芝浦工業大學
SHIBAURA INSTITUTE OF TECHNOLOGY

ICMATE

INVITED TALK

Nanostructured Thin Films for Enhanced Energy Performance: The Role of Artificial Nanodefects

Prof. Paolo Mele
Shibaura Institute of Technology, Tokyo, Japan

23 September 2025 3.00 pm **Participation Link**

Global challenges such as energy shortages and environmental degradation necessitate the development of advanced materials for sustainable energy technologies. Superconducting and thermoelectric materials play a pivotal role, offering efficient solutions for energy transport and conversion, respectively. This presentation focuses on recent advances in nanostructured thin films incorporating artificial nanodefects to significantly enhance the performance of these materials in energy applications.

Superconducting materials, particularly $YBa_2Cu_3O_x$ (YBCO), benefit from the introduction of nanosized defects to improve critical current (Jc) and global pinning force (Fp). By incorporating one-dimensional (1D) $BaSnO_3$ (BSO) nanorods through pulsed laser deposition (PLD), YBCO films achieved F_p^{MAX} = 28.3 GN/m³ at 77K and 3T, with isotropic Jc = 0.3 MA/cm²—double the performance of conventional Nb_3Sn superconductors [1]. Three-dimensional (3D) Y_2O_3 nanoparticles were also integrated into YBCO films, resulting in an F_p^{MAX} of 14.3 GN/m³ at 77K and 3T [2]. The combination of 1D and 3D APCs, realized through alternating layers of BSO nanorods and Y_2O_3 nanoparticles, produced films with enhanced pinning, achieving F_p^{MAX} = 17.6 GN/m³ at 77K and 2.2T [3]. These results underscore the critical role of nanoengineering in optimizing vortex pinning and improving superconducting performance for applications such as current transport and magnet winding.

In the field of thermoelectrics, thin films with nanostructured defects exhibit significant improvements in thermal properties. The introduction of artificial defects such as hydroquinone nanolayers in Al-doped ZnO (AZO) films, prepared by atomic layer deposition (ALD), resulted in thermal conductivity κ = 3.56 W/m×K at 300 K [4]. Similarly, AZO films with polymethylmethacrylate (PMMA) particles, prepared via multi-target PLD (MAPLE), showed κ = 5.9 W/m×K at 300 K and a figure of merit ZT = 0.07 at 600 K [5]. Further nanostructuring of AZO films via Mist-CVD led to the formation of nanopores, yielding κ = 0.60 W/m×K and ZT = 0.06 at 300 K [6]. The dispersion of Al_2O_3 nanoparticles in AZO films, prepared by surface-modified target PLD, resulted in κ = 3.98 W/m×K and ZT = 0.0007 at 600 K [7]. Collectively, these efforts achieved a 1/10 to 1/100 reduction in thermal conductivity and a 3-5 times enhancement in ZT, demonstrating the potential of nanodefects to improve thermoelectric performance.

In conclusion, these findings emphasize the importance of artificial nanosized defects in enhancing the performance of superconducting and thermoelectric thin films. These advances position nanostructured materials as key candidates for future large-scale energy applications, paving the way for more efficient and sustainable technologies.

References on the next page

芝浦工業大學
SHIBAURA INSTITUTE OF TECHNOLOGY

ICMATE

INVITED TALK

Nanostructured Thin Films for Enhanced Energy Performance: The Role of Artificial Nanodefects

Prof. Paolo Mele
Shibaura Institute of Technology, Tokyo, Japan

23 September 2025 3.00 pm **Participation Link**

References:

[1] P. Mele, K. Matsumoto, T. Horide, A. Ichinose, Y. Yoshida, M. Mukaida, S. Horii, R. Kita, Supercond. Sci. Technol., 21 (2008) 032002.

[2] P. Mele, R. Guzman, J. Gazquez, T. Puig, X. Obradors, S. Saini, Y. Yoshida, M. Mukaida, A. Ichinose, K. Matsumoto, M. I. Adam, Supercond. Sci. Technol., 28 (2015) 024006.

[3] P. Mele, M. I. Adam, T. Suzuki, Y. Yoshida, S. Awaji, A. Ichinose, S. Saini, A. K. Jha, K. Matsumoto, Sci. Adv. Mat., 6 (2017) 1042.

[4] T. Tynell, A. Giri, J. Gaskins, P. E. Hopkins, P. Mele, K. Miyazaki, M. Karppinen, J. Mater Chem. A, 2 (2014) 12150.

[5] A. M. Darwish, A. Muhammad, S. S. Sarkisov, P. Mele, S. Saini, J. Liu, J. Shiomi, Compos. Part B: Eng., 167 (2019) 406.

[6] S. Saini, P. Mele, T. Oyake, J. Shiomi, J. Niemelä, M. Karppinen, K. Miyazaki, C. Li, T. Kawaharamura, A. Ichinose, L. Molina-Luna, Thin Solid Films, 685 (2019) 180.

[7] P. Mele et al., in preparation.