Atomic layer deposition of thermoelectric Al -doped ZnO (AZO) films on flexible ion track etched PET templates

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Atomic scale thickness control and superior conformality make ALD the optimal deposition method for preparing nanostructured coatings and in the case of TE materials coatings with tailored thermal and electronic properties [1]. Even more freedom for “the atomic architect” is given by the development of MLD (Molecular Layer Deposition, “The ALD of organic materials”) and the ability prepare organic/inorganic hybrid coatings and superlattice structures.[2] With superlattice structures thermal conductivity of a TE thin films can be significantly reduced e.g with ZnO:HQ(Hydroquinone) by a factor of 1/50 [3]. The most promising field of application of thin film TE devices is in wearable electronics, miniaturized biomedical devices and sensors.

FIGURE-OF-MERIT

TE materials are evaluated by a scale of (dimensionless) figure-of-merit:

$$ZT = \frac{S^2 \sigma T}{\kappa},$$

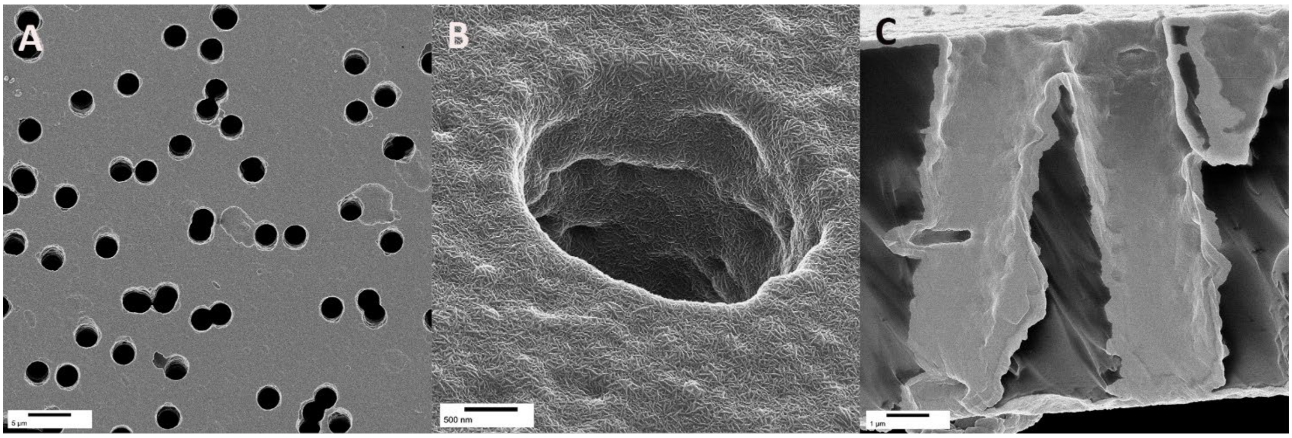
where S is Seebeck coefficient, σ is electrical conductivity and κ is thermal conductivity. These material properties have complex dependencies, and the development of novel TE materials is challenging.

DEPOSITION OF AZO FILMS ON HOLED TEMPLATES

AZO films where prepared on ion track etched PET templates with nominal hole sizes of 100 nm, 400 nm and 3µm provided by Oxyphen Ag (Switzerland). ALD process used was DEZ/TMA and H_2O. For optimal electrical conductivity of the films at 2% [1] a pulse ratio of 50:1 was used.

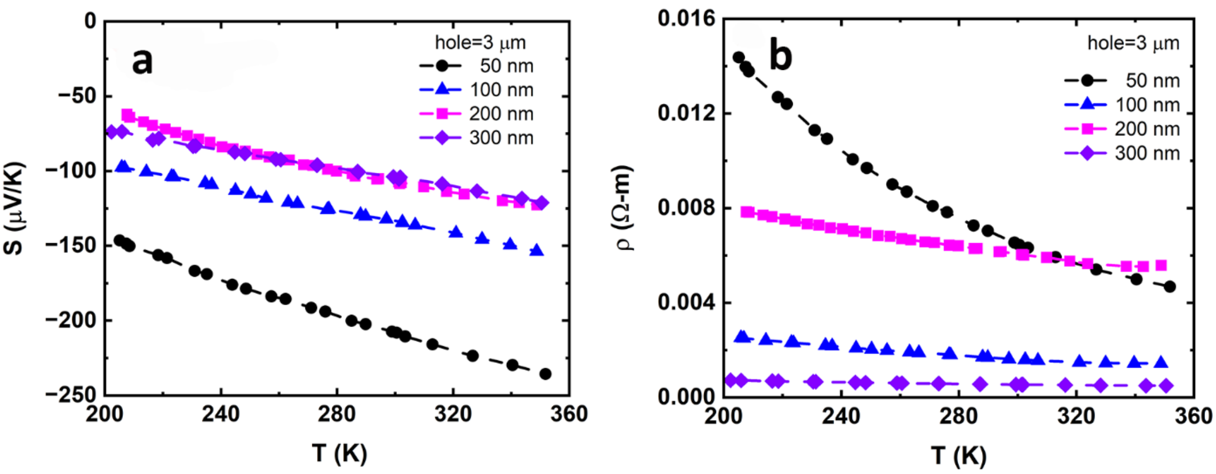
References: [1] Karppinen M. and Karttunen A. J., Department of Chemistry, Aalto University, Finland. ALD of thermoelectric materials, Chapter in ALD book (2015).[2] P. Sundberg, M. Karppinen, Organic and inorganic–organic thin film structures by molecular layer deposition: A review, Beilstein J. Nanotechnol. 5,1104–1136 (2014).[3] F. Krahl, A. Giri, J.A. Tomko, T. Tynell, P.E. Hopkins & M. Karppinen, Thermal conductivity reduction at inorganic-organic interfaces: from regular superlattices to irregular gradient layer sequences, Advanced Materials Interfaces 5, 1701692 (2018).

IMAGING



Helium Ion Microscope (HIM) images of from AZO films deposited on ion track etched PET membrane with nominal hole diameter of 3 µm, approximate hole density $2 \cdot 10^4/mm^2$. a) Tracks are randomly produced by radioactive decay and chemically etched b) A 45° view on a single hole with 200 nm conformal crystalline AZO coating c) Cross-sectional view on 200 nm AZO coating. The cross-sections for HIM imaging were made at Top Analytica Ltd with BIB (Broad Ion Beam) milling system. Images: *S. Kinnunen*, University of Jyväskylä.

MEASURING THERMOELECTRIC PROPERTIES



Seebeck coefficient (a) and electrical resistivity (b) as a function of temperature and ALD coating thickness (shown on the inserts) measured from AZO films deposited on ion track etched PET templates with 3 µm holes. Measurements & images: *T. Girish* (Aalto University)