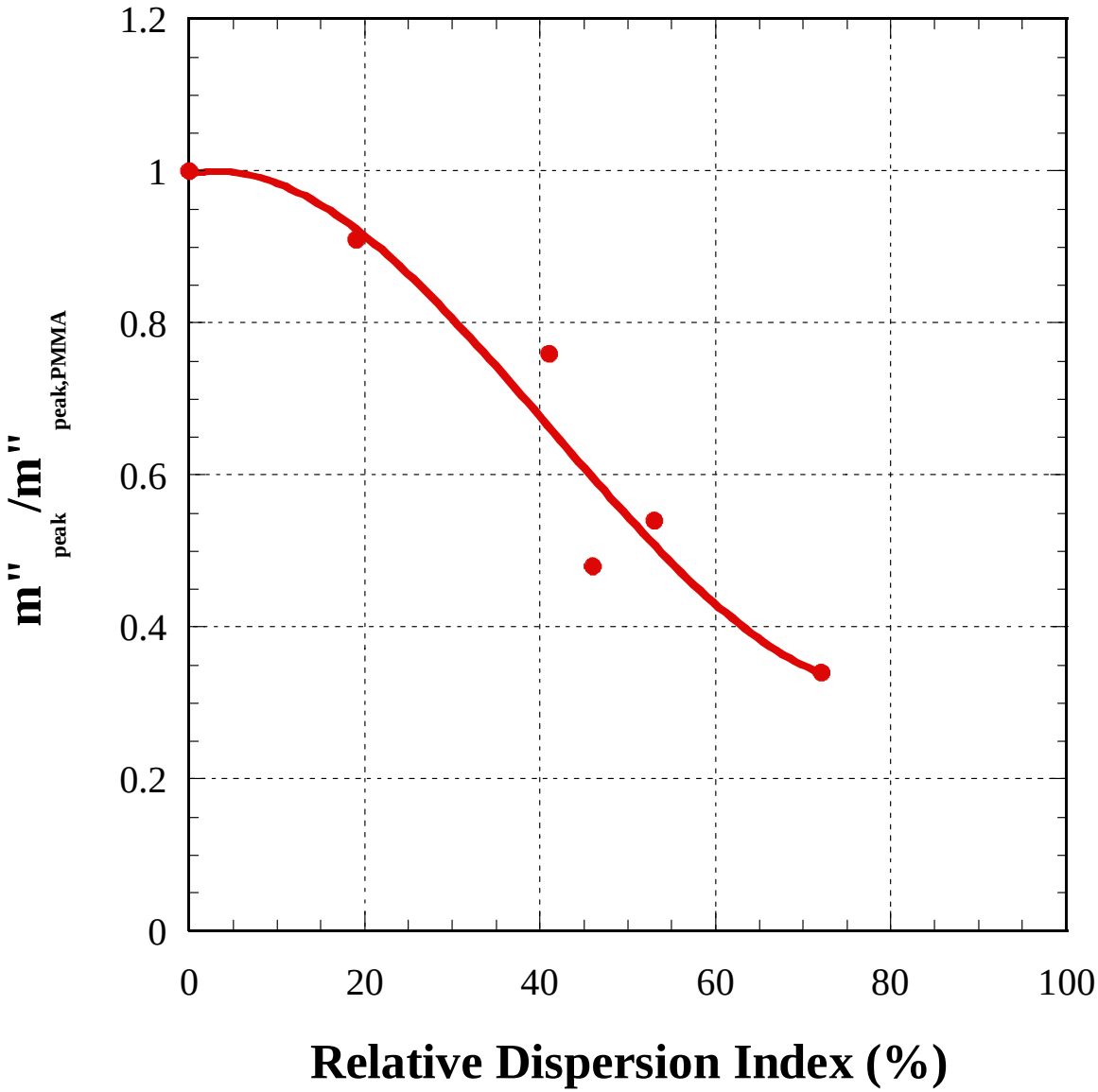
Effects of dispersion of tubes in the nanocomposite samples.

All PMMA/SWNT(0.5%) samples contain the same amount of the tubes.

