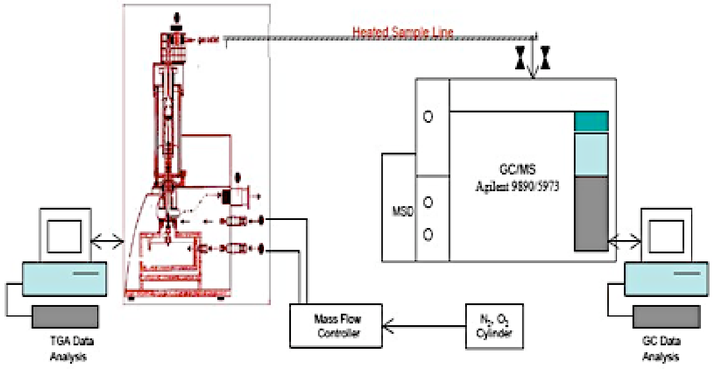
Investigation of Thermo-Gravimetric Analysis on Main Constituents of Scrap Tires and Chemical Analysis Including Light Hydrocarbons, Substituted Aromatics, and Polycyclic Aromatic Hydrocarbon

Eilhann Kwon and Marco J. Castaldi
Department of Earth & Environmental Engineering
Henry Krumb School of Mines
Columbia University, New York, NY 10027

ABSTRACT

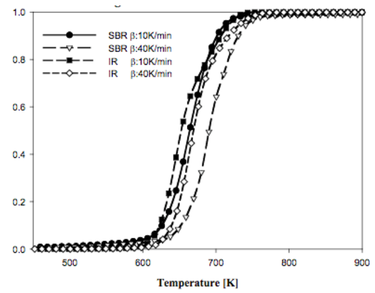
This investigation has been initiated to characterize the thermal decomposition of main constituents of scrap tire and scrap tire with Thermo-Gravimetric Analysis (TGA) in N_2 atmosphere. Moreover, chemical analysis focusing on light hydrocarbons, substituted aromatics, and polycyclic aromatic hydrocarbon have been carried out qualitatively and quantitatively not only to understand the mechanism of thermal degradation of scrap tires and hazardous air pollutants such as PAH, but also to investigate the value of scrap tires as an unconventional fuel. The release of chemicals from scrap tires has been determined experimentally using gas chromatography/mass spectroscopy (GC/MS) coupled to TGA unit. The identities and absolute concentrations of over 60 major and minor species have been established. Significant volatile organic carbons (VOC) including substituted aromatics and PAH were observed between 300°C and 500°C. These measurements supply information on the identities and levels of hazardous air pollutants, and provide useful new data for the development and validation of detailed reaction mechanisms describing their origin and fate. Finally, while high contents of VOC show significant potential to be utilized as an unconventional solid fuel, they also tend to generate hazardous pollutants.

EXPERIMENTAL SETUP

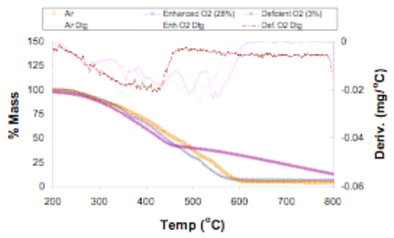


1) 100% N_2 Atmosphere
2) Air Atmosphere (21% O_2)
3) O_2 Enhanced Atmosphere (30% O_2)
4) Lean Atmosphere (7% O_2)

