A COMPARATIVE STUDY OF MICRO & NANOCARBON REINFORCED SYNTHETIC RUBBER COMPOSITES

By

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DECLARATION

I declare that the work presented in this dissertation is my own, carried out under the supervision of Dr Shane Durbach and Dr Sabelo Mhlanga. It is being submitted for the degree of Masters in Science at the University of the Witwatersrand, Johannesburg, and has not been submitted before for any degree or examination at any other university.

James Maifadi

On this 31st day of July 2014

Abstract

This study concentrated on two main thrusts: 1) the optimal synthesis and characterisation of various micro- and nanosized carbon materials and 2) a comparative investigation of the capabilities of these carbonaceous materials to reinforce a locally available styrene butadiene rubber (SBR), which was commonly used to make car tyres. In the former case, a range of carbon materials including nitrogen doped/undoped carbon nanotubes as well as carbon microspheres (CMSs) were successfully synthesized by two different techniques (i.e. chemical vapour deposition (CVD) and hydrothermal synthesis). These were then fully characterised by numerous techniques which included: TEM, TGA, FTIR, PXRD, laser Raman spectroscopy, Zeta potential measurements and BET surface area analysis. In the latter case, these micro and nanocarbon materials were systematically added to SBR at various loadings (ranging from 0.125–0.500% (m/m)). Here the tensile strengths of the resultant composites, loaded with these various micro and nanocarbon materials, were measured for comparison to establish which (if any) was the best reinforcement material for SBR.

Results obtained from the tensile strength measurements of the variously loaded SBR composites, showed that irrespective of the method of synthesis (i.e. CVD or hydrothermal synthesis) carbon microspheres (undoped, doped, functionalised or unfuntionalised) performed more poorly as fillers than carbon nanotubes. Furthermore the results obtained, from the various characterisation techniques mentioned previously, indicated that the lower performance of these microspheres as fillers may have been due to their: size, shape and low surface areas. By contrast when the tensile strengths of SBR reinforced with either CNTs or NCNTs were measured, the former outperformed the latter as fillers. It was speculated, based upon the data obtained, that NCNTs were poorer fillers than CNTs due to their higher negative surface charges, larger diameters and lower crystallinity. Hence this study has shown that low loadings (i.e. 0.250 % (m/m)) of the correctly matched type of carbonaceous material can significantly enhance the tensile strength and Young's modulus of a locally available styrene butadiene rubber.

DEDICATION

Dedicated to my loving late mother

Ziphora Norah Maifadi

And

To new life, my beautiful daughter

Boipelo Maifadi

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Oral and Poster presentations arising from this work

Oral Presentations

- The synthesis and characterization of Carbon nanomaterials produced by CVD and hydrothermal methods for use as fillers in rubber materials, DST-NRF *Centre of Excellence in Strong Materials Conference, Johannesburg* (2011).

Poster Presentation

- A comparative study of nanocarbon reinforced synthesis rubber composite, *NanoAfrica Conference, UFS, Bloemfontein* (2012).
- A comparative study of nanocarbon reinforced synthesis rubber composite, *University of the Witwatersrand Cross-faculty symposium, Johannesburg*, (2012).

Awards Arising from this work

- Awarded 2nd place oral presentation at the DST-NRF *Centre of Excellence in Strong Materials* Conference, Johannesburg (2011).

- Awarded 2nd place poster presentation at the University of the Witwatersrand Cross-faculty symposium, Johannesburg, (2012).

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List of Abbreviations

1D	One dimensional
2D	Two dimensional
3D	Three Dimensional
ASTM	American society for testing and materials
BET	Brunauer-Emmett-Teller
CNT(s)	Carbon nanotube(s)
CMS(s)	Carbon microsphere(s)
CVD	Chemical vapour deposition
DSC	Differential Scanning Calorimetry
E-SBR	Emulsion styrene butadiene rubber
FTIR	Fourier transform infrared
HNO_3	Nitric Acid
h	Hours
Hydro CMS(s)	Hydrothermal synthesized carbon microsphere(s)
Hydro SOCMS(s)	Hydrothermal synthesized sulphur functionalised carbon microsphere(s)
ISO	International Organization for Standardization
mL/min	Millilitre per minute
MWCNT(s)	Multi walled carbon nanotubes(s)
N_2	Nitrogen
NCNT	Nitrogen doped carbon nanotube
NCMSs	Nitrogen doped carbon microsphere(s)
nm	Nanometre
NR	Natural rubber
μm	Micrometre
PCNT	Pristine Carbon nanotubes
PCMSs	Pristine Carbon microspheres
PXRD	Powder X-ray diffraction spectroscopy
RT	Room Temperature
SWCNT(s)	Single walled carbon nanotubes(s)
SBR	Styrene butadiene rubber

S-SBR	Solution styrene butadiene rubber
t	Time
T	Temperature
TBBS	Tert-butyl-2-benzothiazole sulphonamide
TEM	Transmission electron microscopy
TGA	Thermogravimetric analysis
vs.	Versus

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