COM783 – Mecânica de Sistemas Inteligentes: Materiais Inteligentes e Suas Aplicações

Prof. Luã G. Costa

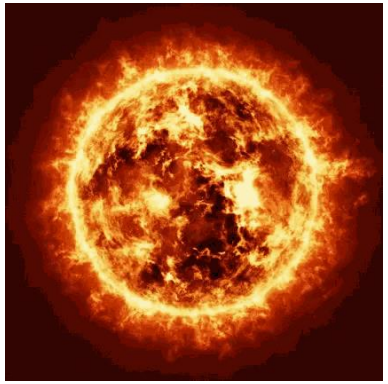
Universidade Federal do Rio de Janeiro (COPPE/UFRJ)

Programa de Engenharia Mecânica (PEM)

Materiais Inteligentes: Acomplamento Multifísico

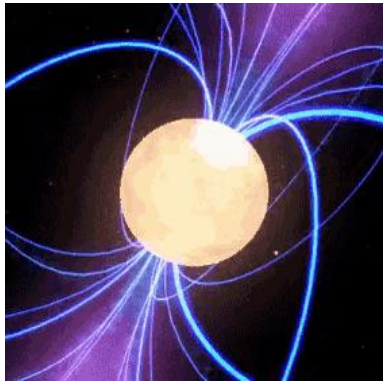
Mecânico

Térmico

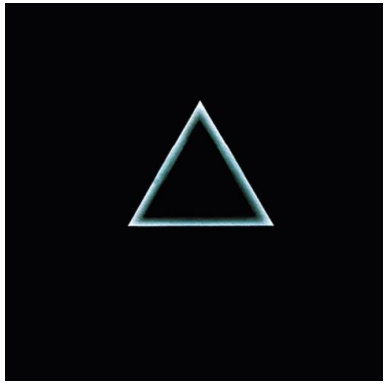


Elétrico

Magnético



Óptico

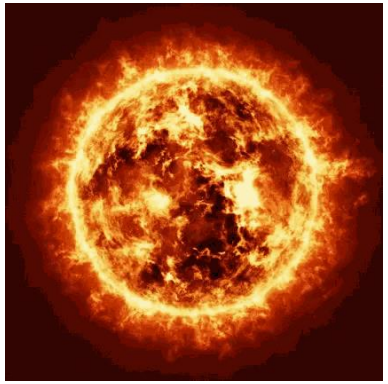


1. Atuadores
2. Sensores
3. Dispositivos de Controle
4. Dissipadores de Energia
5. Colheita de Energia

Materiais Inteligentes: Acomplamento Multifísico

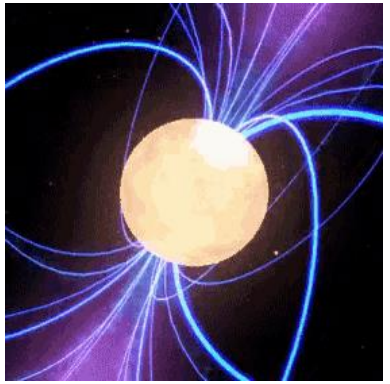
Mecânico

Térmico

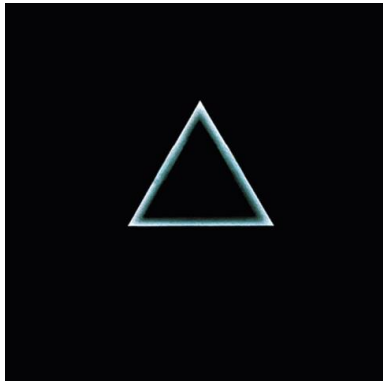


Elétrico

Magnético



Óptico

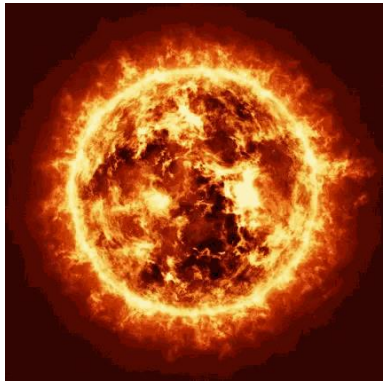


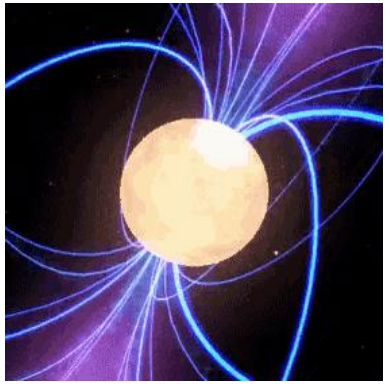
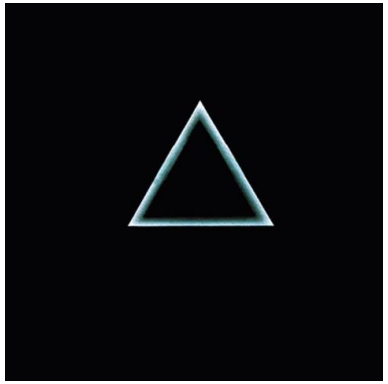
Shape Memory Alloys (SMAs)

Shape Memory Polymers (SMPs)

Materiais Inteligentes: Acomplamento Multifísico

Mecânico | Térmico | Elétrico | Magnético | Óptico

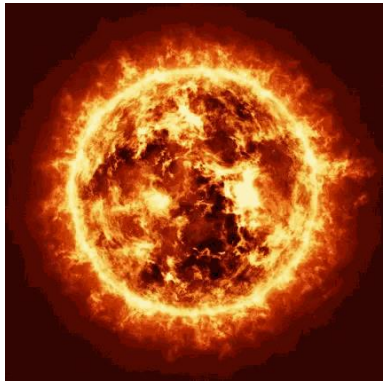
Piezoelétricos

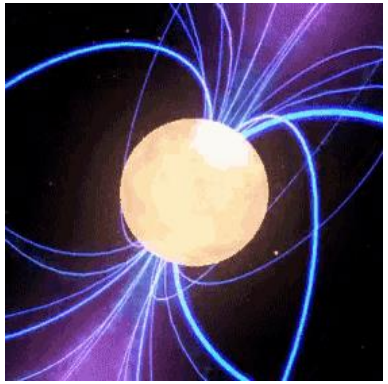
Elastômeros Dielétricos / Eletroestrictivos

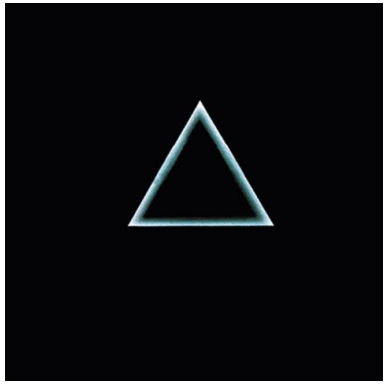
Fluidos Eletroreológicos

Materiais Inteligentes: Acomplamento Multifísico

Mecânico | Térmico | Elétrico | **Magnético** | Óptico





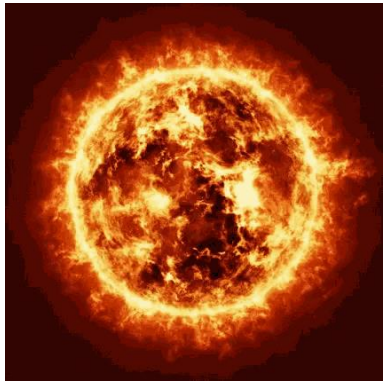


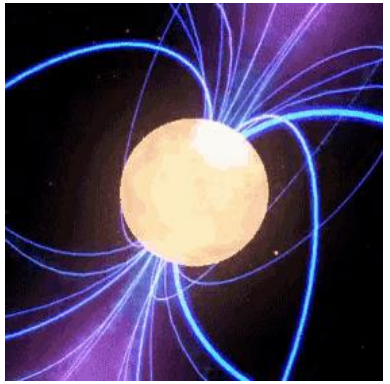
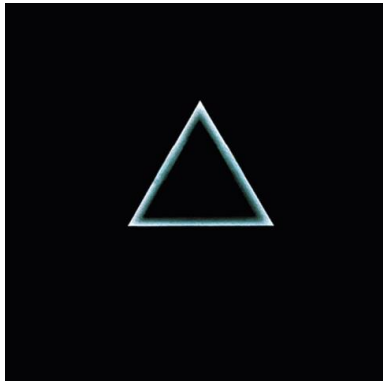
Magnetoestrictivos

Fluidos Magnetoreológicos / Ferrofluidos

Materiais Inteligentes: Acomplamento Multifísico

Mecânico | Térmico | Elétrico | Magnético | Óptico

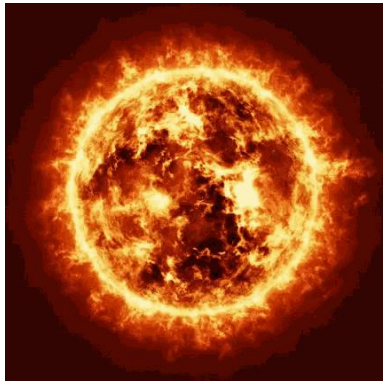



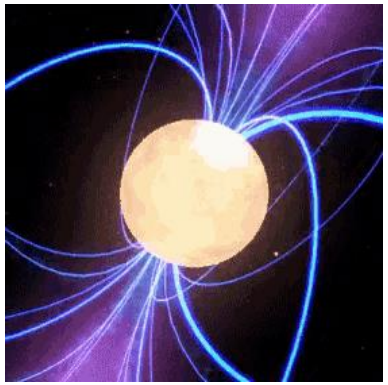
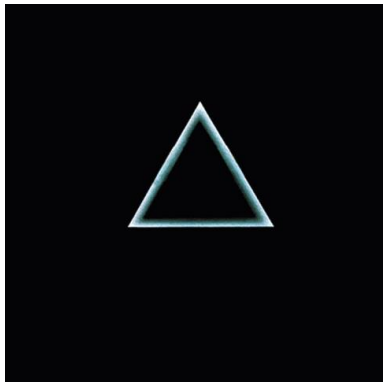



Magnetic Shape Memory Alloys (MSMAs)

Materiais Inteligentes: Acomplamento Multifísico

Mecânico | Térmico | Elétrico | Magnético | **Óptico**

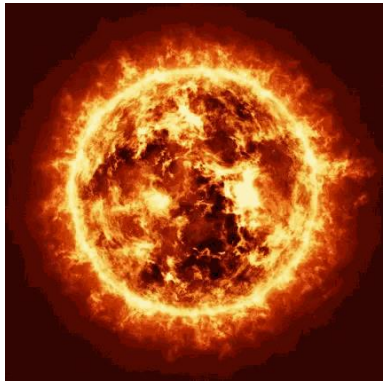



Light-Activated Shape Memory Polymers (LASMPs)

