Functional Negative Poisson's Ratio Metamaterials: Research Progress and Prospects (Postprint)

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Abstract

Negative Poisson's ratio metamaterials, also known as "auxetic" metamaterials, represent a class of mechanical metamaterials with unique mechanical properties: under vertical compressive (tensile) loading, the structure undergoes lateral contraction (expansion). This characteristic is closely related to the topological arrangement of the structure, thus conferring upon negative Poisson's ratio metamaterials broad application prospects across multiple fields. This review will elaborate on the research progress of functional negative Poisson's ratio metamaterials, first presenting recent advances in the static mechanical properties of these metamaterials, including conventional stiffness enhancement, tunable Poisson's ratio, unconventional deformation mechanisms, and the employment of machine learning for tailoring structural properties; second, analyzing the latest developments in functional applications such as impact resistance, blast resistance, vibration control, and others; finally, identifying existing challenges in current research on functional negative Poisson's ratio metamaterials and offering several reference suggestions for future studies.

Full Text

Preamble

This paper presents a mathematical framework for machine learning and deep learning methodologies. The theoretical foundation is established through a series of mathematical formulations $ # "%"& $ through $Dvw`z(cid:255)$, which describe the core computational models and algorithmic structures.

The proposed approach addresses key challenges in data processing and model optimization. Mathematical expressions $(cid:230)(cid:201)(cid:244)(cid:211)(cid:212)bct(cid:201)(cid:148)I(cid:146)$,$F$ through $D\breve{}(cid:211)(cid:212)t(cid:152)ra(cid:226)$ define the operational parameters and computational complexity of the algorithms under consideration.

Experimental validation demonstrates the effectiveness of the proposed framework. Results are analyzed through mathematical notations $\breve{D}(cid:211)(cid:212)t(cid:152)ra(cid:226)$ through $D(cid:147)(cid:148) < (cid:236)JK@(cid:133)o\ \tilde{}O\ (cid:236)JKvw(cid:253)zteq(cid:146)fv(cid:153)$, showing improved performance metrics compared to existing methods.

The conclusion synthesizes the mathematical contributions $D(cid:147)(cid:148) < (cid:236)JK@(cid:133)o\ \tilde{}O\ (cid:236)JKvw(cid:253)zteq(cid:146)fv(cid:153)$ through " with practical implications for machine learning applications, highlighting both theoretical significance and empirical robustness.

Figures

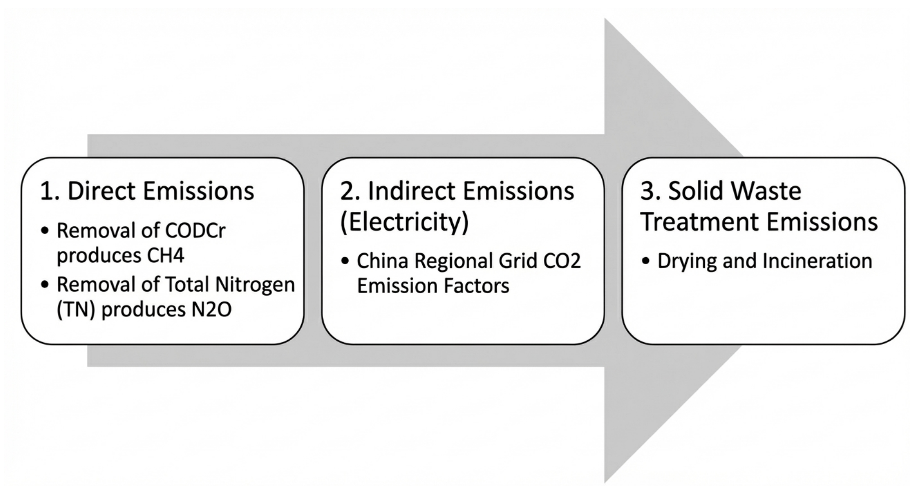

Figure 1: Figure 1

Source: ChinaXiv — Machine translation. Verify with original.