Samples having the level of dispersion of the tubes were prepared by coagulation method with different tube concentrations in DMF


PMMA/SWNT(0.5%) at 50 kW/m² in N₂
Mass Loss Rate (g/m²s)
Time (s)
PMMA
1.2
0.8
0.4
0.1
0.05
0.2
0
5
10
15
20
25
30
35
0
100
200
300
400
500
0
200
400
600
800
1000

Relationship between Normalized Peak Mass Loss of PMMA/SWNT(0.5%) and Relative Dispersion L



Summary

- **Flame retardant mechanism of polymer/carbon nanotube nanocomposites is heat shield effects of network structured protective layer.**
- **Good dispersion of tubes is critical for effective FR performance.**
- **Viscoelastic measurement of initial small amount of samples –dynamic storage modulus measurement- can be used as a screening test.**
- **Weak points:**
  - **About same total heat release rate (slow burning)**
  - **At high concentrations, high thermal conductivity (longer ignition delay, slow flame spread, potentially high peak heat release rate)**
  - **Black color**

Acknowledgement

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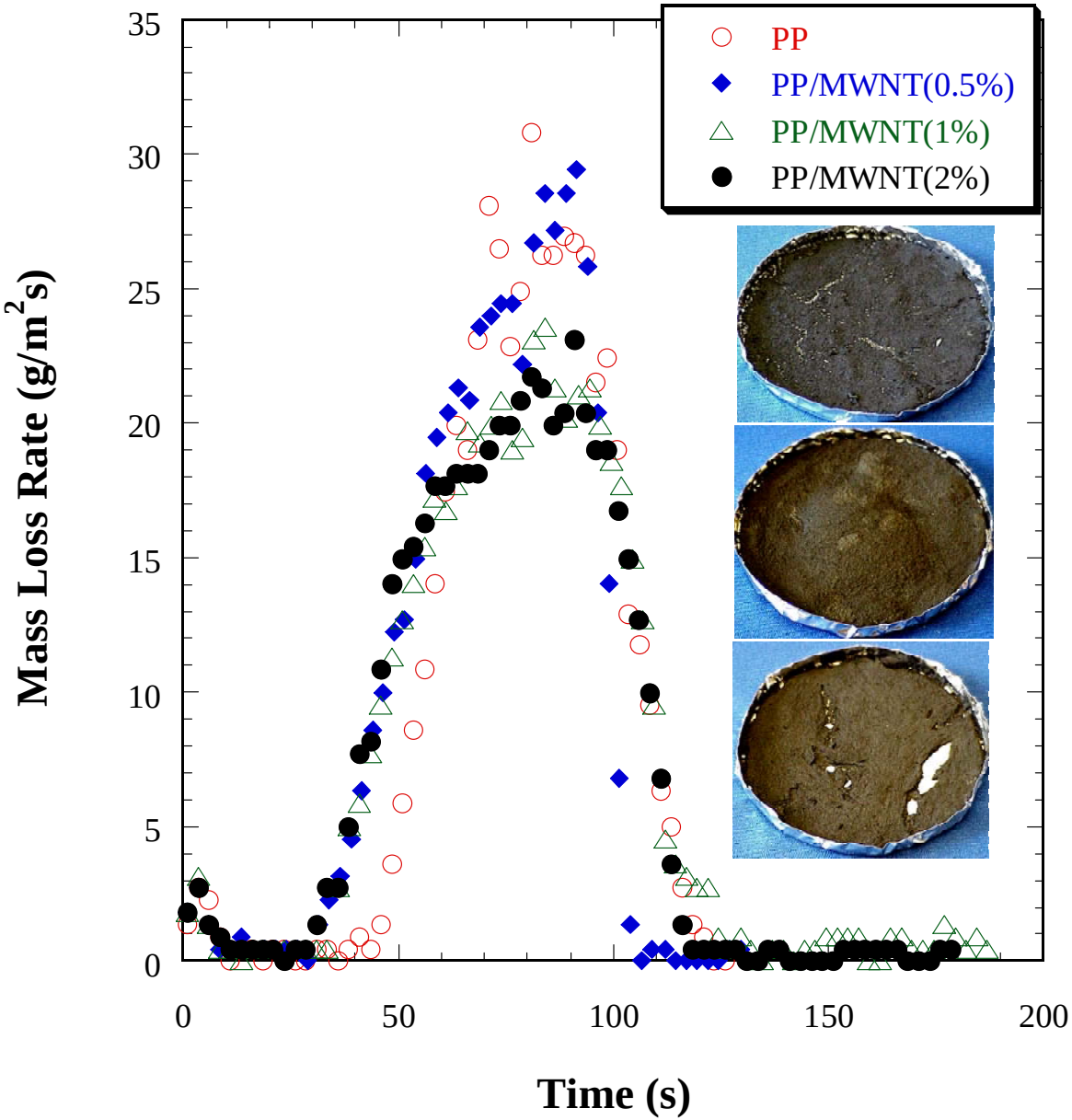
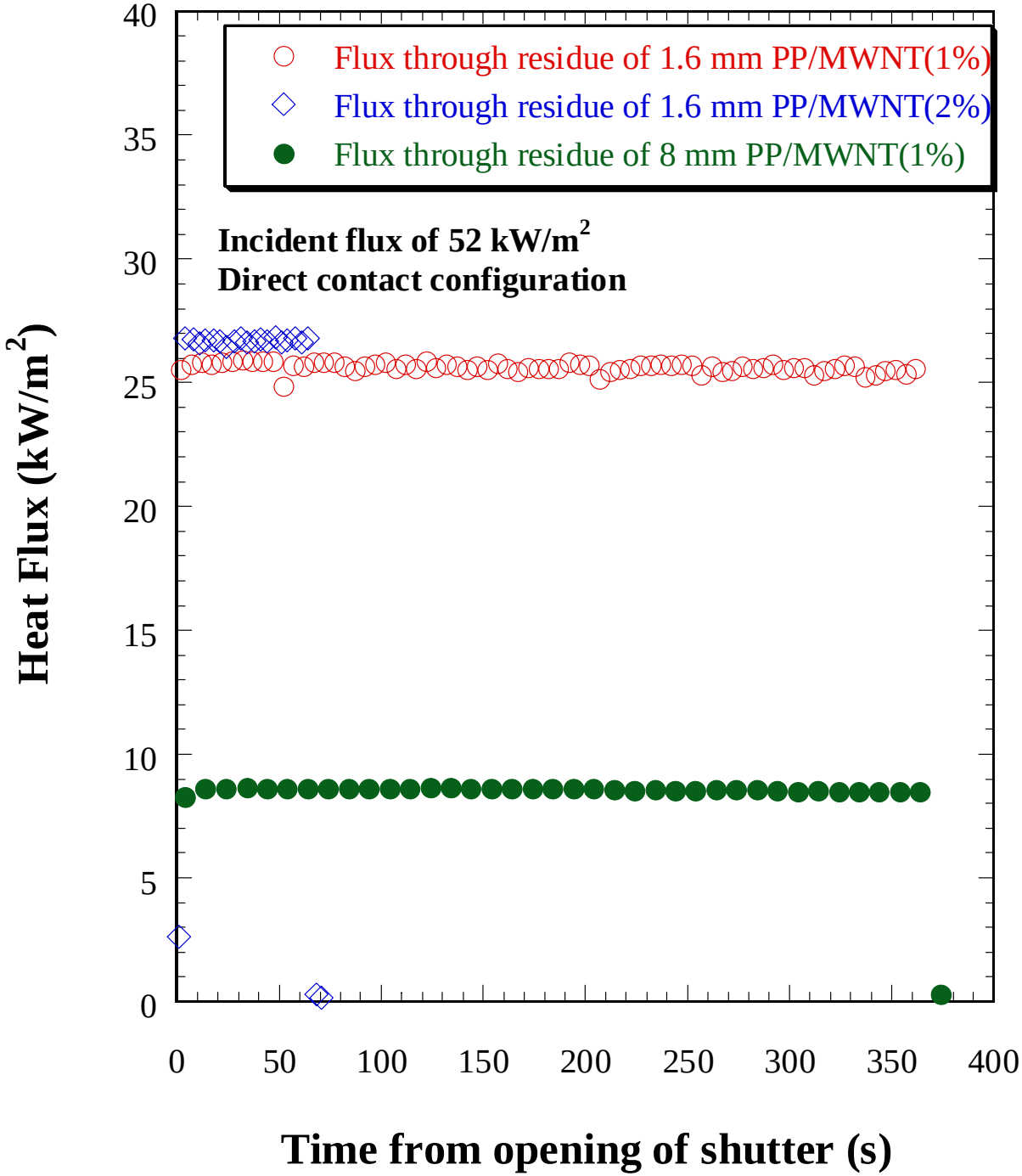
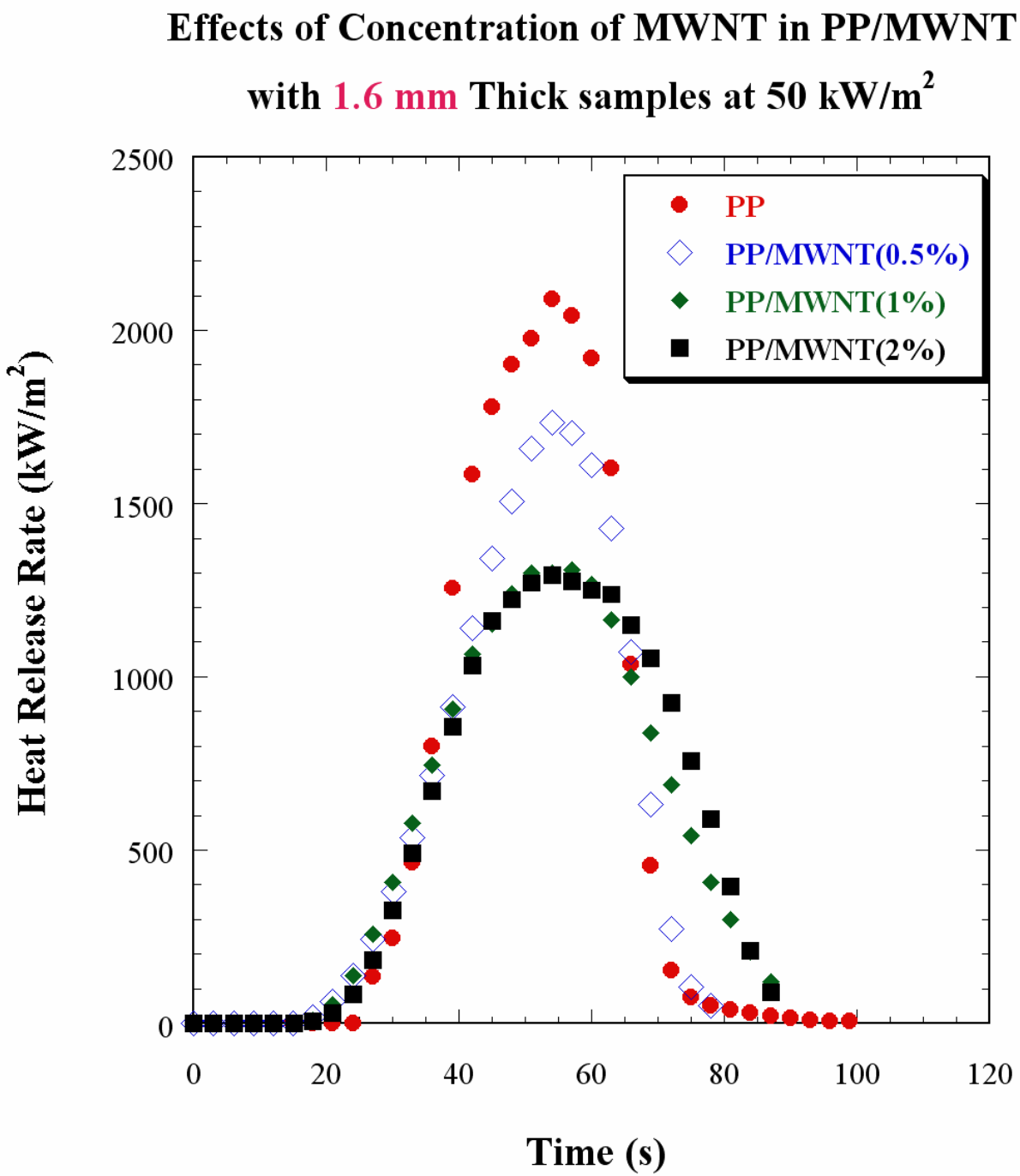
- **Fanming Du, Karen Winey - Univ. Pennsylvania**
- **Bani Cipriano, Srini Raghaven - Univ. Maryland**
- **Jil Hilding, Ying Yang, Eric Grulke - U. Kentucky**