Materiais Inteligentes: Acomplamento Multifísico

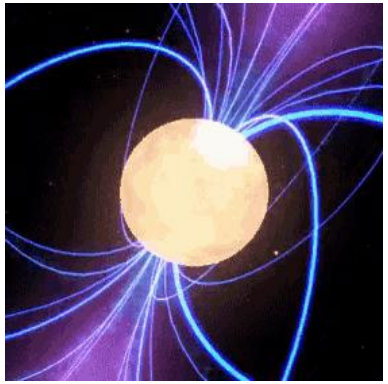
Mecânico

Térmico

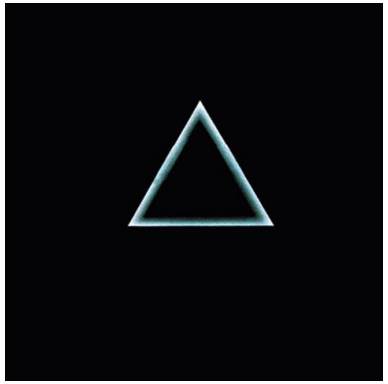


Elétrico

Magnético



Óptico

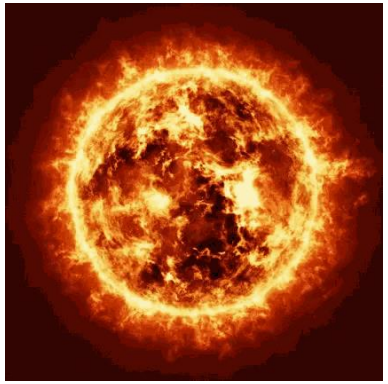


Light-Activated Shape Memory Polymers (LASMPs)

Materiais Inteligentes: Acomplamento Multifísico

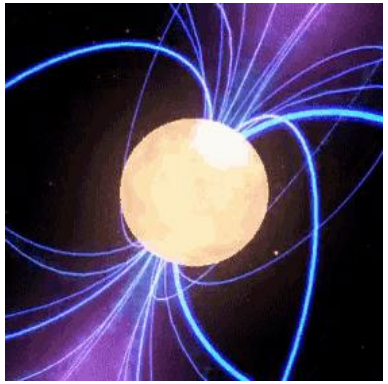
Mecânico

Térmico

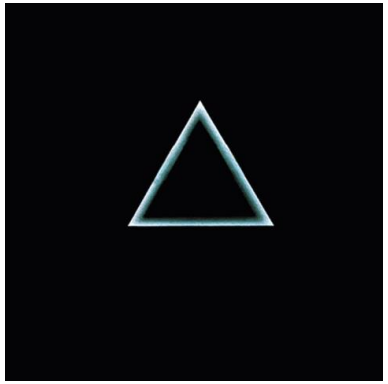


Elétrico

Magnético



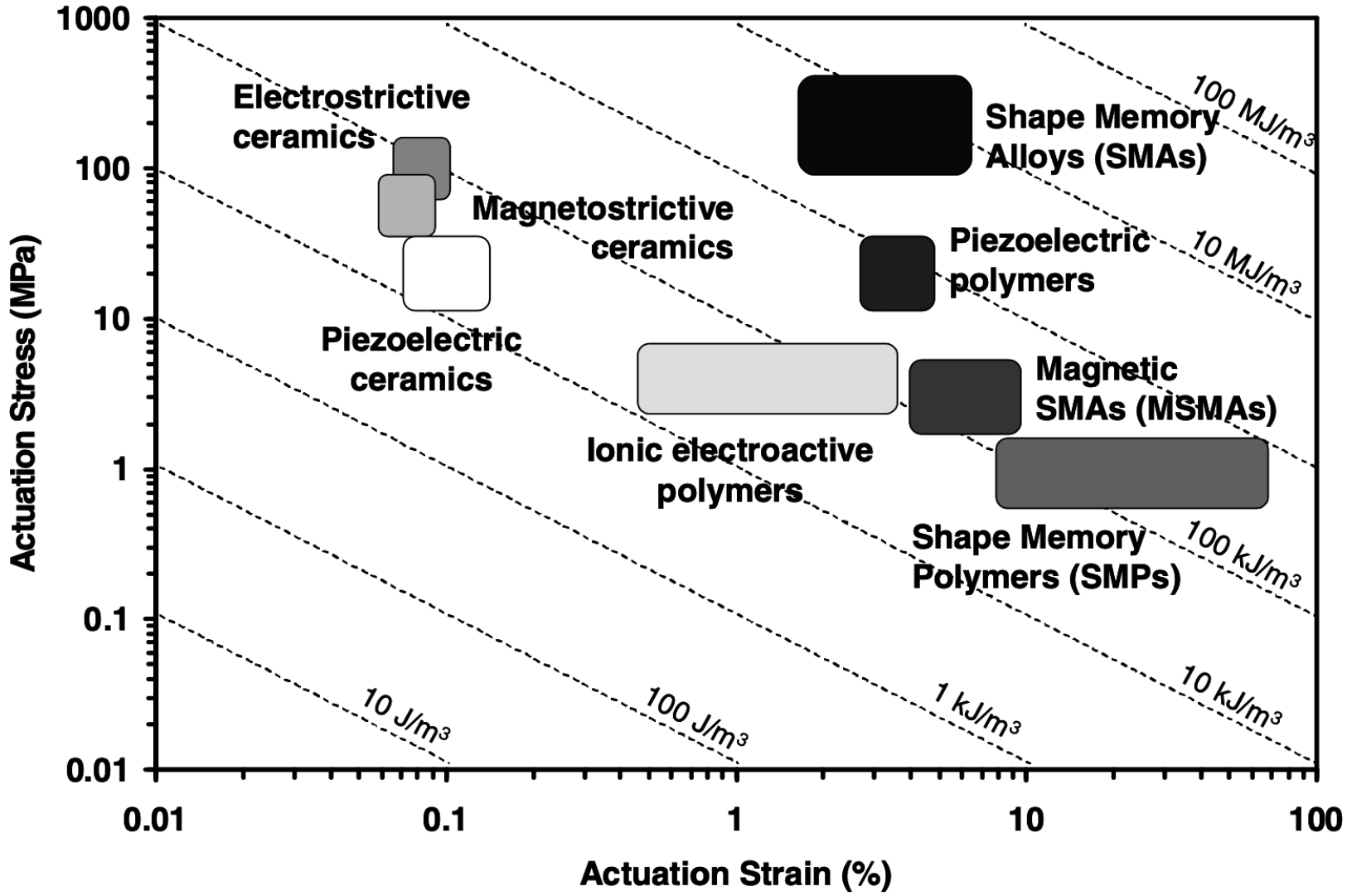
Óptico



Piroelétricos

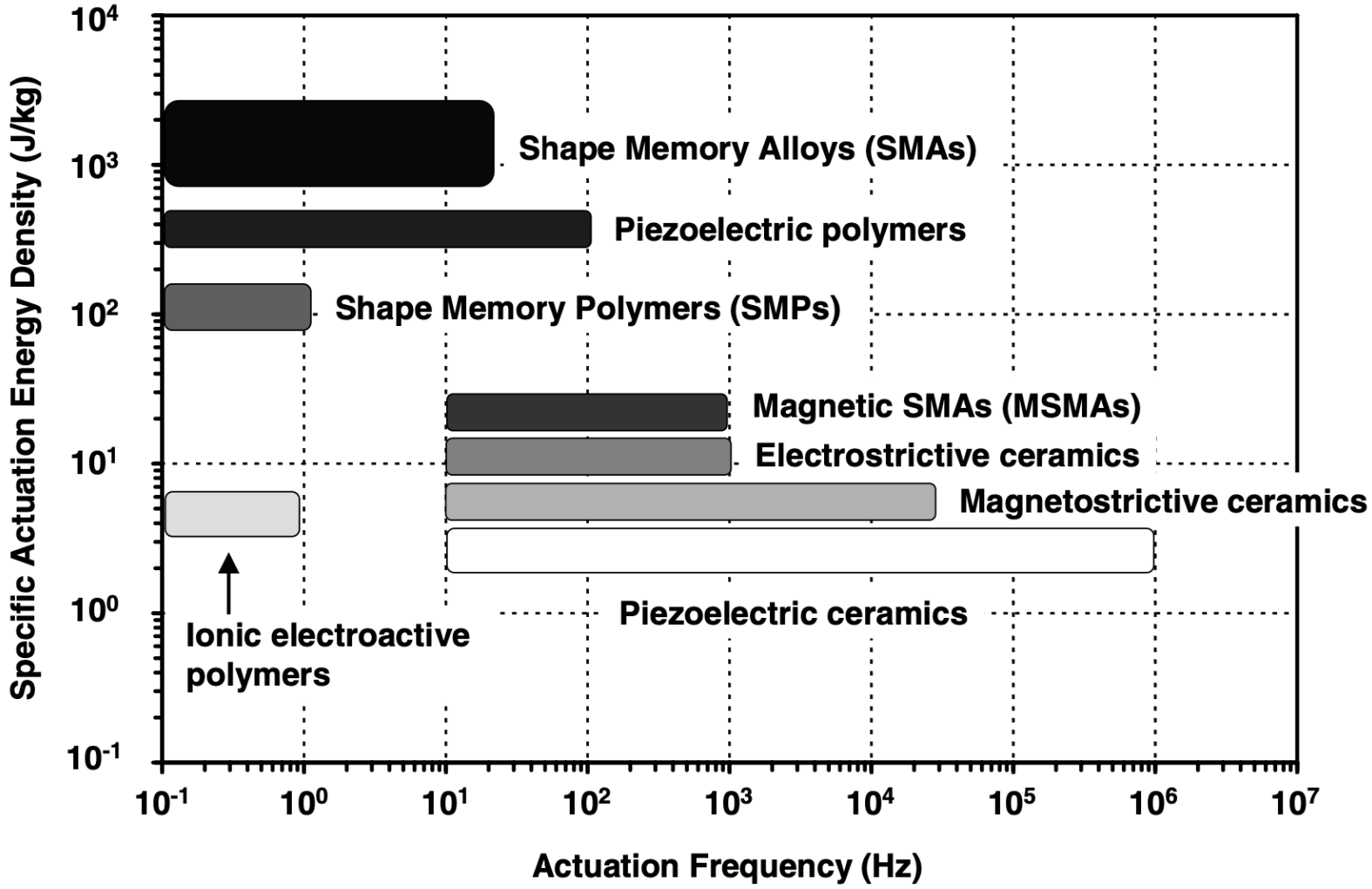
Termoelétricos

Materiais Inteligentes



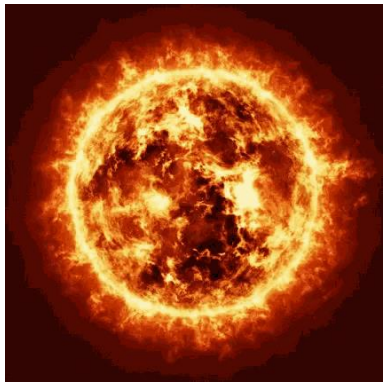
Materiais Inteligentes

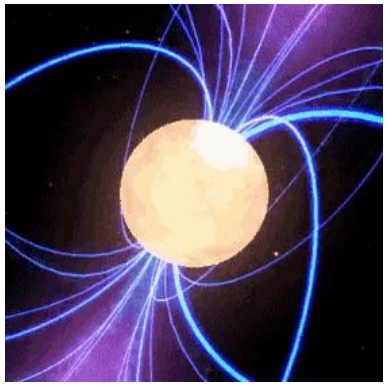
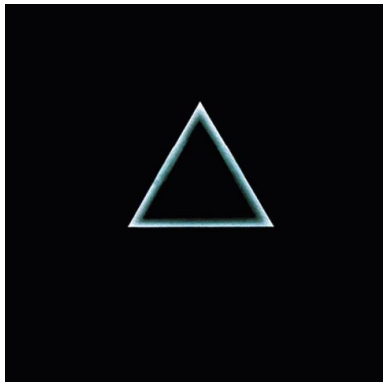
Trabalho disponível por unidade de volume