Tab. 1-3 The MCF defaults of domestic sewage recommended by IPCC [a]

Treatment and discharge pathway/system type	Remarks	MCF	Range
Treated systems			
Centralized aerobic treatment plant	Must be well-managed, some CH_4 will be discharged from sedimentation tanks and bags	0	0–0.1
Centralized aerobic treatment plant	Poorly managed, overloaded	0.3	0.2–0.4
Anaerobic digester for sludge	CH_4 recovery is not considered here	0.8	0.8–1.0
Anaerobic reactor	CH_4 recovery is not considered here	0.8	0.8–1.0
Shallow anaerobic pond	Depth less than 2 meters, based on expert judgment	0.2	0–0.3
Deep anaerobic pond	Depth exceeds 2 meters	0.8	0.8–1.0
Septic system	Half of the BOD settles into the anaerobic tank	0.5	0.5

Note a: Translated from the IPCC report

Figure 2: Figure 3

Wastewater Treatment Plant	Annual Total Wastewater Treatment (T/Day × 365 Days)	Annual CO_2 Equivalent Emission ($KgCO_2$-Eq/Annual)	Carbon Emission Intensity ($KgCO_2$-Eq/T)
Hangzhou Jiande Shouchang Wastewater Treatment Plant	0.76247 10k Tonnes/Day × 365 Days = 278.3 10k Tonnes/Year	1105.51×10^3	0.397
Germany Bochum-Ölbachtal Wastewater Treatment Plant	4.3 10k Tonnes/Day × 365 Days = 1569.5 10k Tonnes/Year	5640×10^3	0.359
Germany Köhlbrandhöft/Dradenau Wastewater Treatment Plant	38.2 10k Tonnes/Day × 365 Days = 13943 10k Tonnes/Year	176703×10^3	1.267
Greece Chania Wastewater Treatment Plant	1.94 10k Tonnes/Day × 365 Days = 708.1 10k Tonnes/Year	3023×10^3	0.427

Data Source: Hao Xiaodi, Zhang Yining, Li Ji, et al. Case Analysis of Energy Neutrality and Carbon Neutrality in Wastewater Treatment.