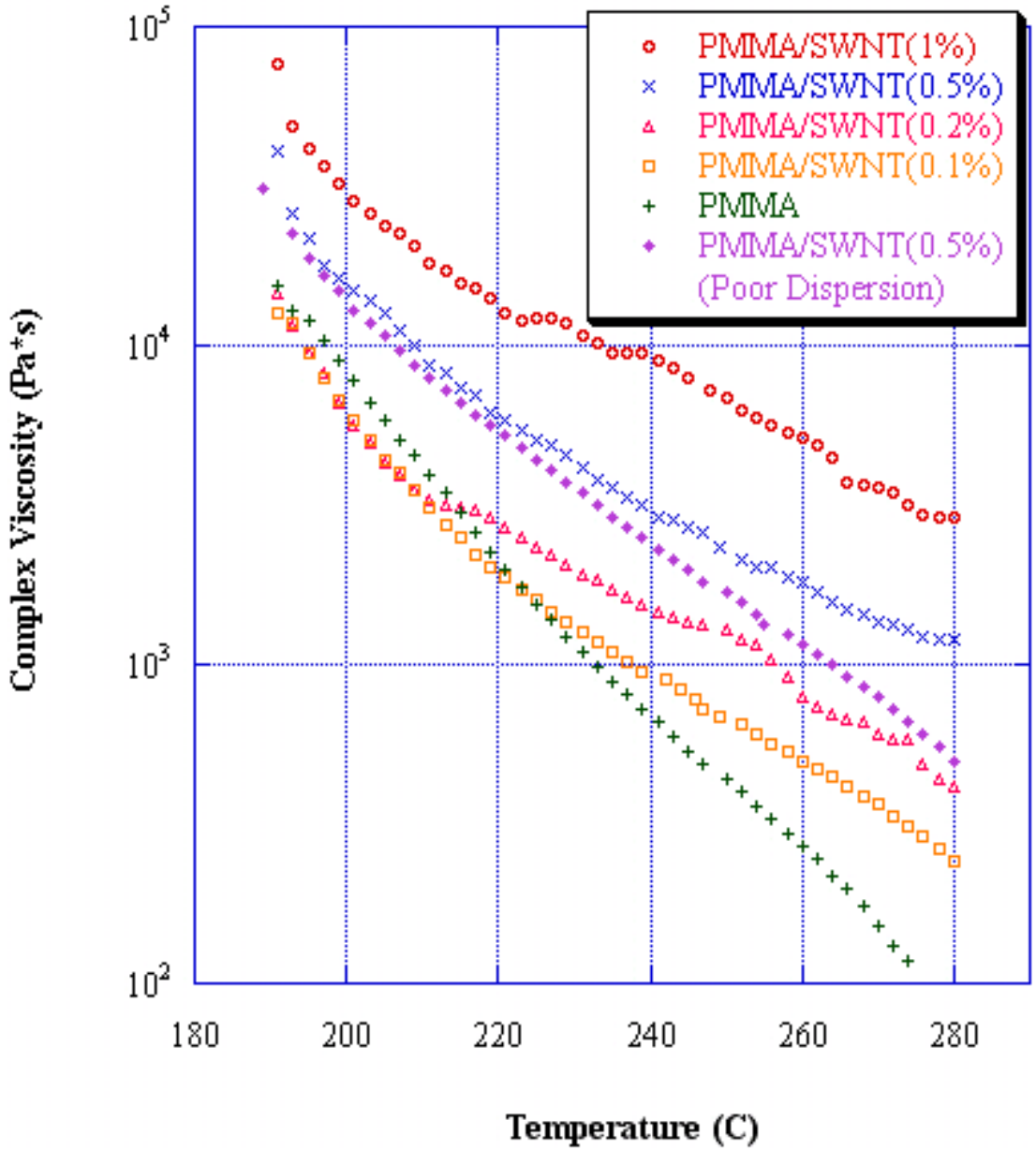
Effects of MWNT concentration on mass loss rate of 1. 6 mm thick PP/MWNT at 50 kW/m^2 in Nitrogen