Materiais Inteligentes: Acomplamento Multifísico

Mecânico | Térmico | Elétrico | Magnético | Óptico

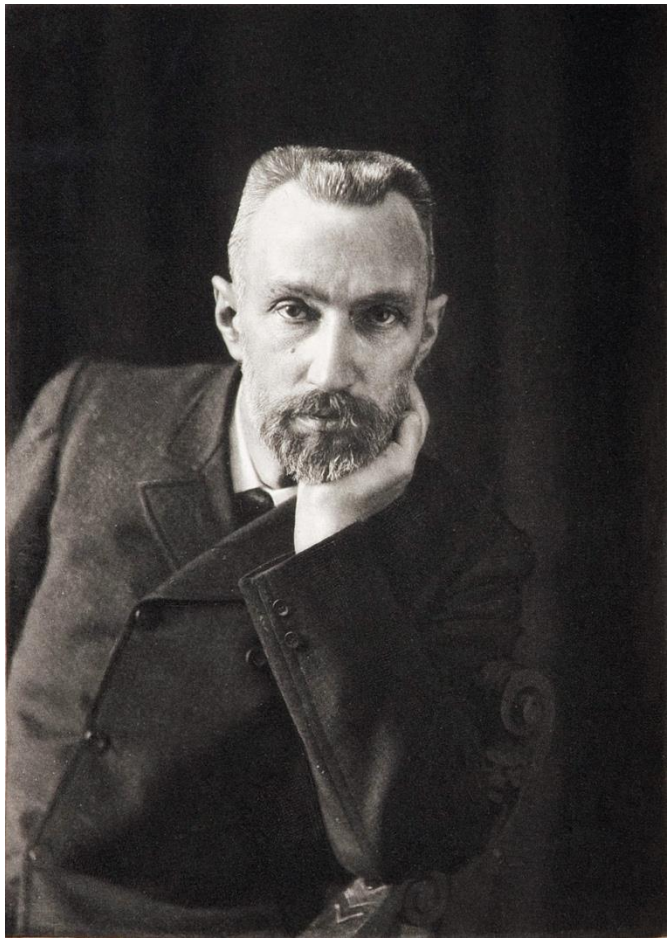
Piezoelétricos

Elastômeros Dielétricos / Eletroestrictivos

Fluidos Eletroreológicos

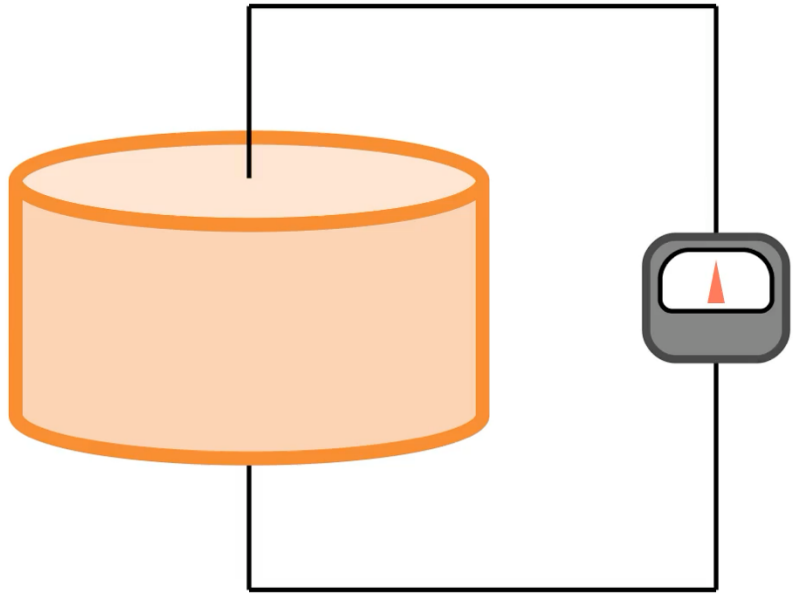
Piezoeletricidade

Pierre Curie (1859 – 1906)



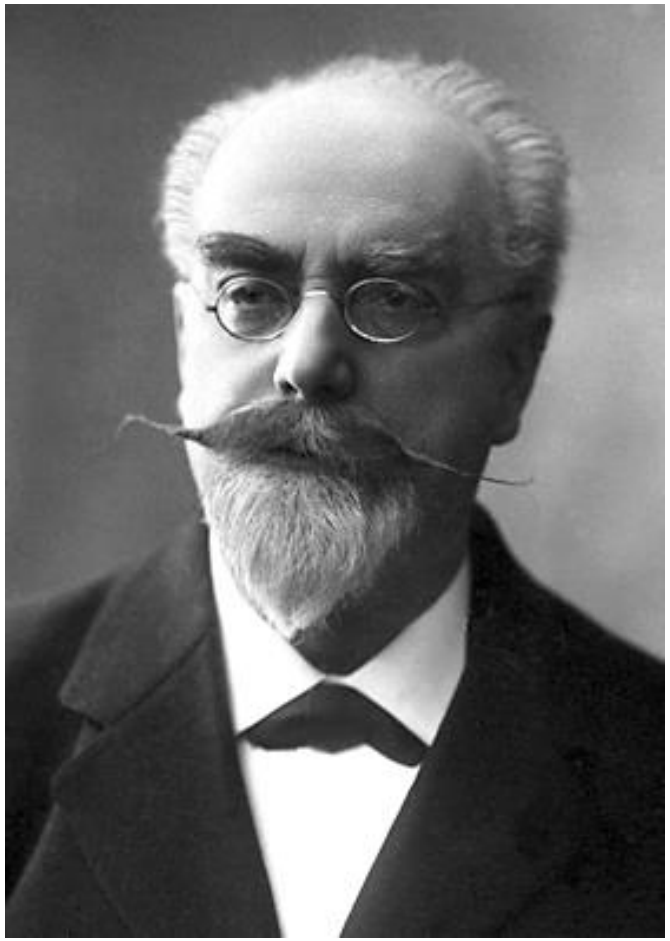
Paul-Jacques Curie (1856 – 1941)

Efeito Direto (1880)

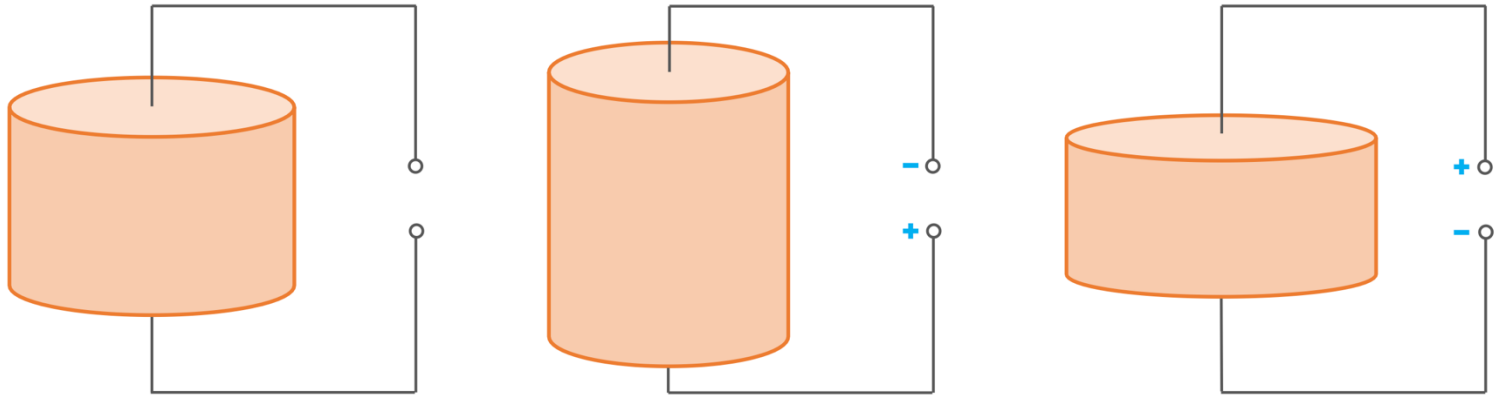


Piezoeletricidade

Gabriel Lippmann (1845 – 1921)



Efeito Inverso (1881)



Processo Reversível!

Materiais Piezoelétricos

Quartzo

Osso

Topázio

Lead Zirconate Titanate (PZT)

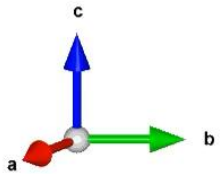
Polyvinylidene Fluoride (PVDF)

