# Chemical Vapour Deposition of Carbon Nanotubes

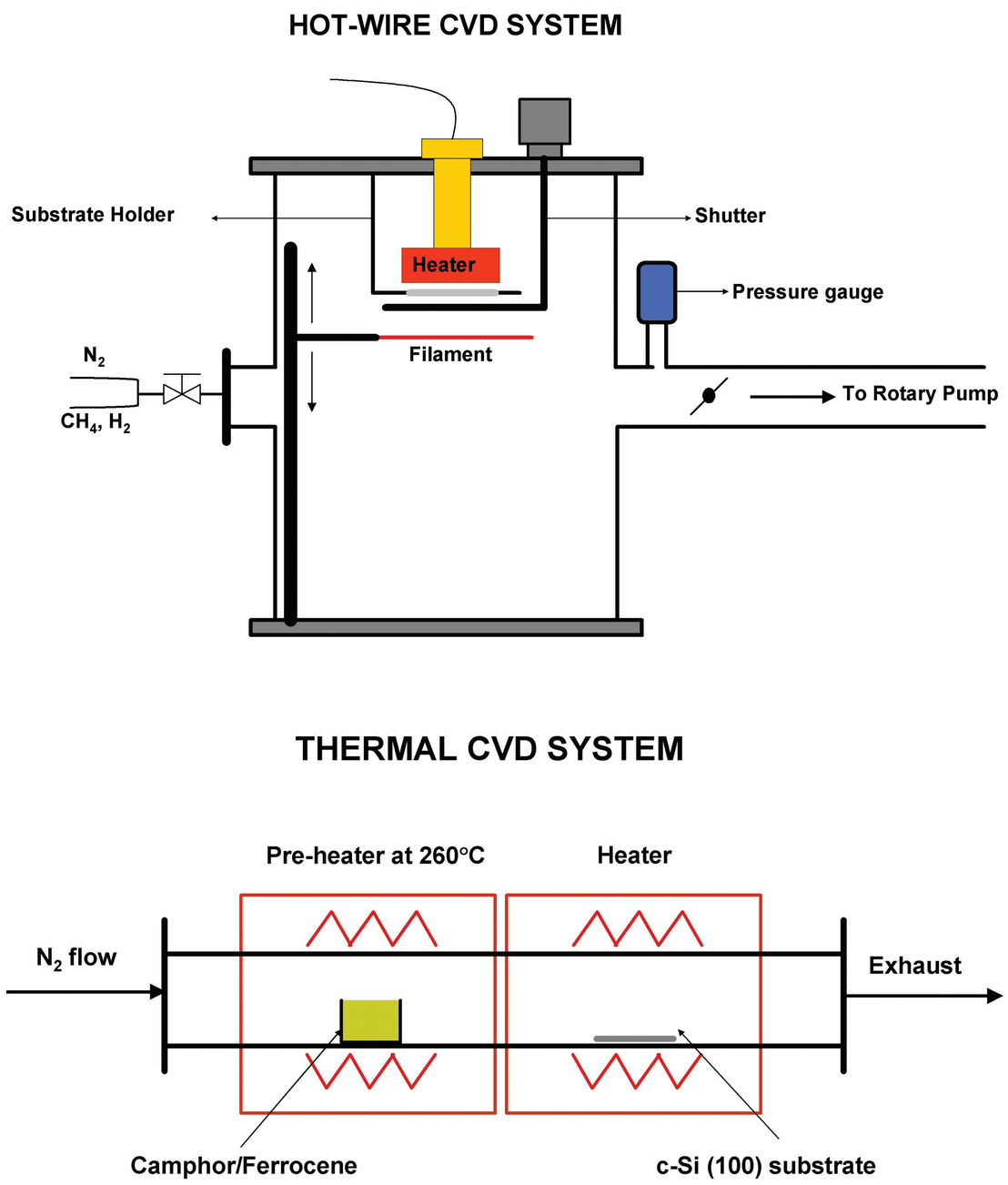
CJ ARENDSE[1], GF MALGAS[1], FR CUMMINGS[1,2] AND NP CELE[1,3]
[1]CSIR Materials Science and Manufacturing, PO Box 395, Pretoria 0001
[2]Department of Physics, University of the Western Cape, Private Bag X17, Bellville 7530
[3]Department of Physics and Engineering, University of Zululand, Private Bag X1001, KwaDlangezwa 3886
[1]Email: carendse@csir.co.za

## ABSTRACT/INTRODUCTION

Carbon nanotubes (CNTs) have proven to show great promise in a wide variety of applications such as fabrication of strong composites, nano-scale electronic devices, electrochemical devices, power devices, etc. This is largely due to the fact that CNTs exhibit exceptional chemical and physical properties related to toughness, chemical inertness, magnetism, and electrical and thermal conductivity.

