

International Union for Vacuum Science, Technique, and Applications Special Session

Room Palm 5-6 - Session IUVESTA-WeM

IUVESTA Special Session

Moderator: Ivan G. Petrov, University of Illinois at Urbana-Champaign, USA

8:00am **IUVESTA-WeM-1 The Enabling Power of Vacuum Science, IUVESTA and Field-Deployable Quantum-Based Innovations with the NIST-on-a-Chip Program, Jay Hendricks [jay.hendricks@nist.gov]**, NIST, USA **INVITED**
I'll bring context to the talk with a short introduction of IUVESTA, the International Union for Vacuum Science, Technique and Application. As President, a main priority is public outreach to highlight the impact of vacuum technology on everyday life. Our IUVESTA Divisions are making significant contributions to the development of faster, smaller, and more energy-efficient technologies, from computer chips to artificial intelligence systems, self-driving cars, and more energy-efficient systems.

The redefinition of the International System of Units (SI) has opened up new avenues for realizing fundamental units, enabling the development of innovative measurement technologies that are quantum-based. The emergence of these quantum-based metrology systems has the potential to transform various fields, but also raises important questions about their miniaturization, deployment, and impact on the metrology ecosystem. This talk will explore the exciting possibilities and challenges arising from these advancements, with a focus on the role of metrology institutes in the new era of quantum-based measurement.

The vacuum technology technical core of the presentation will delve into recent breakthroughs in quantum-based measurement methods, including the Fixed Length Optical Cavity (FLOC) for pressure measurement and the Cold Atom Vacuum Standard (CAVS) for vacuum metrology. These cutting-edge approaches leverage fundamental physics, quantum mechanics, and photonics to achieve high accuracy and precision. The use of photons for measurement readout enables the exploitation of the rapidly growing field of photonics, paving the way for the development of compact, field-deployable measurement systems.

The NIST on a Chip program will be highlighted as a key initiative driving the miniaturization of measurement technologies. By exploring the intersection of quantum-based metrology, photonics, and miniaturization, this talk aims to spark a discussion on the future of metrology and the role of metrology institutes in this new ecosystem where field-deployable systems are in use.

8:40am **IUVESTA-WeM-3 Chalcogenide Ovonic Threshold Switch (OTS) and Selector-Only Memory (SOM) Devices for Neuromorphic Applications, Jong-Souk Yeo [jongsoukyeo@yonsei.ac.kr]**, Siwon Park, Young-Min Kim, Sangyeop Kim, Yonsei University, Republic of Korea **INVITED**

As artificial intelligence and data-intensive applications continue to drive rapid changes in computing paradigms, energy-efficient and highly scalable hardware architectures are increasingly important. Resistive switching devices have emerged as promising building blocks for next-generation memory due to their simple structure, low power consumption, and compatibility with high-density integration.

Ovonic Threshold Switches (OTS) are particularly attractive as selector devices in cross-point memory arrays because of their abrupt threshold switching behavior and high on/off ratios, which effectively suppress sneak currents. However, achieving reliable operation and scalability requires a thorough understanding of the switching mechanisms and systematic optimization at the material level.

In this work, we present a comprehensive optimization strategy for OTS devices by investigating how material composition influences electrical switching characteristics. Switching behavior is shown to depend strongly on compositional tuning and local bonding configurations. By extending to more complex multi-component material systems, we develop a deeper understanding of how specific bonding configurations influence device characteristics, resulting in significantly enhanced on/off ratios and improved stability. These results establish clear composition-structure-property relationships that provide practical guidelines for high-performance OTS design.

Based on the optimized device, we demonstrate a low-power artificial neuron that exhibits leaky-integrate-and-fire behavior. The firing frequency of the neuron can be modulated by external load conditions, confirming its capability to emulate key features of biological neural dynamics.

In addition, polarity-dependent threshold voltage modulation is observed in OTS devices and is attributed to asymmetric local structural configurations, as confirmed by molecular dynamics simulations. This intrinsic asymmetry allows controllable threshold tuning to be used as a memory element, thus enabling a selector-only memory architecture that potentially replaces conventional selector-resistor functionality with a single device.

