**Title:** Traceability for indentation measurements in Brinell, Vickers and Knoop hardness

**Description and Objectives:**
Hardness is a crucial mechanical property of materials, serving as an indicator of surface strength while also providing valuable insights into other mechanical characteristics, such as wear resistance, deformation behavior, and overall durability. Given its significance, reliable and accurate hardness measurements are essential in nearly all fields of engineering, from materials science and mechanical engineering to quality control in manufacturing.

Several standardized hardness testing methods exist, including Brinell, Vickers, and Knoop hardness tests. These methods rely on measuring the dimensions of residual indentations left by an indenter under controlled conditions. However, the accuracy of these measurements is highly dependent on various factors, including the imaging and processing instruments, operator expertise, and any software used for evaluation. Consequently, inconsistencies among different laboratories arise due to the lack of a well-defined and universally accepted indentation measurement methodology.

This PhD research aims to address these inconsistencies by systematically studying the factors influencing indentation measurements across different instruments, testing methods, operators, and software. The goal is to establish a robust, standardized methodology for consistent and traceable hardness measurements, particularly at the level of National Metrology Institutes (NMIs), calibration laboratories, and industrial testing facilities. This work is part of a European project funded by EURAMET, reflecting its broader impact on metrology and standardization efforts in hardness testing.

Objectives of the PhD research:

1. Characterization of 3D indentations by using advanced imaging to analyze 3D indentation geometry across Brinell, Vickers, and Knoop methods and compare with traditional 2D measurements.
2. Investigation of influencing factors, e.g., short-term creep, indenter geometry, material properties, temperature fluctuations, and instrumental factors on hardness measurements.
3. Development of a hardness measurement model by creating and validating a mathematical model to describe testing conditions, improve traceability, and reduce measurement uncertainties.
4. Development of automated measurement techniques using image processing and machine learning to minimize operator influence and enhance accuracy.
5. Establishment of best practices to contribute to international hardness testing standards to improve consistency across laboratories and industries.

By addressing these key research challenges, this PhD work aims to enhance the precision and reliability of hardness testing methodologies, contributing to improved material characterization and quality assurance processes in both research and industrial settings. Furthermore, the outcomes of this study will support the development of new international standards for hardness measurement, fostering greater consistency and comparability across laboratories worldwide.