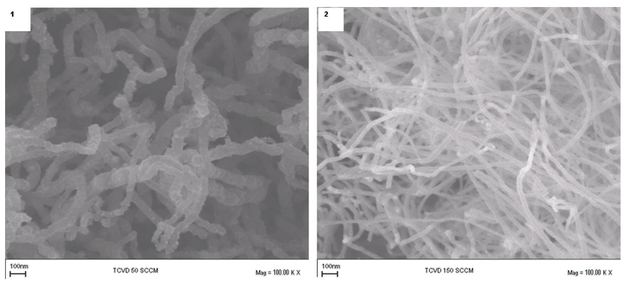
A variety of preparation methods to synthesise CNTs are known, e.g. carbon-arc discharge, laser ablation of carbon, thermal chemical vapour deposition (CVD), plasma enhanced CVD and microwave CVD. Most of these preparation methods require high process temperatures and are not easily controllable. Recently, hot-wire CVD was used to grow single-walled CNTs at a growth temperature of 450°C [**1-2**]. It has been shown that, compared to thermal- and plasma enhanced CVD, hot-wire CVD allows for the controlled growth of CNTs with diameters ≥ 1 nm and high crystallinity [**1-2**]. Furthermore, hot-wire CVD is inexpensive, effective, more versatile and easily scalable to large substrate sizes. In this paper, we present a design of the hot-wire CVD system constructed at the CSIR for the deposition of CNTs. Additionally, we will report on the structure of CNTs deposited by thermal CVD [**3**] using camphor as the carbon precursor.

## EXPERIMENTAL

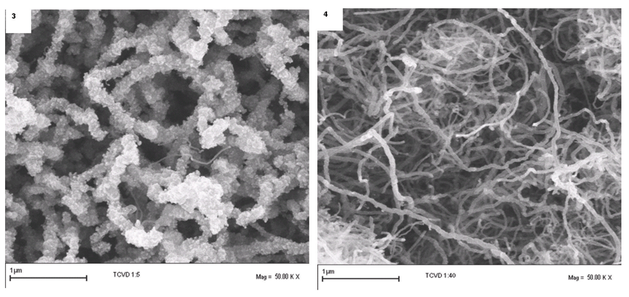



| SERIES | TEMPERATURE (°C) | $N_2$ FLOW (SCCM) | CAMPHOR/FERROCENE RATIO |
|---|---|---|---|
| A | 750 | 50 – 200 | 20:1 |
| B | 750 | 50 | 5:1 – 40:1 |
| C | 600 – 900 | 50 | 20:1 |

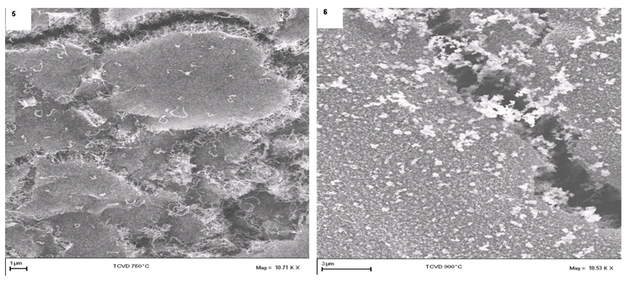
## RESULTS AND DISCUSSION




Series A (**Fig. 1 – 2**)
- CNT growth observed at $N_2$ flow rate ≤ 150 sccm;
- Increase in flow rate results in an increased CNT length and decreased diameter.




Series B (**Fig. 3 – 4**)
- CNT growth observed only in presence of ferrocene;
- Increase in camphor concentration results in an increased CNT length and decreased diameter;
- Presence of non-nanotube impurities decrease at higher camphor concentrations.




Series C (**Fig. 5 – 6**)
- CNT growth observed at temperatures ≥ 700 °C
- Aligned (partially) CNTs observed at 750 °C

## CONCLUSION

CNT growth is dependent on the precursor concentration, growth temperature and carrier gas flow rate. In this study the following optimum growth conditions have been identified for aligned CNTs with reduced diameters, increased length and improved purity:

- Growth temperature = 750°C;
- $N_2$ flow rate = 150 sccm; and
- Camphor/ferrocene ratio = 40:1.

## REFERENCES

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3. M Kumar and Y Ando, *Chemical Physics Letters* 374 (2003) 521