Naturais

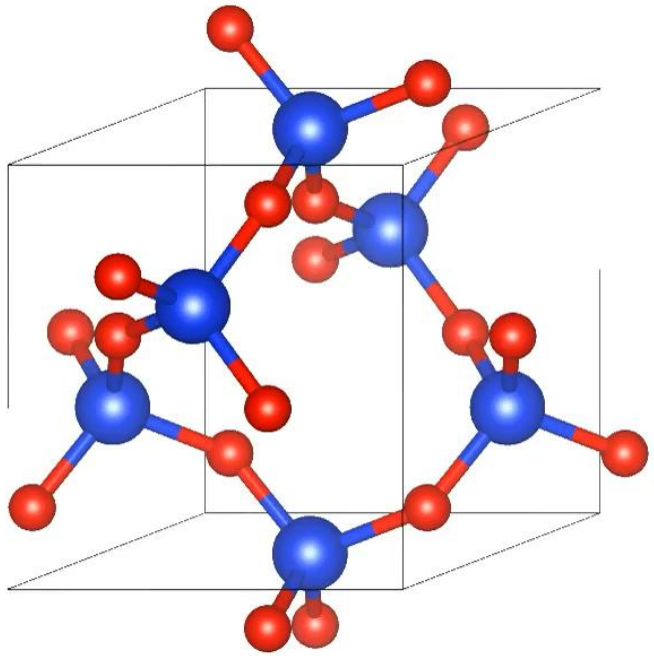
Sintéticos

Materiais Piezoelétricos – Princípio de Funcionamento

Quartzo



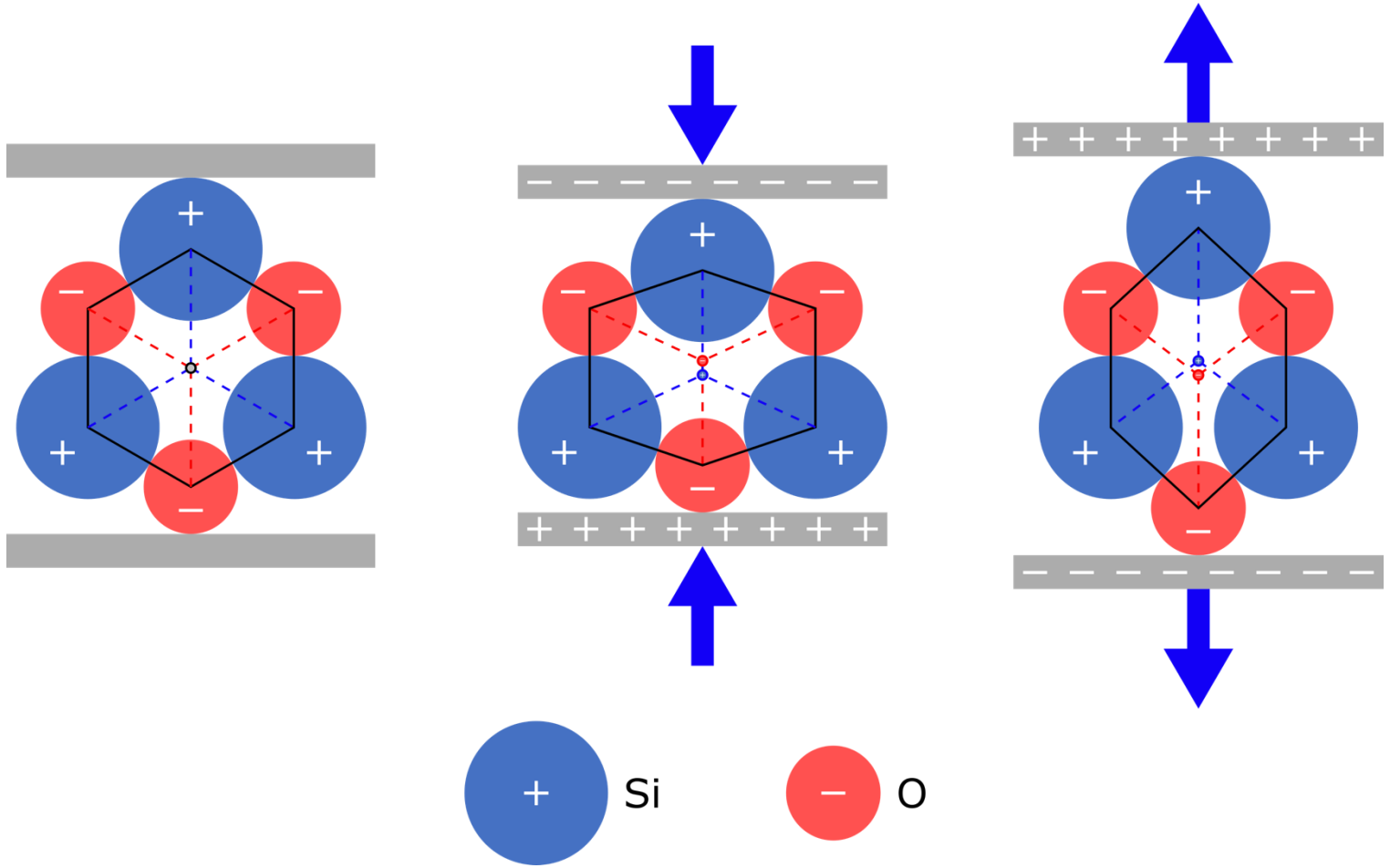
SiO_2



Materiais Piezoelétricos – Princípio de Funcionamento

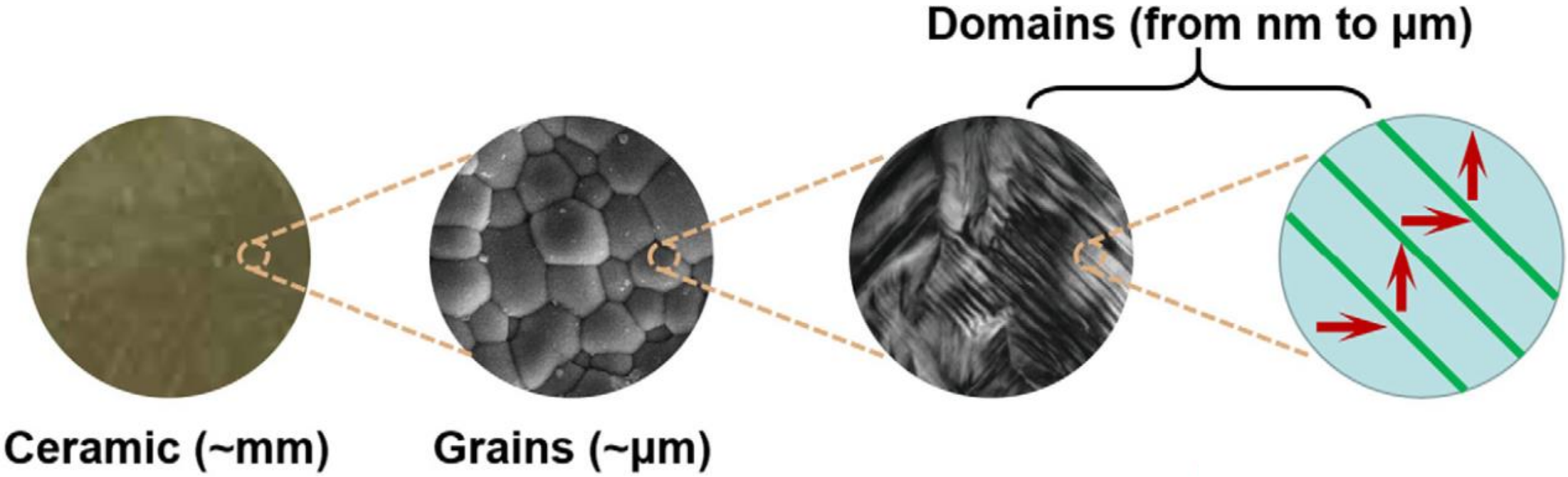
Quartzo

Estrutura Não Centrossimétrica!



Materiais Piezoelétricos – Método de Produção

REQUISITO: Material ser ferroelétrico (possuir polarização elétrica espontânea)



Materiais Piezoelétricos – Método de Produção

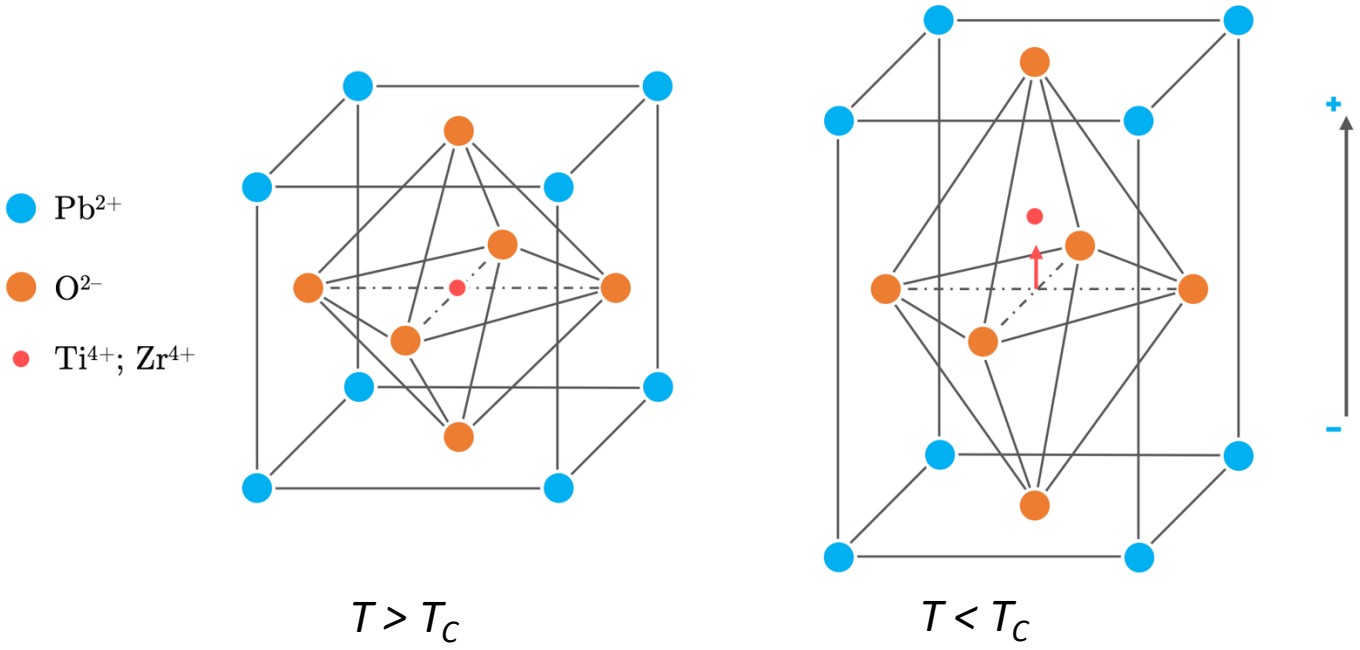
Lead Zirconate Titanate (PZT)

1. Os materiais brutos em (Pb, Zr, Ti) em formato de pó são misturados acima da temperatura de Curie (T_C).
2. O material resultante é moldado na geometria desejada

Materiais Piezoelétricos – Método de Produção

Lead Zirconate Titanate (PZT)

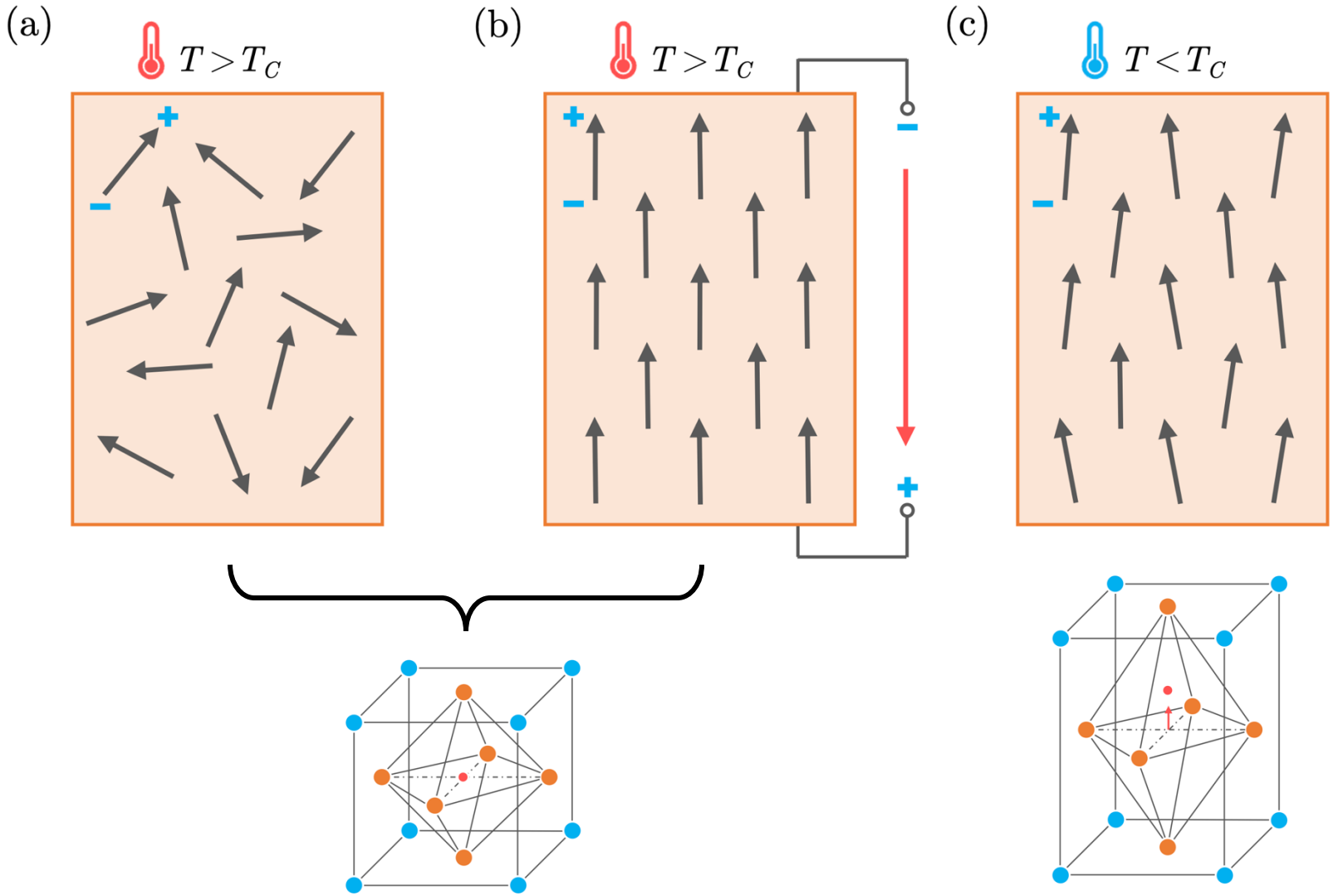
1. Os materiais brutos em (Pb, Zr, Ti) em formato de pó são misturados acima da temperatura de Curie (T_C).
2. O material resultante é moldado na geometria desejada