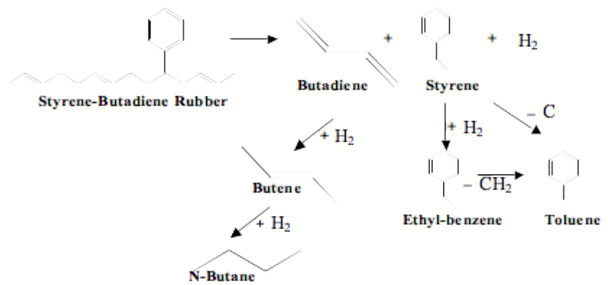
RESULT & DISCUSSION



TG curves for SBR and IR in N_2 Atmosphere at various heating rate

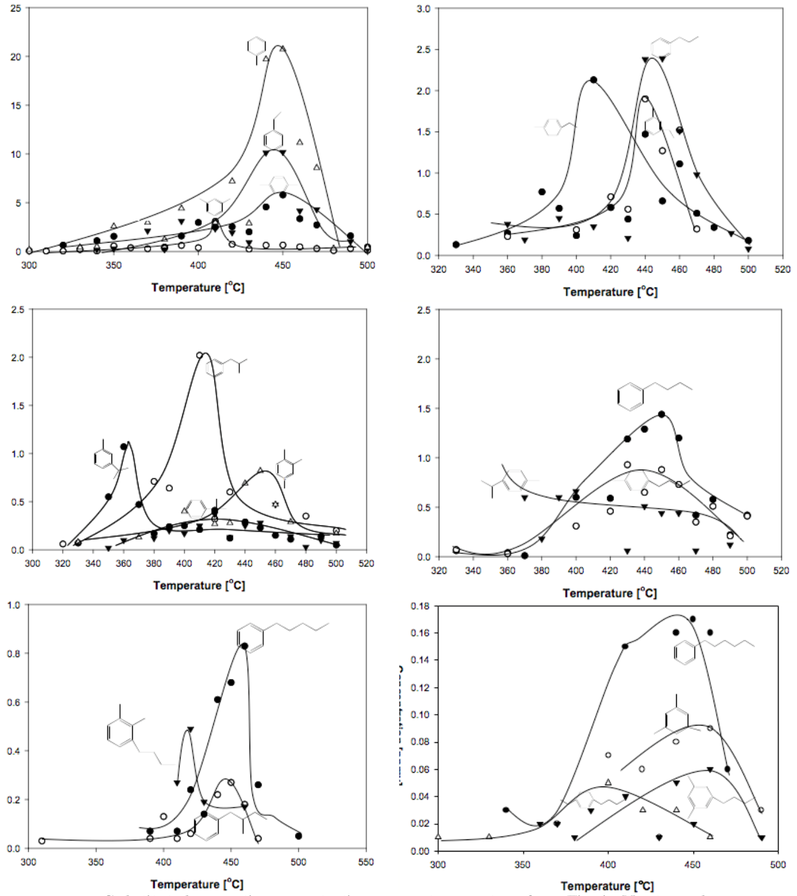


TGA results of combustion reactions under O_2 and N_2 atmospheres (Air – 20% O_2; enhanced O_2 – 28% O_2; deficient O_2 – 3% O_2) heated at 10 K min^{-1}

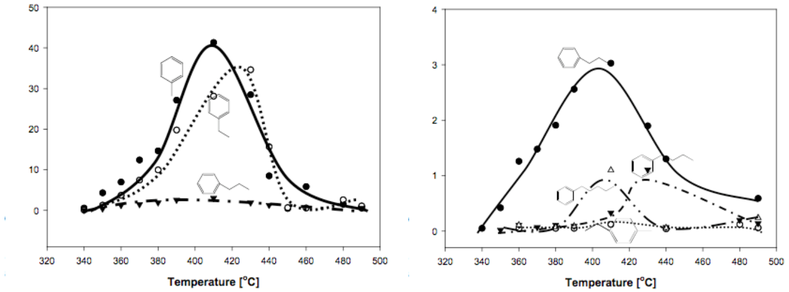


SBR breakdown mechanism based on TGA and GC/MS data

First there is breakage between the ligand and butadiene backbone which results in some hydrogen liberation. The backbone can continue to be hydrogenated to various extents leading to the mixture of C_4's which were observed in GC analysis. The styrene ligand can undergo various transformations leading to the substituted PAHs observed in the TGA effluent.

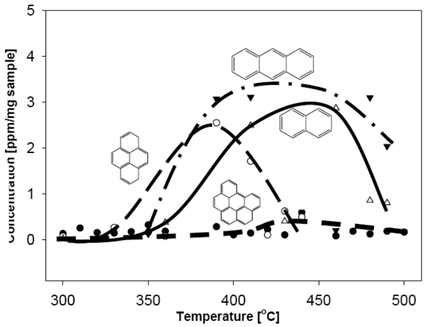


Substituted aromatic concentration versus temperature from Tire in N_2 atmosphere



Substituted aromatic concentration versus temperature from SBR in N_2 atmosphere

The styrene backbone on co-polymer show complex breaking down behavior. Moreover, the substituted aromatic compounds are a starting material to form PAHs. Thus, to confirm their contribution to create PAHs, the follow up test carried out to quantify and identify the PAHs. The representative PAHs from 2 rings to 6 rings, such as naphthalene, anthracene, pyrene, and benzo[g,h,i]perylene, were shown



PAHs concentration versus temperature from SBR in N_2 atmosphere

Several substituted aromatic compounds were formed with respects to the temperature. Among the substituted aromatics, concentrations of toluene and ethyl benzene are apparently dominant. In addition, other substituted aromatic compounds, such as propyl benzene, butyl benzene, and phenyl benzene, were observed. The substituted aromatic concentration reached higher temperature than light hydrocarbon does. Thus, this leads to conclusion that PAHs formation occurs more rapidly relatively in high temperature regime.

CONCLUSION

1) From several series of experiments, light hydrocarbon species, such as methane and n-butane, 32 substituted aromatic compounds, and 16 PAHs were identified and quantified. The concentration of PAHs reaches up to 4.5PPM.

2) Compared to previous PAHs formation mechanism, current body of this work shows that even in low temperature regime 3 ring's and 4 ring's PAHs were created before formation of naphthalene. Furthermore, breaking down SBR shows highly concentrated PAHs.

3) Combining detailed measurements of the main constituents of tires using TGA-GC/MS with gross measurements from real tire samples has enabled a simple mechanism to be developed.