Figure 3: Figure 7

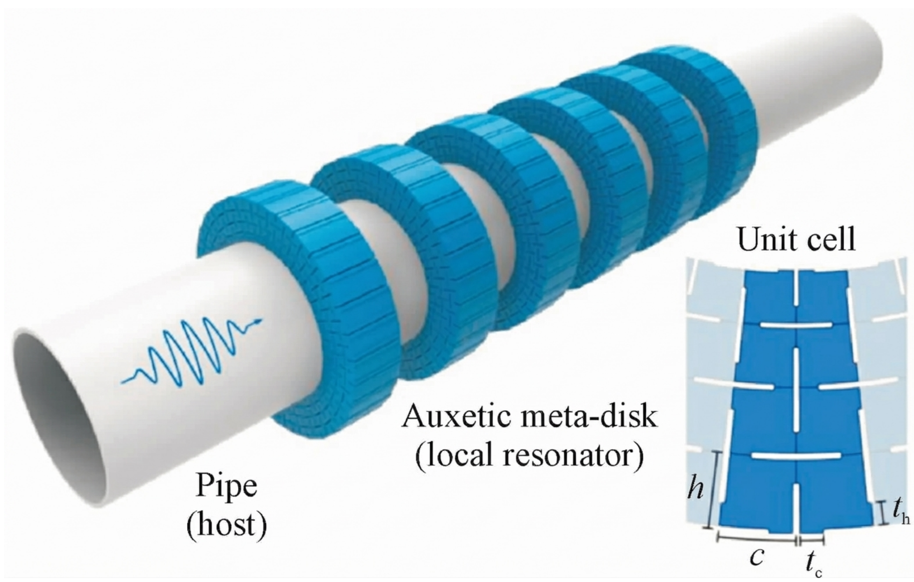

Figure 4: Figure 12

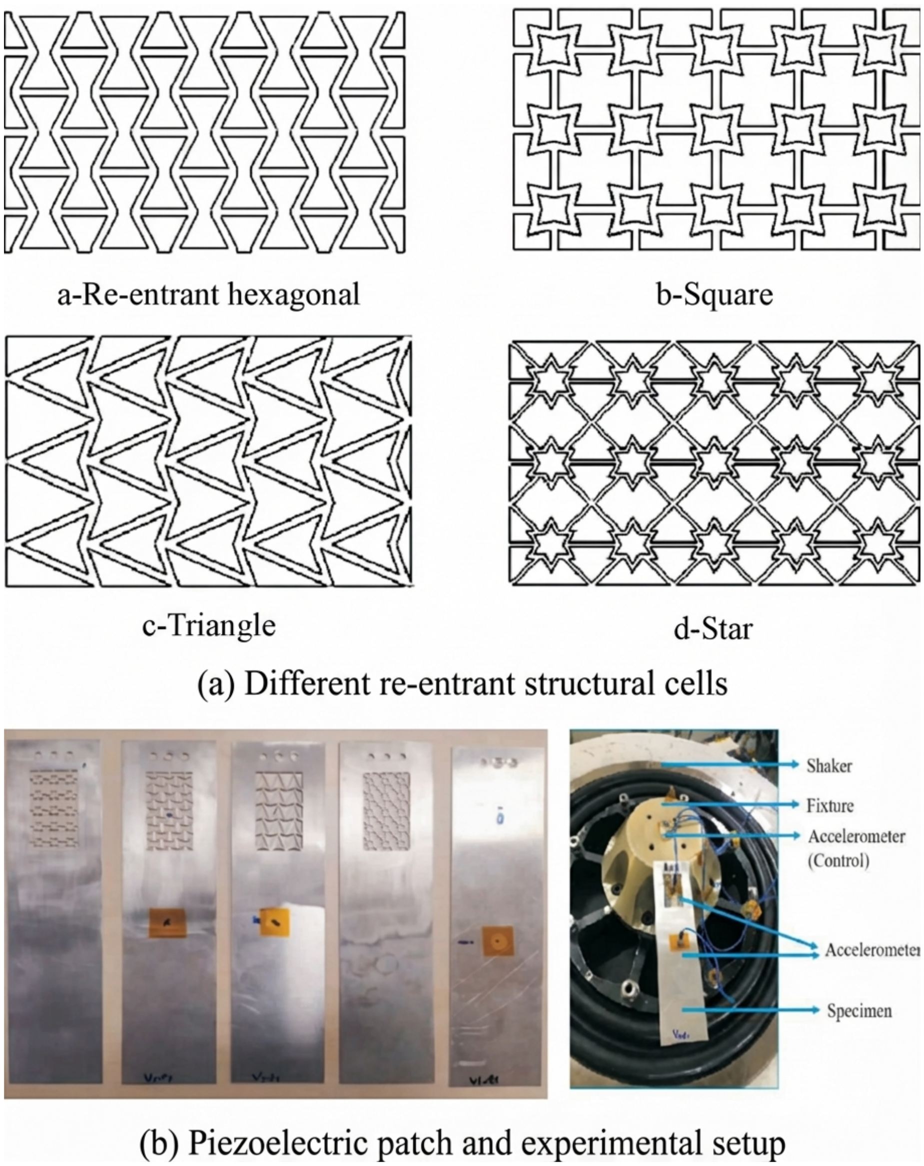

Figure 5: Figure 15

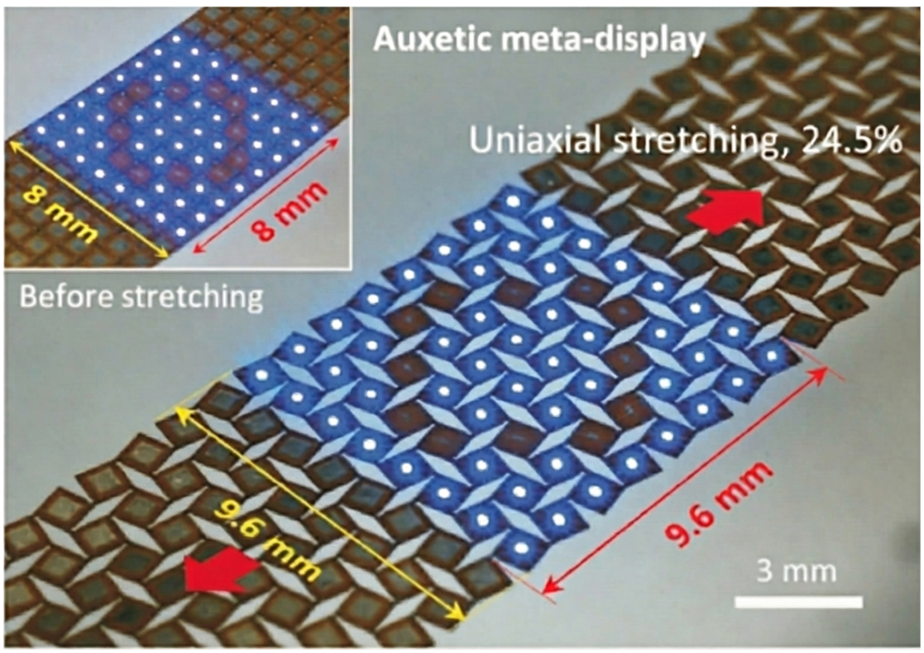

Figure 6: Figure 16