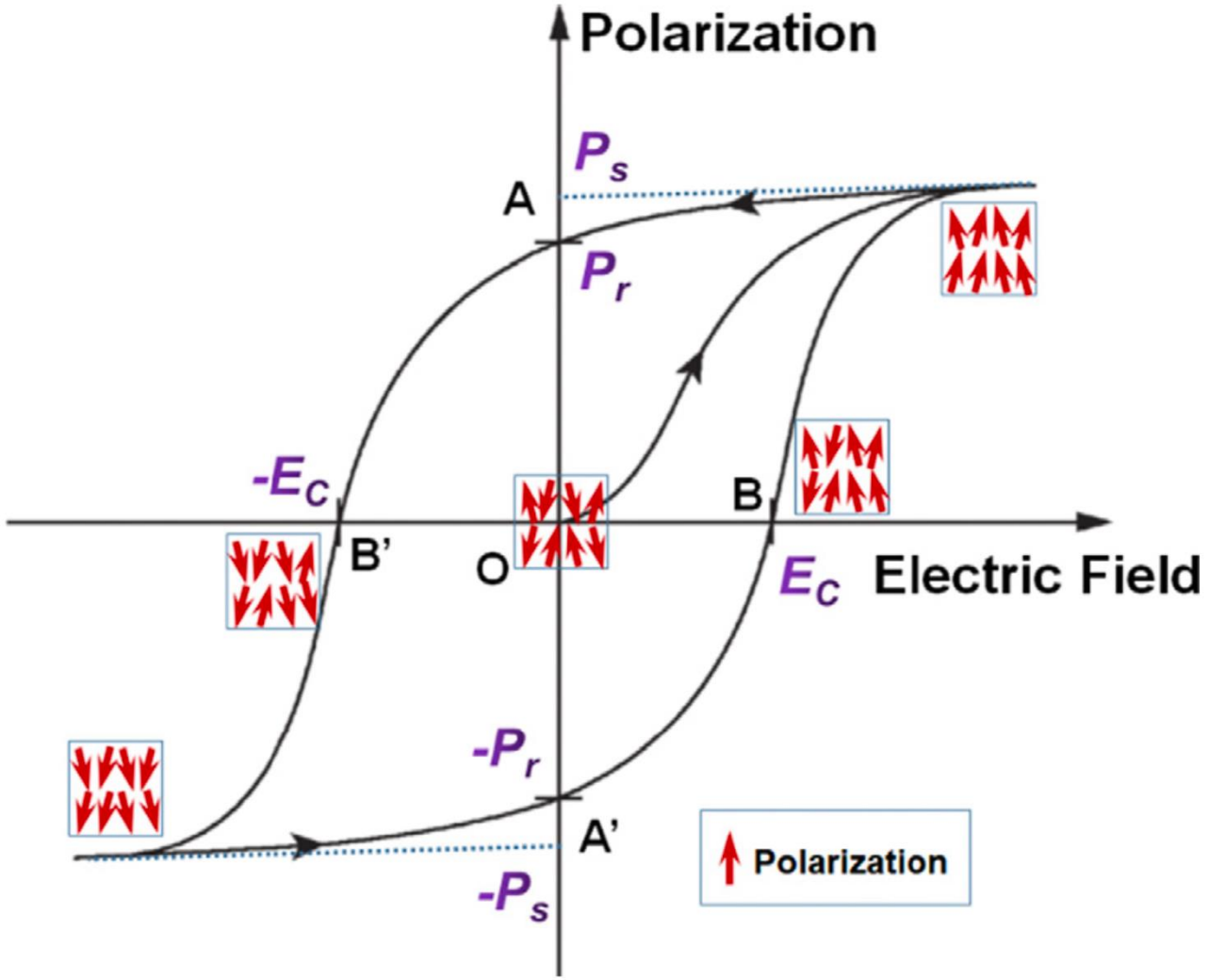
$T > T_C$ $T < T_C$

Materiais Piezoelétricos – Método de Produção

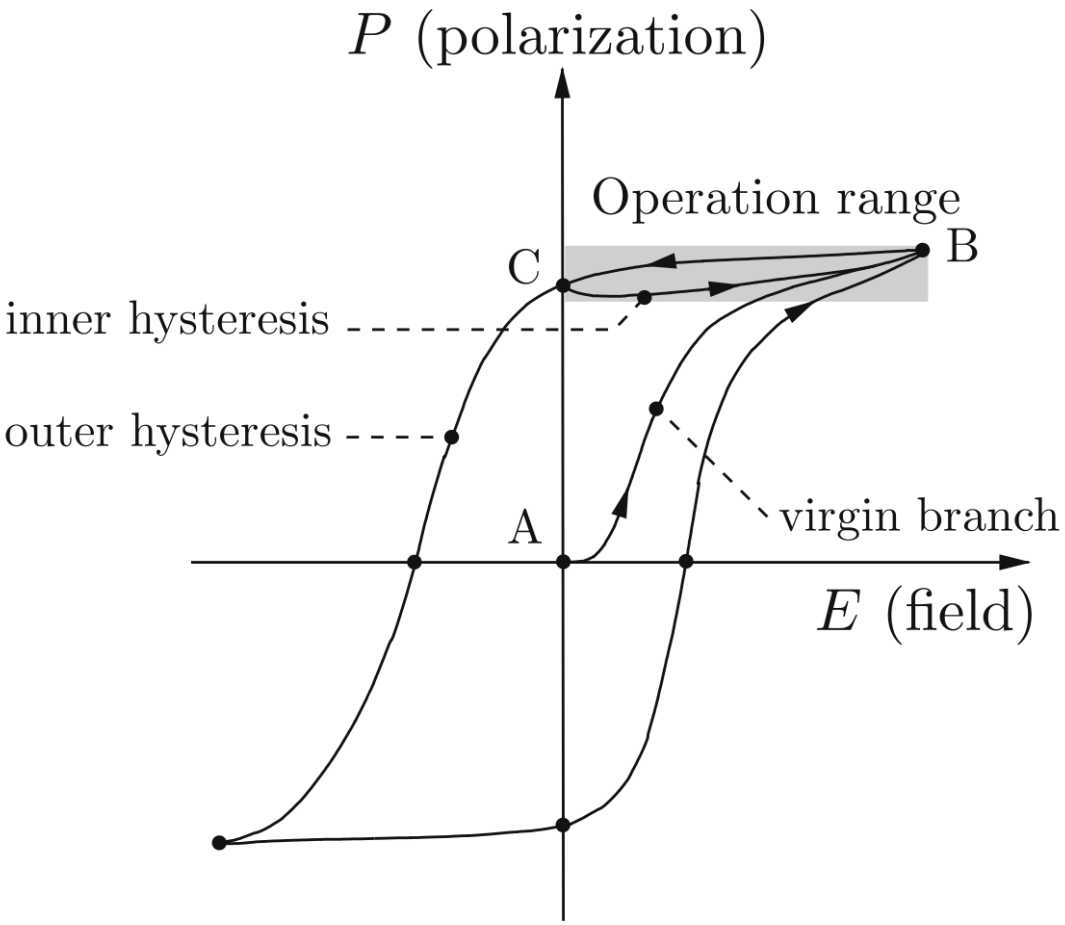
Lead Zirconate Titanate (PZT)



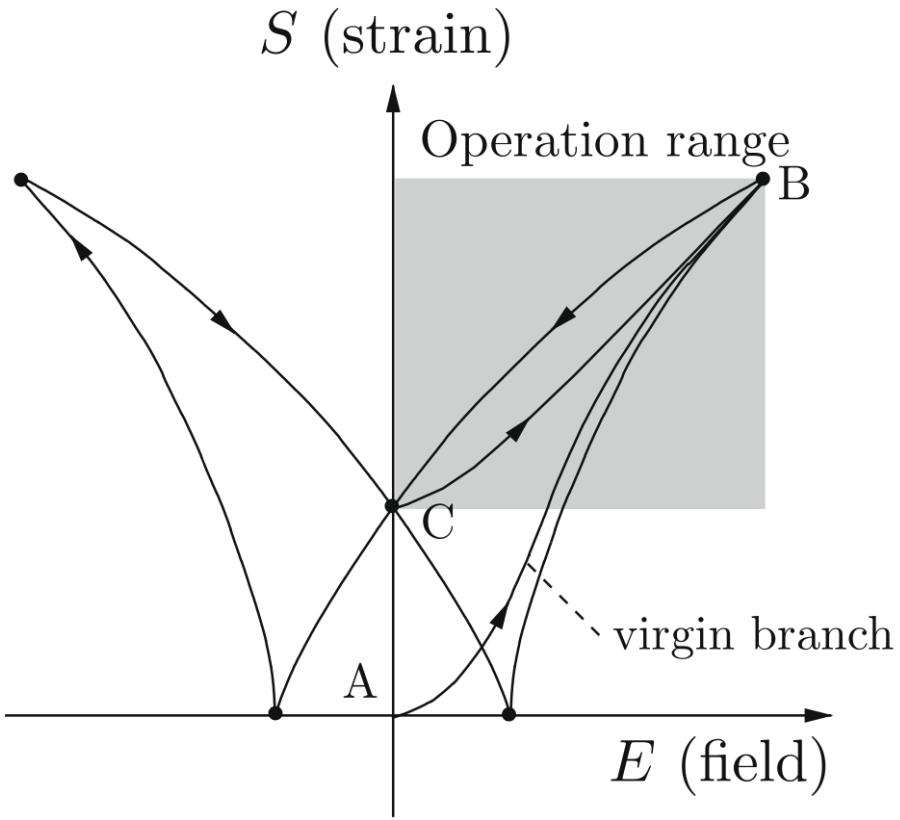
Materiais Piezoelétricos – Método de Produção