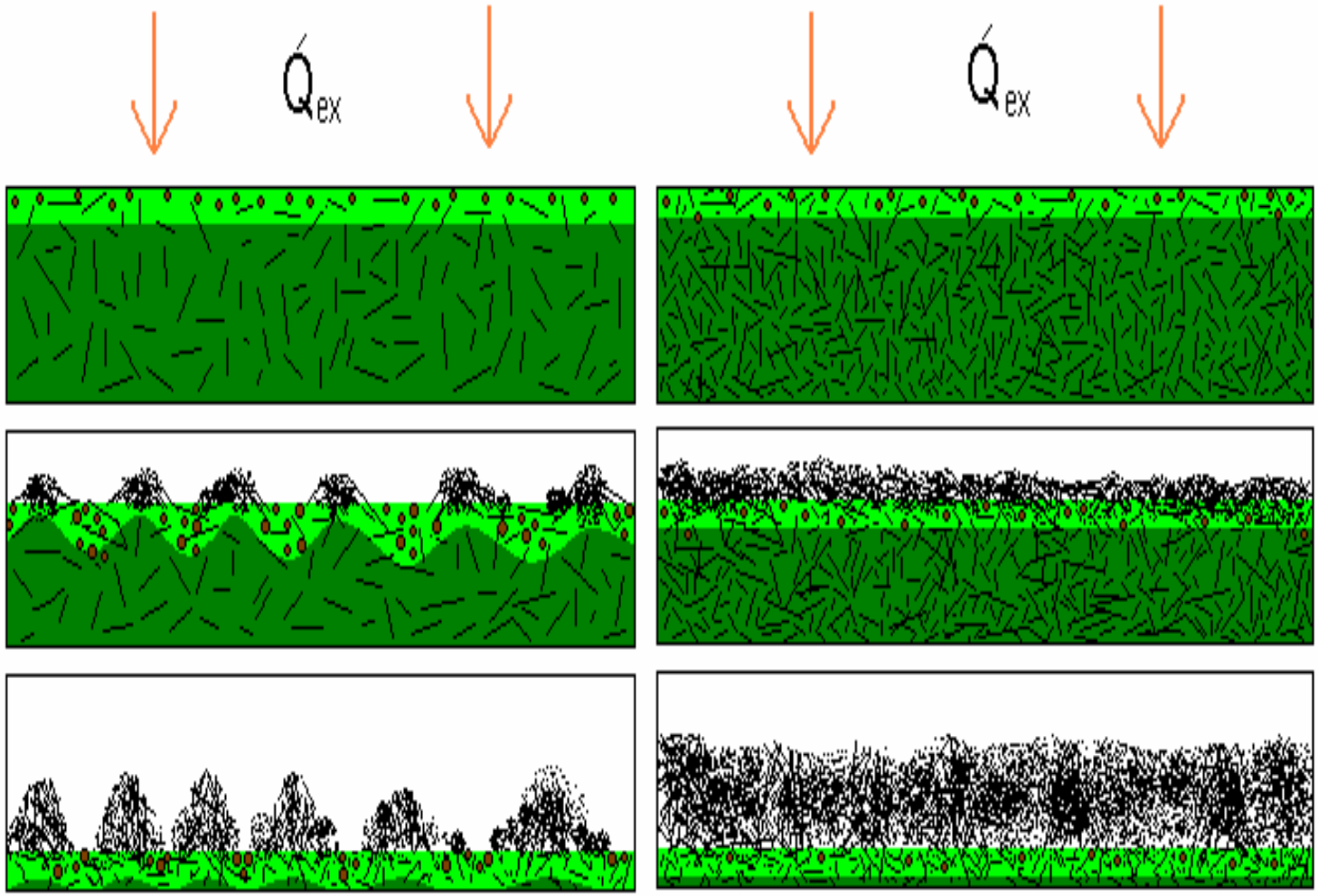



Flux through residue of 1.6 mm PP/MWNT(1%)
Flux through residue of 1.6 mm PP/MWNT(2%)
Flux through residue of 8 mm PP/MWNT(1%)
Incident flux of 52 kW/m2
Direct contact configuration
Heat Flux (kW/m2)
Time from opening of shutter (s)
0
5
10
15
20
25
30
35
40
0
50
100
150
200
250
300
350
400


Effects of Concentration of MWNT in PP/MWNT
with 1.6 mm Thick samples at 50 kW/m2
PP
PP/MWNT(0.5%)
PP/MWNT(1%)
PP/MWNT(2%)
Heat Release Rate (kW/m2)
Time (s)
0
500
1000
1500
2000
2500
0
20
40
60
80
100
120

Effects of the addition of SWNT on complex viscosity of PMMA at 0.1 rad/s in nitrogen




Q́ex
Q́ex