ΕΥΡΩΠΑΪΚΟ ΚΟΙΝΩΝΙΚΟ ΤΑΜΕΙΟ

Επιχειρησιακό Πρόγραμμα

Ανάπτυξη Ανθρώπινου Δυναμικού, Εκπαίδευση & Δια Βίου Μάθηση

ΕΙΔΙΚΟΣ ΛΟΓΑΡΙΑΣΜΟΣ ΚΟΝΔΥΛΙΩΝ
ΕΡΕΥΝΑΣ ΑΡΙΣΤΟΤΕΛΕΙΟΥ
ΠΑΝΕΠΙΣΤΗΜΙΟΥ ΘΕΣΣΑΛΟΝΙΚΗΣ

ΑΡΙΣΤΟΤΕΛΕΙΟ ΠΑΝΕΠΙΣΤΗΜΙΟ
ΘΕΣΣΑΛΟΝΙΚΗΣ

ΕΔΒΜ34 Project 95385
MIS 5005454

Υλικές Αστάθειες, Φαινόμενα Κλίμακας, και Μορφογένεση: Νανοϋλικά και Εγκέφαλος

Ευρωπαϊκή Ένωση
Ευρωπαϊκό Κοινωνικό Ταμείο

- **Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης**

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Υλικές Αστάθειες, Φαινόμενα Κλίμακας, και Μορφογένεση: Νανοϋλικά και Εγκέφαλος [ΕΔΒΜ34 MIS 5005454]

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Summary

Model analogies between pattern formation of defects in deforming engineering materials under application of external stress and morphogenesis of cellular structures in ageing brain tissue under development of internal stress are investigated. When differential equations are not available, dominant characteristics of such processes are pursued through Tsallis q-statistics methodology applied to the aforementioned nonliving and living systems.

Benchmark Results

• Material Defect vs Brain Defect Model Analogies

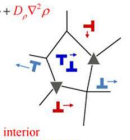
-Defect Kinetics in Nanopolycrystals during stress (deformation) application

$$\rho_t = A_\rho\rho - B_\rho\rho^2 - C_0\frac{\rho}{d} + C_3\rho\varphi + \omega M\vartheta + N\frac{\psi}{d} + D_\rho\nabla^2\rho$$

$$\varphi_t = A_\varphi\rho + B_\varphi\rho^2 - C_4\rho\varphi - K\varphi + D_\varphi\nabla^2\varphi$$

$$\psi_t = C_1\frac{\rho}{d} + A_\psi\psi - B_\psi\psi^2 + D_\psi\nabla^2\psi$$

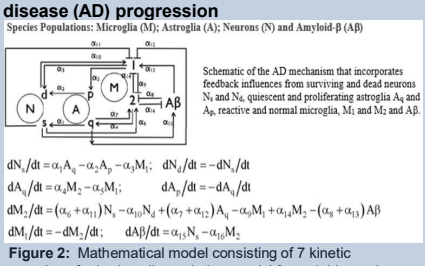
$$\vartheta_t = C_2\frac{\rho}{\omega d^2} - P_1\rho\vartheta - P_2\psi\vartheta - G\vartheta + D_\vartheta\nabla^2\vartheta$$



ρ – mobile dislocations in the grain interior
φ – low-mobility (immobile) dislocations (dipoles)
ψ – grain boundary sliding dislocations
ϑ – immobile junction disclinations

Figure 1: Reaction-Diffusion type equations for the dominant families of structural defects in nanopolycrystals.

- Cell Kinetics in brain tissue during Alzheimer disease (AD) progression



$$dN_q/dt = \alpha_1 A_q - \alpha_2 A_p - \alpha_3 M_1; \quad dN_q/dt = -dN_q/dt$$

$$dA_q/dt = \alpha_4 M_2 - \alpha_5 M_1; \quad dA_p/dt = -dA_q/dt$$

$$dM_2/dt = (\alpha_6 + \alpha_{11})N_s - \alpha_{10}N_4 + (\alpha_7 + \alpha_{12})A_q - \alpha_9 M_1 + \alpha_{14}M_2 - (\alpha_8 + \alpha_{13})A\beta$$

$$dM_1/dt = -dM_2/dt; \quad dA\beta/dt = \alpha_{15}N_s - \alpha_{16}M_2$$

Figure 2: Mathematical model consisting of 7 kinetic equations for brain cell populations and Aβ amyloid protein

• Tsallis q-statistics preliminaries

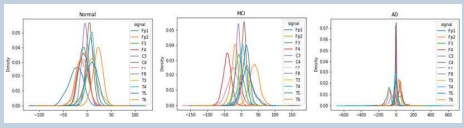


Figure 3: Indicative whole EEG Probability Density Functions for Healthy (Normal), MCI and AD samples.

Deliverables

A. Journal Publications

- A.C. Tsolakis, G. Petsos, O. Kapetanou, I.N. Nikolaidis, and E.C. Aifantis, *Model analogies between pattern formation in deforming engineering materials & morphogenesis in ageing human brains, J. Mech. Beh. Mat.* **28**, 95-106, 2019

B. Conference Proceedings/Presentations

- A.C. Tsolakis, O. Kapetanou, G. Petsos, I.N. Nikolaidis, and E.C. Aifantis, Combination of Tsallis Entropy and Higutchi Fractal Dimension for Quantifying Changes in EEG Signals in Alzheimer's Disease, Conf. Proc. BIOTECHNO 2019, June 02-June 06, 2019 - Athens, Greece
- E.C. Aifantis, G. Petsos, A. Tsolakis, O. Kapetanou, I. Nikolaidis, Heterogeneous and Gradient Materials (HGM III): Tailoring Mechanical Incompatibility for Superior Properties, *TMS Annual Meeting & Exhibition*, San Antonio 10-14 March, 2019. [INVITED]

C. Workshops/Symposia

- C.Tsallis Mini-Symposium Sept 21, 2018
- Shechtman-Suresh Honorary Symposium Nov 30- Dec 2, 2018.

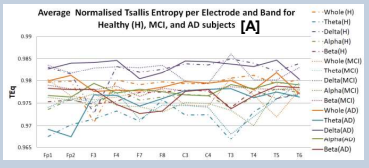


Figure 4A: Average Normalised Tsallis Entropy (TE) per electrode and band for the three sample groups (1' examined interval – closed eyes).

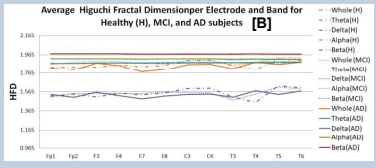


Figure 4B: Average Higuchi Fractal Dimension (HFD) per electrode and band for the three sample groups (1' examined interval – closed eyes).

Conclusions

Differential equations for various families of structural defects in deforming nanomaterials are shown to resemble corresponding differential equations for various families of cells/proteins in ageing brains. When the experimentally recorded data for signals and images cannot be interpreted through differential equations, the methodology of Tsallis q-statistics seems to be promising for capturing statistical features of the observed behavior for both nonliving and living systems.