Materiais Piezoelétricos – Método de Produção

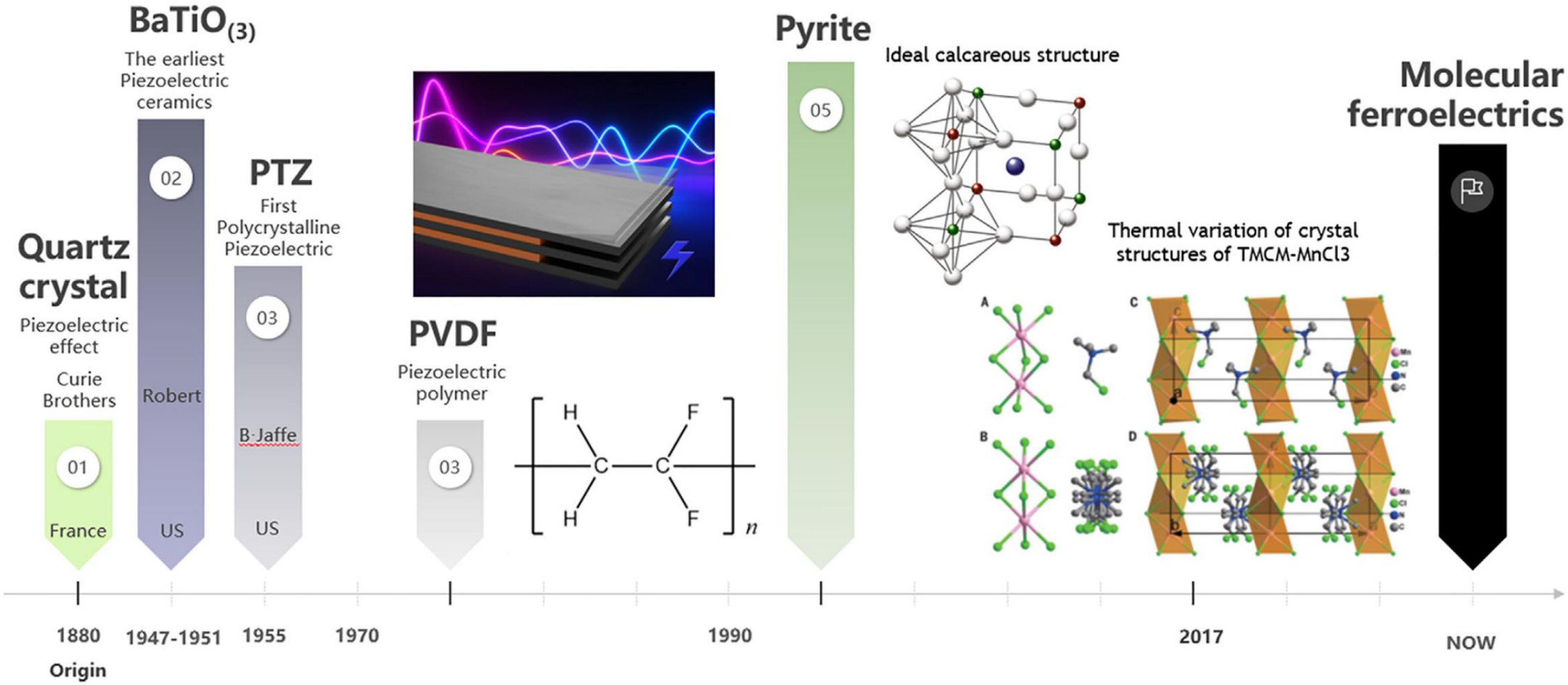


(a) Polarization diagram



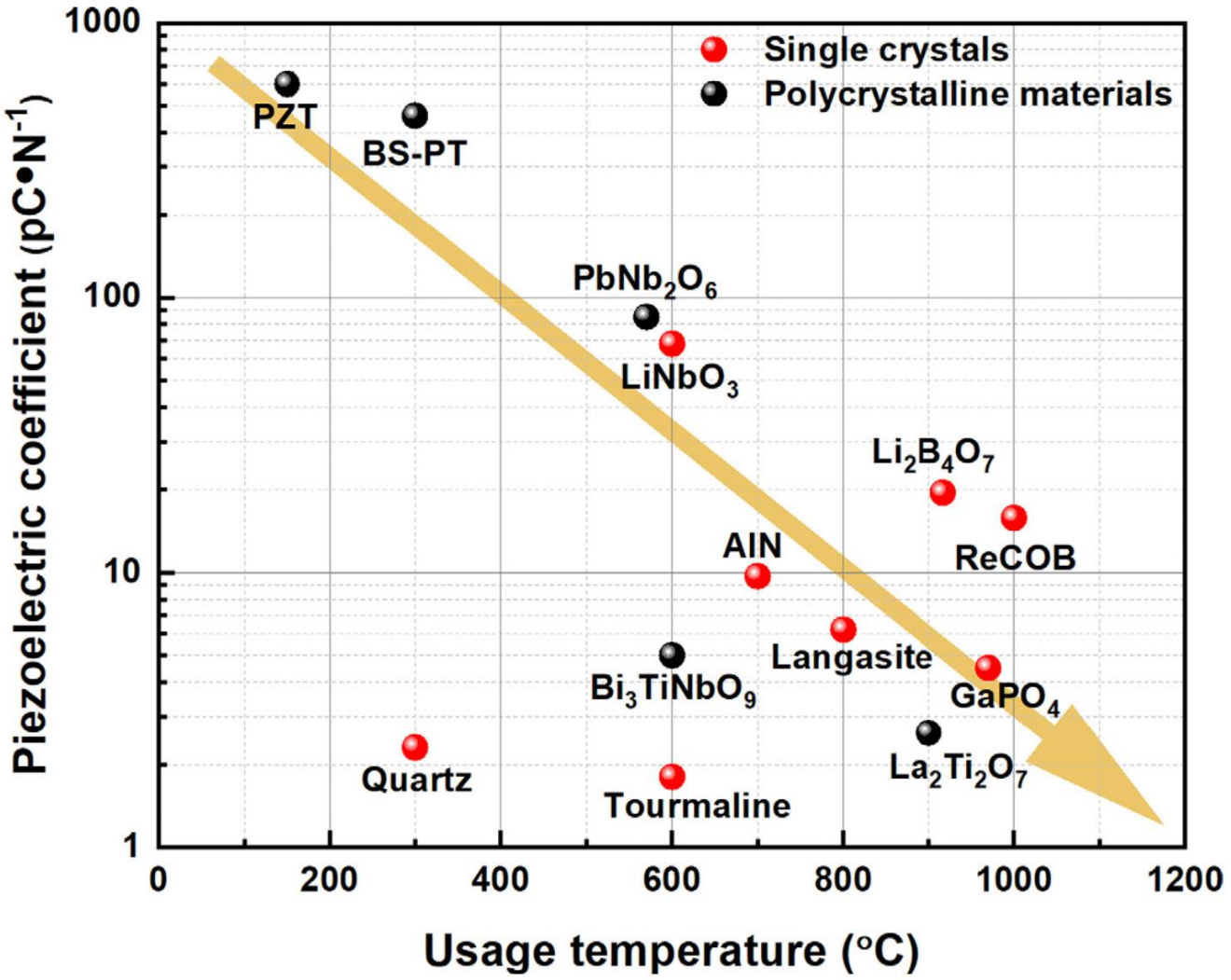
(b) Butterfly diagram

Linha do Tempo



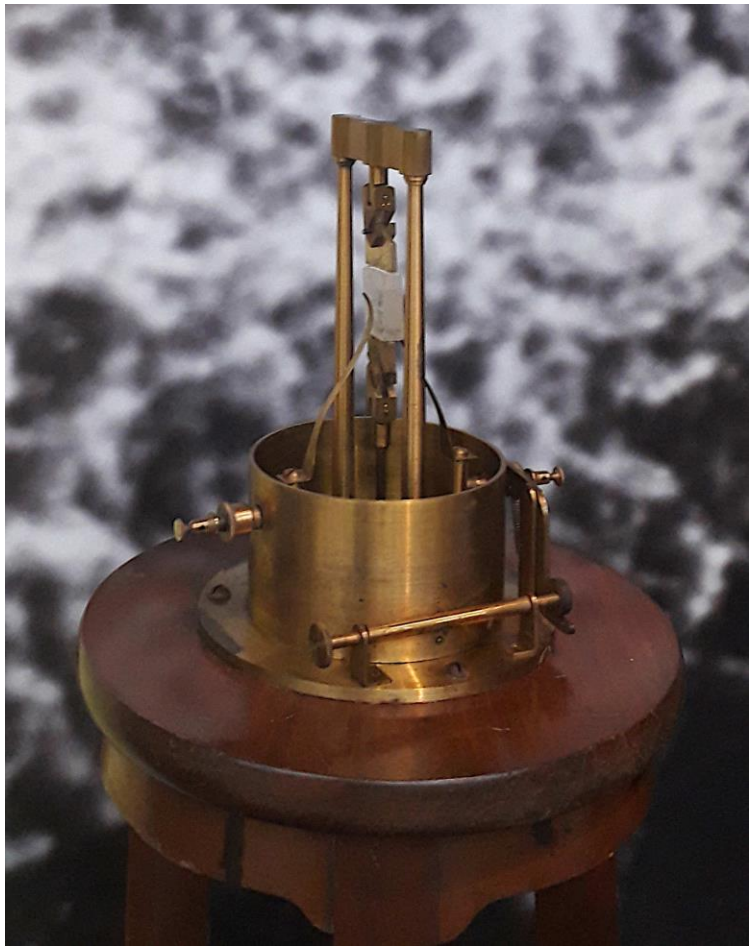
Wu et al. (2021)

Materiais Piezoelétricos – Desafios



Materiais Piezoelétricos – Aplicações

Eletrômetro de Quartzo (1898)

