

# **$\mu$ SR studies in hemoglobin derivatives (oxyHb, deoxyHb, metHb and COHb) solutions**

A.D. Pant<sup>1,2#</sup>, A. Koda<sup>1,2</sup>, B. Geil<sup>3</sup>, A. Shrestha<sup>4</sup>, A. Dahal<sup>4</sup>, H.S. Mallik<sup>4</sup>, J. Nakamura<sup>1,2</sup>,  
K. Ishida<sup>1,2</sup>, H. Sakai<sup>5</sup>, K. Shimomura<sup>1,2</sup>, and J. S. Schultz<sup>6</sup>

<sup>1</sup>*Institute of Materials Structure Science, KEK, 1-1 Oho, Tsukuba, Ibaraki 305-0801, Japan*

<sup>2</sup>*Muon Section, Materials and Life Science Division, J-PARC center, 2-4 Shirane Shirakata, Tokai-mura, Naka-gun, Ibaraki 319-1195, Japan*

<sup>3</sup>*Institut für Physikalische Chemie, Universität Göttingen, Tammannstrasse 6, 37077 Göttingen, Germany*

<sup>4</sup>*Central Department of Physics, Tribhuvan University, Kathmandu, Nepal*

<sup>5</sup>*Department of Chemistry, Nara Medical University, Japan*

<sup>6</sup>*Department of Bio Medical Engineering, University of Houston, USA*

#Corresponding E-mail [pant@post.kek.jp](mailto:pant@post.kek.jp)

Hypoxia, low oxygen concentration, plays a crucial role for diagnosis and management of treatment of tumor/cancer [1-3]. Even though there are several existing methods to measure oxygen in tissues [3], we propose a noninvasive muon method to detect three-dimensional distribution of oxygen eventually in human body. So far, we have tested the sensitivity and reliability of the proposed muon method by detecting low oxygen in water and dilute protein solutions [4].

To understand the behavior of muon and muonium in the biosamples, we perform systematic experimental (muon spin rotation and relaxation,  $\mu$ SR) and theoretical studies [5] starting from water, buffer [6] and hemoglobin derivatives (oxyhemoglobin (oxyHb), deoxyhemoglobin (deoxyHb), methemoglobin (metHb) and carboxyhemoglobin (COHb)). In liquid water, we found two muon species – a diamagnetic muon and a paramagnetic isotropic muonium. However, in frozen water, two diamagnetic muon species and an anisotropic muonium signals were observed both in zero-field and weak transverse field measurements. The details of  $\mu$ SR measurements in four Hb derivatives and comparison with water and buffer will be discussed in the symposium.

## References

- [1] J. M. Brown and W. R. Wilson, *Nat. Rev. Cancer*, **4** (2004) 437
- [2] J. P.B. O'Connor, et al., *Cancer Research*, **76** (2016) 787
- [3] J. L. Tatum, et al., *Int J Radiat Biol*, **82** (2006) 699
- [4] A. D. Pant, et al., *NIM. A* **1011** (2021) 165561; *J.Phys.Conf. Ser.* **551**, 012043 (2014)
- [5] A. Shrestha, et al., *oral/poster, this symposium.*
- [6] A. Dahal, et al., *poster, this symposium.*