LIMAT B
Laboratory of Materials Engineering of Brittany

PhD Proposal

UBS
University of South Brittany

Development of selective conductive polymer nanocomposites CPC for the prevention of bedsores

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Smart Plastics

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Context & Scientific objectives:

The Smart Plastics Group of LIMAT^{B} (UE4250) at the University of South Brittany (UBS) has worked for over ten years on the development of electrically conductive polymer nanocomposites (CPC) for the design of sensors of volatile organic compounds (VOC). A marking feature of these sensitive materials is that they can act as a transducer, i.e., converting the information of the presence of a given organic vapour resistive into an electrical signal. This principle is used in electronic noses (e-nose), which are mimicking the mammals' olfactory system, in the sense that the identification of vapour molecules is done by the combination of signals of thousands of receptors. E-noses can also be assembled with several hundreds of transducers but the current challenges are to reduce their amount by increasing their selectivity. This was made possible by the discovery of new materials. Initially based on the combination of transducers based metal oxides then intrinsically conductive polymers and conductive polymer composites based carbon nanoparticles, we have recently shown that it was possible to make them also with carbon nanotubes (CNT) [1-6, 20].

Our most important findings are related to the fact that it is possible to improve the sensitivity of CNT-based sensors by in-situ polymerization grafting [1] using hierarchical multiscale conductive structures [2, 6, 20]. On the other hand one can adjust the selectivity of the sensors playing on the solubility parameter of the matrix [3] and combining CNT with conducting polymer nanoparticles [4] or graphene nanosheets of [19]. Recent studies have shown that the analysis of VOC in patients' breath with e-noses and / or chromatography allowed the early diagnosis of certain lung cancers [7-9], skin [10] or even prostate [11]. This is why we have focused our recent work on the detection of biomarkers [5, 19-20].

More recently conductive polymer nanocomposites CPC proved to be sensitive to strain and thus found important applications in the field of structural health monitoring of composites [12-15] and intelligent textiles used for body motion monitoring [16-19].

The specific PhD subject concerns the development of multifunctional conductive polymer nanocomposite sensors that will be selective to biomarkers (VOC) released from skin with and without bedsores and sensitive to deformations, to diagnose the advancement of the disease. In this perspective it seems very interesting to combine our expertise in physical chemistry of nanocomposites and smart plastics to those of the Kerpape Center for Functional Recovery and Hill-Rom Company, in the practical study of pathologies associated to bedsores and strategies to limit their development.

Required skills

Applicants should hold a Master degree in polymer science. A background in synthesis and characterization of nanocomposites will be appreciated. Ideally, he/she should also have some expertise in biology, chemistry, electronics or mechanics. Team capability, organizational talents and very good skills in English are required.

