

<u>Information on Postgraduate Research Scholarship - Ref: VCS-FES-13-22</u>			
Faculty:	Engineering and Science	Department:	Engineering
Lead Supervisor:	Professor Kyriakos Porfyrakis FRSC		
Project Title:	Endohedral fullerenes for portable atomic clocks: molecules carrying time		
Project Description:	<p>Description Clocks are found inside billions of computer chips, worldwide. Atomic clocks enable accurate localization by timing, as used in GPS systems. At present, most atomic clocks are large and power-hungry; there is a clear need for a clock that could work inside a portable device. We are proposing a completely new approach to atomic timekeeping: a low-cost, solid-state miniature atomic clock using nature's atom traps: endohedral fullerenes. Endohedral fullerenes are molecules in which spin-active atoms or clusters are trapped inside a carbon cage. While protected by the cage from environmental disturbances, the resonances of the spin can be interrogated by radiofrequency magnetic fields. This is the basis for an entirely condensed-matter frequency standard.</p> <p>Portable atomic clocks may find a number of new applications. For example, warehouses, postal depots, and even subways may in future be equipped with their own local positioning systems using small-scale wireless base stations. Parcels, equipment, and people could then be tracked via time-of-flight of radio signals. Even driverless cars would benefit from an on-board device that kept very accurate time, particularly in challenging terrains, such as tunnels, where the satellite GPS signal is weak.</p> <p>Objective and strategy The main objective of the project is to evaluate a number of different endohedral fullerene molecules for their use as frequency reference standards for atomic clocks.</p> <p>In this project, we shall synthesise endohedral fullerenes such as N@C₆₀ and metallic endohedral fullerenes (metallofullerenes) using state-of-the-art production facilities including an ion implantation reactor and an arc-discharge reactor. We shall purify these molecules using high performance liquid chromatography (HPLC) and we shall characterize them spectroscopically using UV-Vis absorption spectroscopy, mass spectrometry, electron paramagnetic resonance (EPR) spectroscopy and other methodologies. Hence, the PhD student working on the project, will acquire significant skills in the synthesis and characterization of nanomaterials and will be trained in state-of-the-art techniques that can be found in only a handful of laboratories worldwide.</p> <p>We shall assess the use of several endohedral fullerenes as atomic clock elements. We shall optimise their performance as frequency standards by</p>		

improving their purity, optimising solution concentrations, and chemically functionalising them where necessary. We shall attempt to synthesize other endohedral fullerenes such as P@C₆₀, which also possess clock transitions.

The student will be part of the carbon nanomaterials group at the School of Engineering, University of Greenwich. There will be opportunity for collaborations nationally and internationally including the University of Oxford, where we will evaluate the EPR properties of our molecules.

References

1. "Caging atoms for a better atomic clock", K. Porfyakis and E. A. Laird, *IEEE Spectrum*, (2017), 54 (12), 34-39.
2. "The spin resonance clock transition of the endohedral fullerene 15N@C₆₀", R. T. Harding, S. Zhou, J. Zhou, G. A. D. Briggs, K. Porfyakis, E. A. Laird, T. Lindvall, W. K. Myers and A. Ardavan, *Physical review letters* (2017), 119 (14), 140801.

Duration:	3 years, Full-Time Study	
Bursary available (subject to satisfactory performance):		
Year 1: £17,668 (FT)		
Year 2: In line with UKRI rate		
Year 3: In line with UKRI rate		
In addition, the successful candidate will receive a contribution to tuition fees equivalent to the university's Home rate, currently £4,596 (FT) for the duration of their scholarship. International applicants will need to pay the remaining tuition fee for the duration of their scholarship.		
This fee is subject to an annual increase.		
Person Specification of Essential (E) or Desirable (D) requirements:		
Criteria:		E or D
Education and Training:		
<ul style="list-style-type: none"> 1st Class or 2nd class, First Division (Upper Second Class) honours degree OR a taught master's degree with a minimum of 60% in all areas of assessment (UK or UK equivalent) in a relevant area to the proposed research Project (inclusive of but not limited to Materials Science, Chemistry or Chemical Engineering). 		E
<ul style="list-style-type: none"> For those whose first language is not English and/or if from a country where English is not the majority spoken language (as recognised by the UKBA), a language proficiency score of at least IELTS 6.5 (in all elements of the test) or an equivalent UK VISA and Immigration secure English Language Test is required if your programme falls within the faculty of Engineering and Science a language proficiency score of at least IELTS 6.5 overall with a minimum of 6.0 in all elements of the test or an equivalent UK VISA and Immigration secure English Language Test is required. Unless the degree above was taught in English and obtained in a majority English-speaking country, e.g. UK, USA, Australia, New Zealand, etc, as recognised by the UKBA. 		E
Experience & Skills:		
<ul style="list-style-type: none"> Previous experience in undertaking research (e.g. undergraduate or taught master's dissertation) 		E
<ul style="list-style-type: none"> Experience in synthesis of carbon nanomaterials 		D
<ul style="list-style-type: none"> Knowledge of spectroscopic characterization (UV-Vis, NMR, Mass Spec) 		D
<ul style="list-style-type: none"> Knowledge of fullerene chemistry 		D

• An understanding of basic laboratory procedures	D
• An understanding of laboratory safety protocols	D
Personal Attributes:	
• Understands the fundamental differences between a taught degree and a research degree in terms of approach and personal discipline/motivation	E
• Able to, under guidance, complete independent work successfully	E
• Self-motivated and a team player.	E
• Has excellent written and oral communication skills	E
• Being passionate about the topic of research	D
Other Requirements:	
• This scholarship may require Academic Technology Approval Scheme approval for the successful candidate if from outside of the EU/EEA	E
• The scholarship must commence before 31 st July 2023	E
Closing date for applications:	midnight UTC on 19th June 2023
For further information contact:	Kyriakos Porfyraakis (K.Porfyraakis@greenwich.ac.uk)
<p>Making an application: Please read this information before making an application. Information on the application process is available at: https://www.gre.ac.uk/research/study/apply/application-process. Applications need to be made online via this link. No other form of application will be considered.</p> <p>All applications must include the following information. Applications not containing these documents will not be considered.</p> <ul style="list-style-type: none"> • VC Scholarship Reference Number (Ref)– included in the personal statement section • Personal Statement - outlining your motivation for applying for this PhD, and your previous research experience (e.g., as a research assistant or completing a dissertation). • Academic qualification certificates/transcripts* • IELTS/English Language certificate if you are an international applicant or if English is not your first language or you are from a country where English is not the majority spoken language as defined by the UK Border Agency * • Research Proposal* (ca. 1500 words- please use the template available from: research-proposal-template.pdf (gre.ac.uk)) • academic qualification certificates/transcripts and IELTS/English Language certificate if you are an international applicant or if English is not your first language or you are from a country where English is not the majority spoken language as defined by the UK Border Agency * • Your complete CV* • Two reference letters (one ideally from a dissertation supervisor)* <p><i>*upload to the qualification section of the application form. Attachments must be in PDF format. You will need to submit this as 1 single PDF, to be uploaded as an attachment.</i></p> <p>Before submitting your application, you are encouraged to liaise with the Lead Supervisor on the details above.</p>	