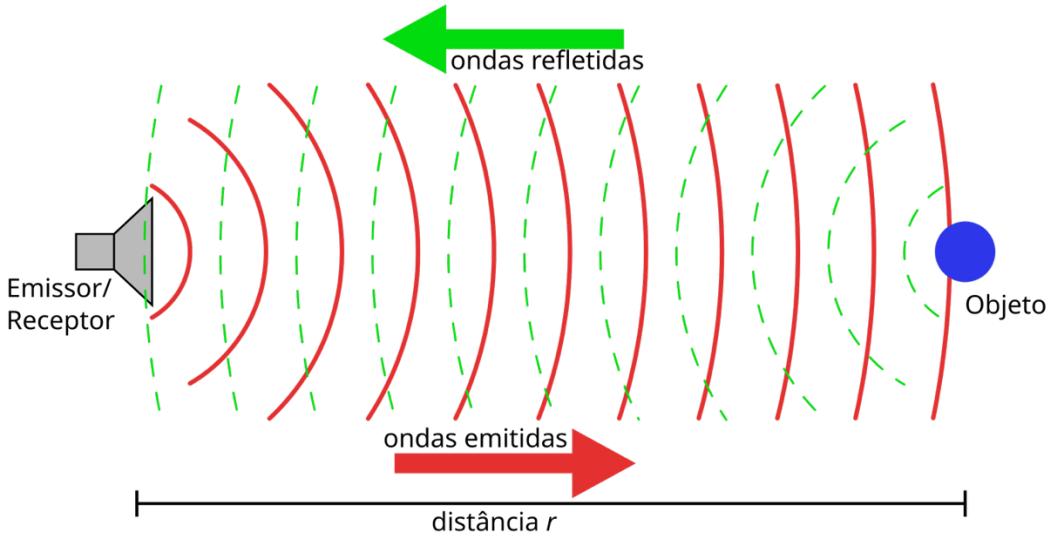


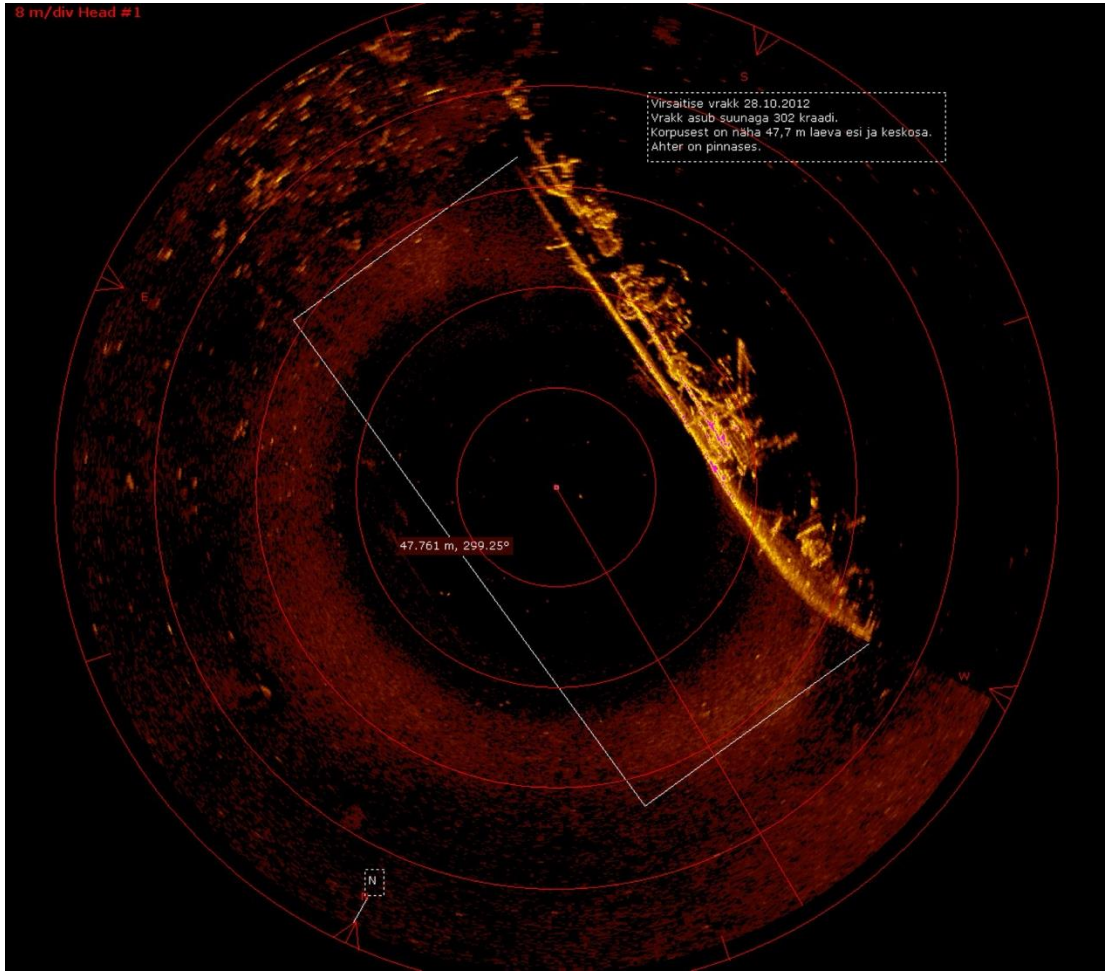
Po

Ra

Materiais Piezoelétricos – Aplicações

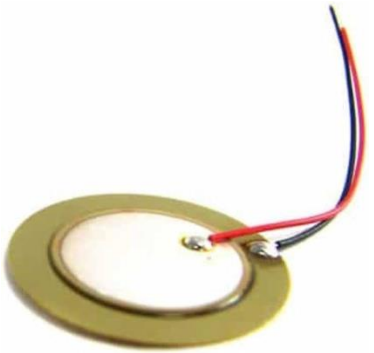
Sonar – Primeira Guerra Mundial (1917)

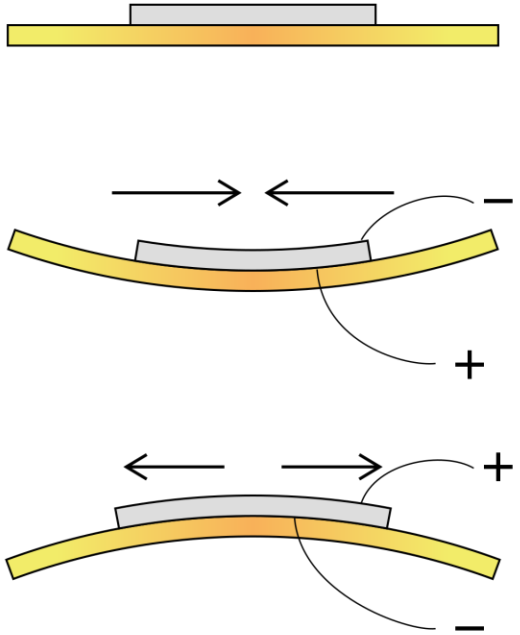




Materiais Piezoelétricos – Atuadores e Sensores

Fonógrafo, Captadores e Emissor de Sons





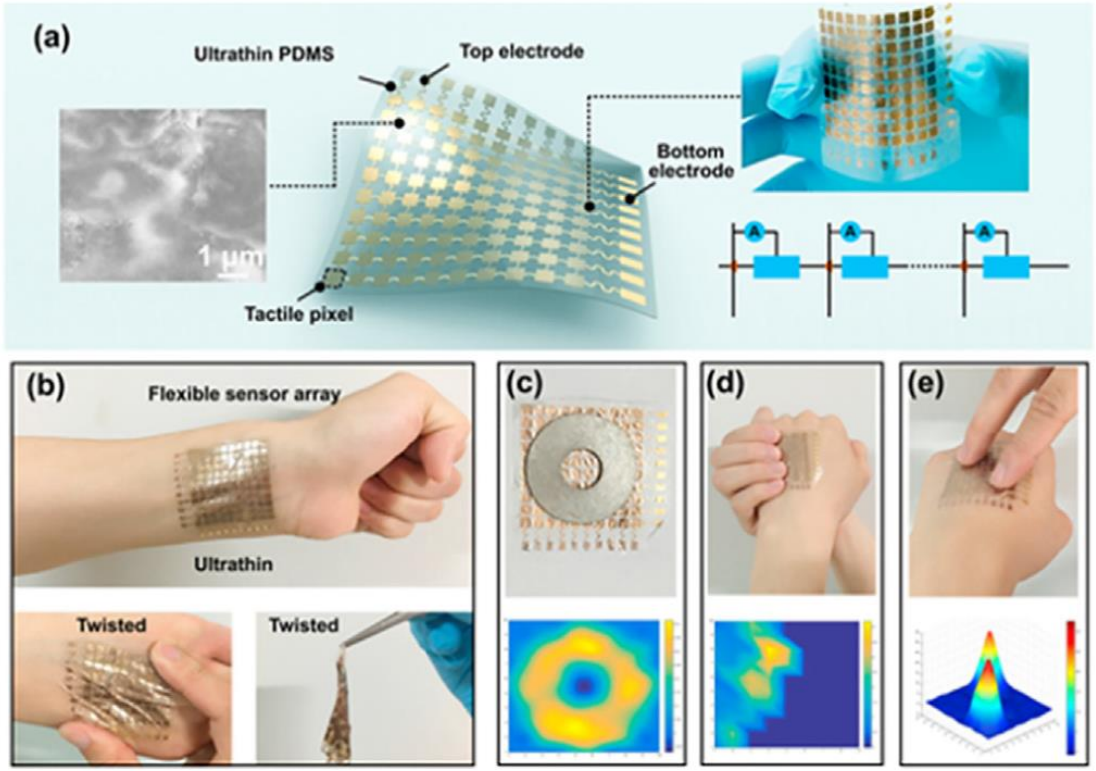
Materiais Piezoelétricos – Atuadores e Sensores

Isqueiro Piezoelétrico

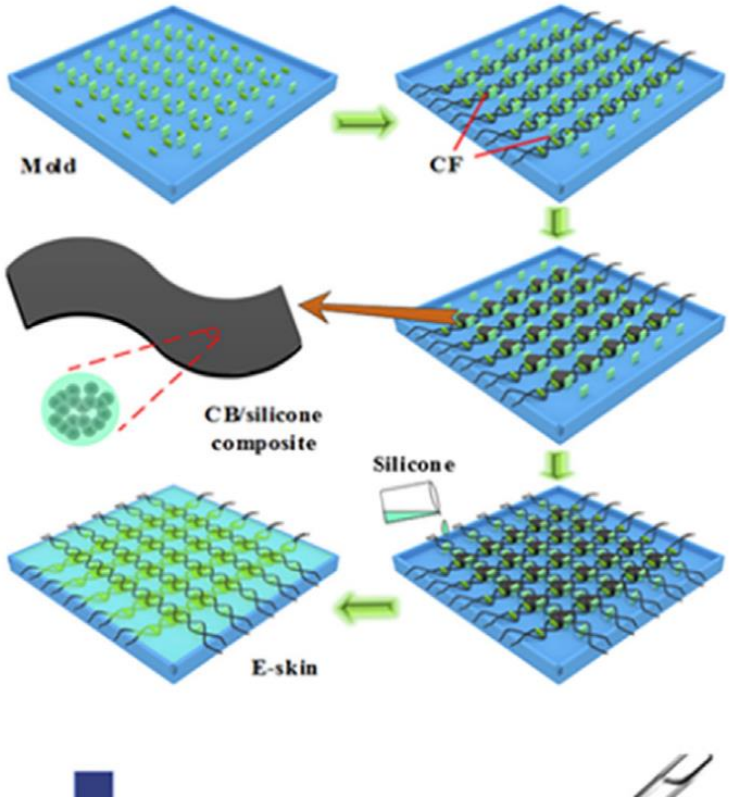
Materiais Piezoelétricos – Atuadores e Sensores

Sensores Flexíveis

(A)

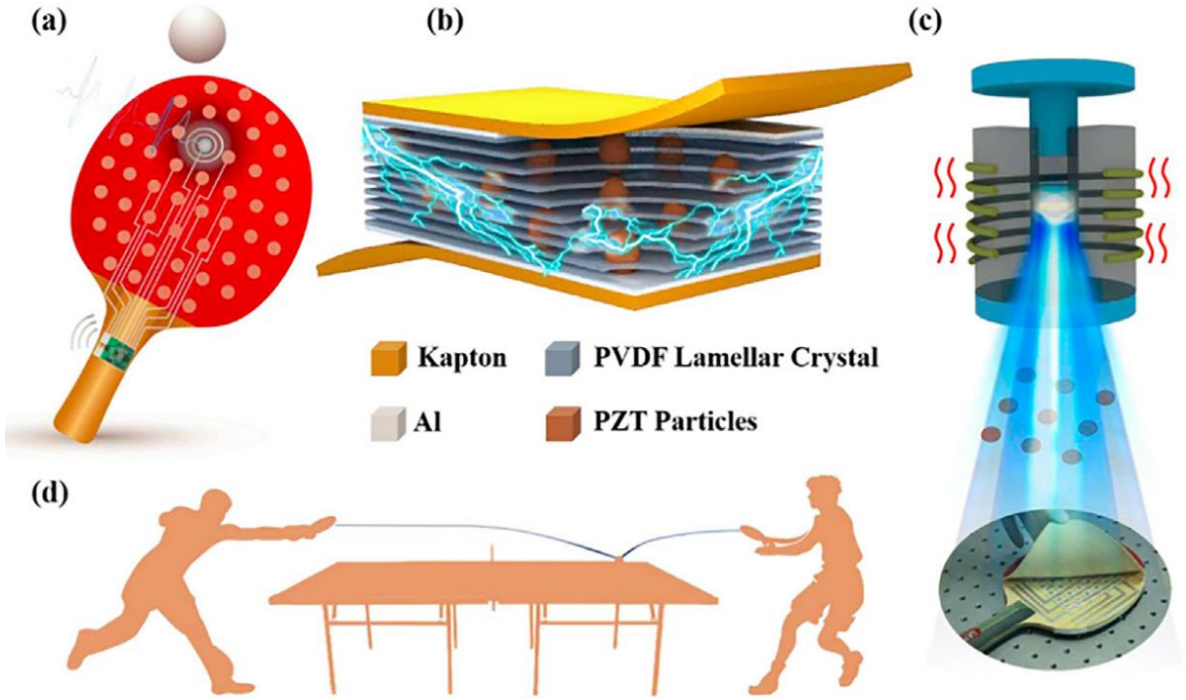


(B)