References

1. Castro, J. Lu, S. Bruzaud, B. Kumar, J. F. Feller, "Carbon nanotube / poly(ε-caprolactone) composite vapor sensors", Carbon, 47, 1930-1942 (2009).
2. J. Lu, B. Kumar, M. Castro, J. F. Feller, "Vapour sensing with conductive polymer nanocomposites (CPC): Polycarbonate-carbon nanotubes transducers with hierarchical structure processed by spray layer by layer, Sensors & Actuators B: Chemical, 140, 451-460 (2009).
3. B. Kumar, J. F. Feller, M. Castro, J. Read, "Conductive Polymer nano-bio-Composites (CPC): Chitosan-carbon nanotube transducers assembled via spray layer by layer for volatile organic compound sensing", Talanta, 81, 908-915 (2010).
4. J. Lu, B. J. Park, B. Kumar, M. Castro, H. J. Choi, J. F. Feller, Hybrid vapor sensor: nanobead polyaniline-carbon nanotube architecture with tuneable chemo-electrical behavior, Nanotechnology, 21, 255501, 1-10 (2010).
5. Castro, B. Kumar, J. F. Feller, Z. Haddi, A. Amari, B. Bouchikhi, Novel e-nose for the discrimination of volatile organic biomarkers with year array of carbon nanotube (CNT) conductive polymer nanocomposites (CPC) sensors, Sensors & Actuators B: Chemical, 159, 213-219 (2011).
6. J. F. Feller, J. Lu, K. Zhang, B. Kumar, M. Castro, N. Gatt, H. J. Choi, Novel architecture of carbon nanotube decorated poly (methyl methacrylate) MICROBEAD vapor sensors assembled by spray layer by layer, Journal of Materials Chemistry, 21, 4142-4149 (2011).
7. R. F. Machado, D. Laskowski, O. Deffenderfer, T. Burch, S. Zheng, P. J. Mazzone, T. Mekhail, C. Jennings, J. K. Stoller, J. Pyle, J. Duncan R. A. Dweik, S. C. Erzurum, "Detection of lung cancer by sensor array analyzes of breath Capable of causing," American Journal of Respiratory and Critical Care Medicine, 171, 1286-1291 (2005).
8. G. Peng, U. Tisch, H. Haick, Detection of nonpolar molecules by means clustering of carrier scattering in random networks of carbon nanotubes: Toward diagnosis of diseases via breath samples, Nano Letters, 9, 4, 1362-1368 (2009).
9. G. Peng, U. Tisch, O. Adams, Hakim, N. Shehada, Y. Y. Broza, S. Billan, R. Abdah-Bortnyak, A. Kuten, H. Haick, Diagnosing lung cancer in breath using gold nanoparticles Capable of causing, Nature Nanotechnology, 4, 669-673 (2009).
10. C. A. Acevedo, E. Y. Sanchez, J. G. Reyes, M. E. Young, Volatile profiles of human skin cell cultures in different degrees of senescence, Journal of Chromatography B, 878, 449-455 (2010).
11. J. N. Cornu, G. Cancel-Tassin, V. Ondet, C. Girardet, O. Cussenot, Olfactory detection of prostate cancer by dogs sniffing urine: A step forward in early diagnosis, European Urology, 59, 197-201 (2011).
12. W. Li, D. He, Z. Dang, J. Bai, In situ damage sensing in the glass fabric reinforced epoxy composites containing CNT-Al_2O_3 hybrids, Composites Science & Technology, 99, 8-14 (2014).
13. S. Luo, W. Obitayo, T. Liu, SWCNT thin film enabled fiber sensors for life-long structural health monitoring of polymeric composites – From manufacturing, utilization to failure, Carbon, 76, 321–329 (2014).
14. L. Gao, E. T. Thostenson, Z. Zhang, T. W. Chou, Coupled carbon nanotube network and acoustic emission monitoring for sensing of damage development in composites, Carbon, 47, 1381-1388 (2009).
15. Z. Levin, C. Robert, J. F. Feller, M. Castro, J. C. Grunlan, Flexible latex-polyaniline segregated network composite coating capable of measuring large strain on epoxy, Smart Materials & Structures, 22, 015008, 1-9 (2013).
16. T. Yamada, Y. Hayamizu, Y. Yamamoto, Y. Yomogid, A. Izadi-Najafabadi, D. N. Futaba, K. Hata, A stretchable carbon nanotube strain sensor for human-motion detection, Nature Nanotechnology, 6, 296–301 (2011).
17. C. S. Boland, U. Khan, C. Backes, A. O'Neill, J. McCauley, S. Duane, R. Shanker, Y. Liu, I. Jurewicz, A. B. Dalton, J. N. Coleman, Sensitive, high-strain, high-rate bodily motion sensors based on graphene rubber composites, ACS Nano, 8, 9, 8819-8830 (2014).
18. C. Robert, J. F. Feller, M. Castro, Sensing skin for strain monitoring made of PC-CNT conductive polymer nanocomposite sprayed layer by layer, ACS Applied Materials & Interfaces, 4, 7, 3508-3516 (2012).
19. T. T. Tung, Castro, T. Y. Kim, K. S. Suh, J. F. Feller, Graphene quantum resistive sensing skin for the detection of biomarkers alteration, Journal of Materials Chemistry, 22, 21754-21766 (2012).
20. S. Nag, L. Duarte, E. Bertrand, V. Celton, M. Castro, V. Choudhary, P. Guégan, J. F. Feller, Ultrasensitive QRS made by supramolecular assembly of functionalized cyclodextrins and graphene for the detection of lung cancer VOC biomarkers, Journal of Materials Chemistry B: Biology & Medicine, 2014, 2, 38, 6571-6579.