This enhanced understanding of OTS devices provides valuable insights and design strategies for compact and energy-efficient neuromorphic applications.

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9:20am **IUVESTA-WeM-5 Quantum Effects of Hydrogen in Metal Thin Films, Katsuyuki Fukutani [fukutani@iis.u-tokyo.ac.jp]**, University of Tokyo, Japan **INVITED**

Hydrogen absorption in metals is relevant to a variety of energy- and environment-related applications, including hydrogen storage, high-temperature superconductivity, and catalytic reactivity [1]. Because hydrogen is the lightest atom, it is often argued that hydrogen in metals exhibits quantum effects arising from zero-point vibrations and quantum tunneling. To investigate the behavior of hydrogen in metal thin films, our group has developed nuclear reaction analysis (NRA) [2] combined with channeling and electrical resistance measurements. Using this approach, we have studied the structure and diffusion of hydrogen in typical hydrogen-absorbing metals of titanium and palladium, in which quantum effects play a significant role [3-5].

Titanium hydride thin films with a thickness of 90 nm were fabricated on MgO(110) substrates by reactive magnetron sputtering. Two-dimensional NRA mapping revealed axial and planar channeling patterns. By comparison with trajectory simulations, approximately 10% of the hydrogen was found to occupy octahedral sites, while the remaining hydrogen resided at tetrahedral sites. In contrast, deuterium was found to occupy exclusively the tetrahedral sites, a difference attributed to zero-point vibrational effects [3]. A palladium thin film with a thickness of 10 nm was fabricated on a glass substrate and hydrogenated either by hydrogen gas exposure followed by quenching or by low-energy hydrogen ion irradiation. In both cases, hydrogen initially occupied metastable hydride states and was observed to migrate to stable states. By measuring the time evolution of the film resistance, hydrogen diffusion in the films was analyzed, revealing a crossover from a classical thermally activated regime to a quantum regime [4,5].

1. K. Fukutani et al., Chem. Rec. 17, 233 (2017).
2. M. Wilde and K. Fukutani, Surf. Sci. Rep. 69 (2014) 196;
3. T. Ozawa et al., Nat. Commun. 15, 9558 (2024).
4. T. Ozawa et al., J. Phys. Chem. Solids 185, 111741 (2024).
5. T. Ozawa et al., Sci. Adv. 11, eady8495 (2025).

11:00am **IUVESTA-WeM-10 Stable and Metastable High Entropy Alloys, Sven Ulrich [sven.ulrich@kit.edu]**, Dimitri Litvinov, Jarir Aktaa, Adam Bichler, Michael Stueber, Karlsruhe Institute of Technology (KIT), Institute for Applied Materials (IAM), Germany **INVITED**

In stable high entropy alloys (HEA) the individual elements must have the same crystal structure. Of the 80 non-radioactive elements in the periodic table, 14 metallic elements (Al, Ca, Ni, Cu, Ag, Au, Pb, Pt, Rh, Ir, Sr, Ce, Yb) have a face-centered cubic structure at room temperature, 14 elements (Li, Na, K, Rb, Cs, Ba, Eu, V, Cr, Fe (a), Nb, Mo, Ta, W) have a body-centered cubic crystal structure, and 22 elements have a hexagonal close-packed crystal structure (Be, Mg, Sc, Ti, Co, Zn, Zr, Cd, Hf, Y, La, Nd, Gd, Tb, Dy, Ho, Er, Tm, Lu, Ru, Os, Re). They represent the maximum number of elements of the corresponding stable HEA. Adding an element with a foreign crystal structure below the solubility limit also results in a stable HEA. Examples are given for the various cases. However, metastable HEA can form above this solubility limit. As an example, single-phase, body-centered cubic Ni-containing (Cr, Mo, Nb, Ta, V, W) HEA thin film are examined in detail with regard to their global and local elemental composition (EPMA, STEM, EDX), topology using SEM, and microstructure using XRD and HRTEM. The coatings were produced by non-reactive d.c. magnetron sputtering of a Cr-Mo-Nb-Ta-V-W-Ni target in argon plasma at 0.2 Pa.

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