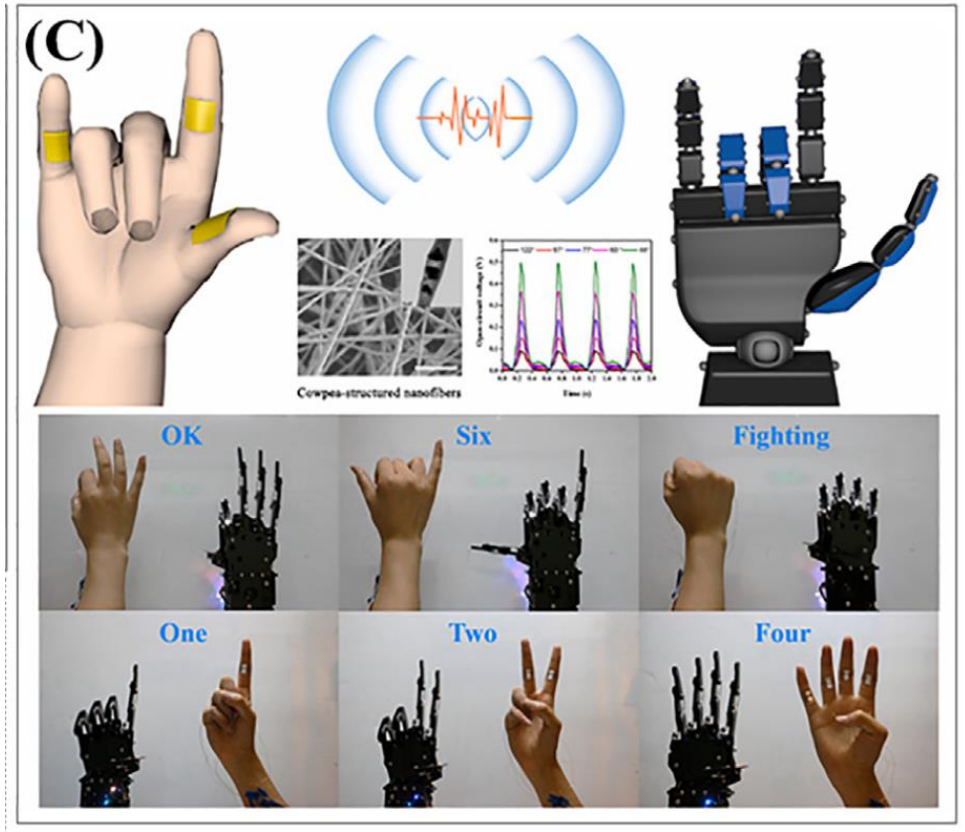
Materiais Piezoelétricos – Atuadores e Sensores

Sistema de Treinamento Inteligente



Tian et al. (2019)

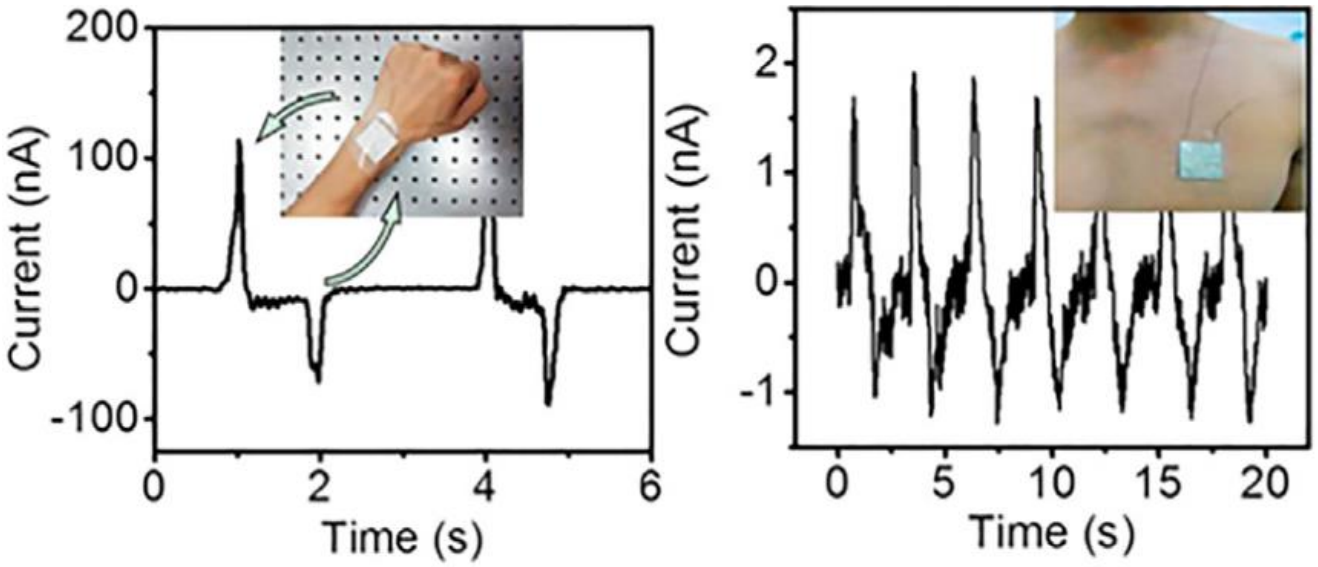
Controlador por Realimentação (Feedback)



Deng et al. (2019)

Materiais Piezoelétricos – Atuadores e Sensores

Sensores Biométrico – Monitoramento Fisiológico

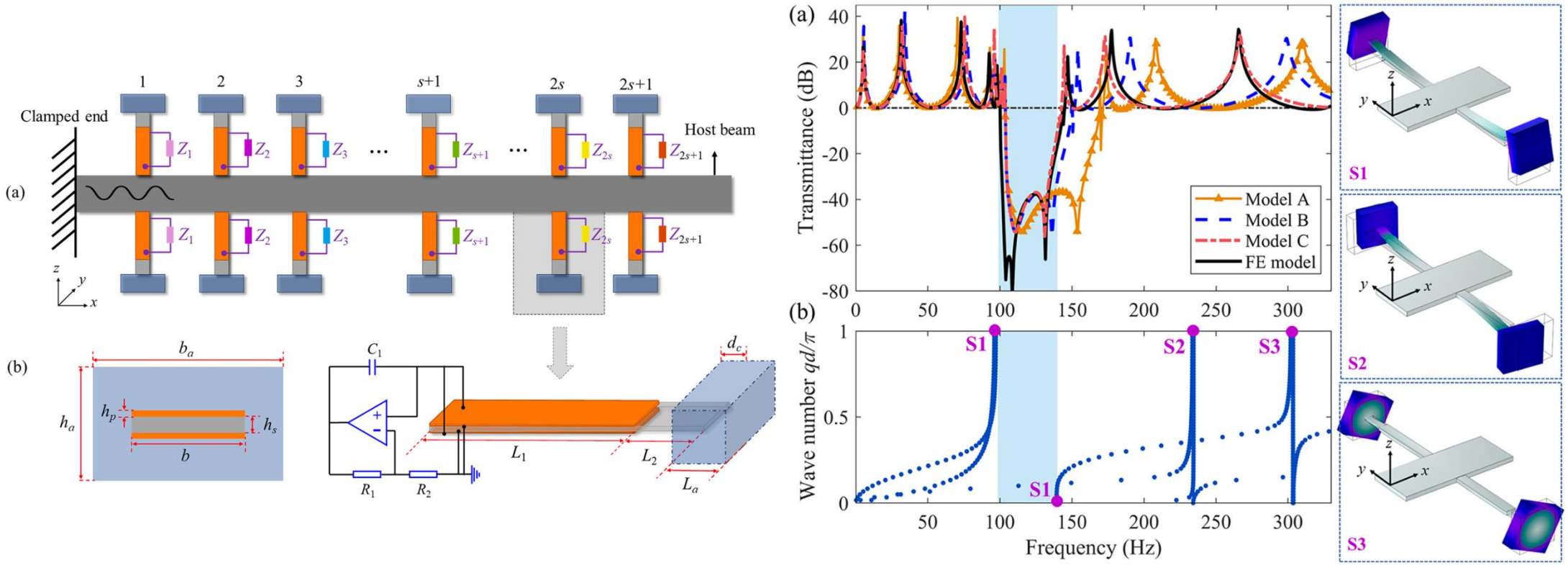


Wang et al. (2017)

Controle tátil

Materiais Piezoelétricos – Controle e Atenuação de Vibração

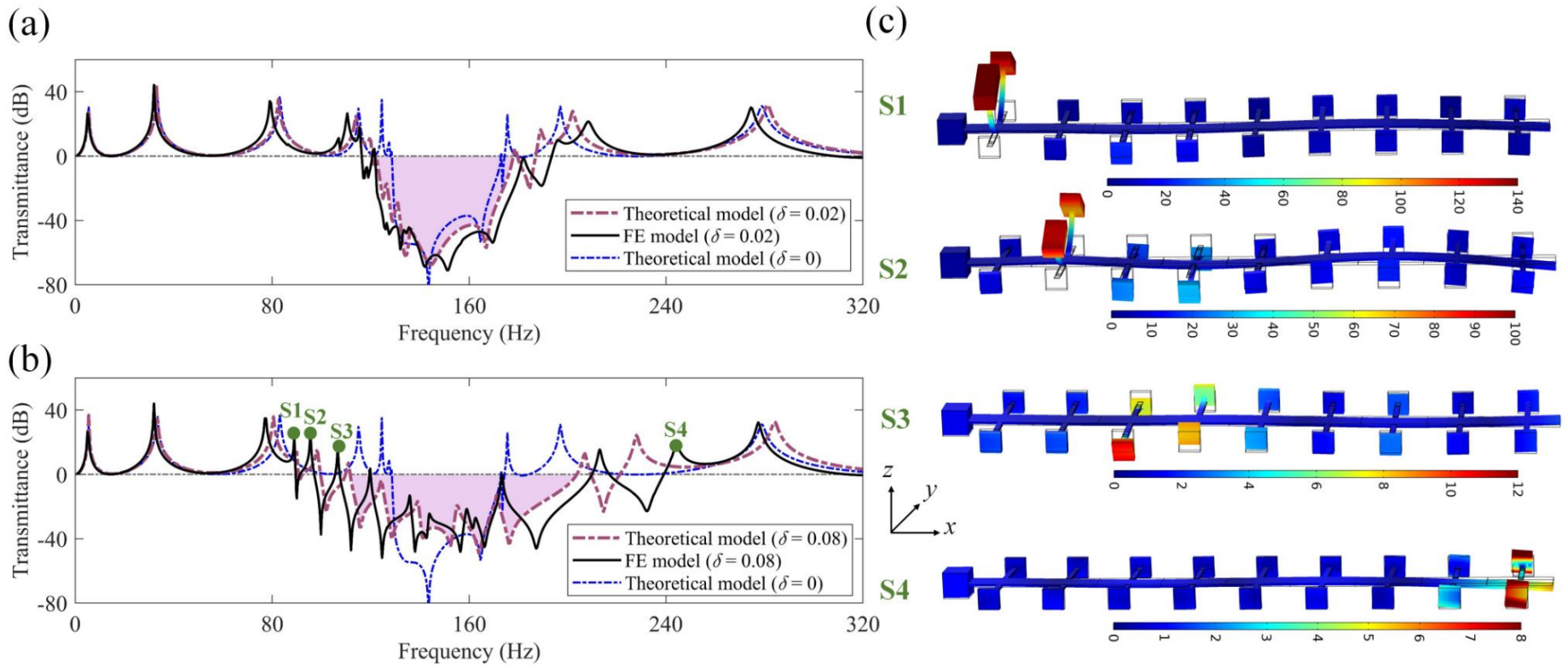
Metaestruturas Eletromecânicas



Jian et al. (2024)

Materiais Piezoelétricos – Controle e Atenuação de Vibração

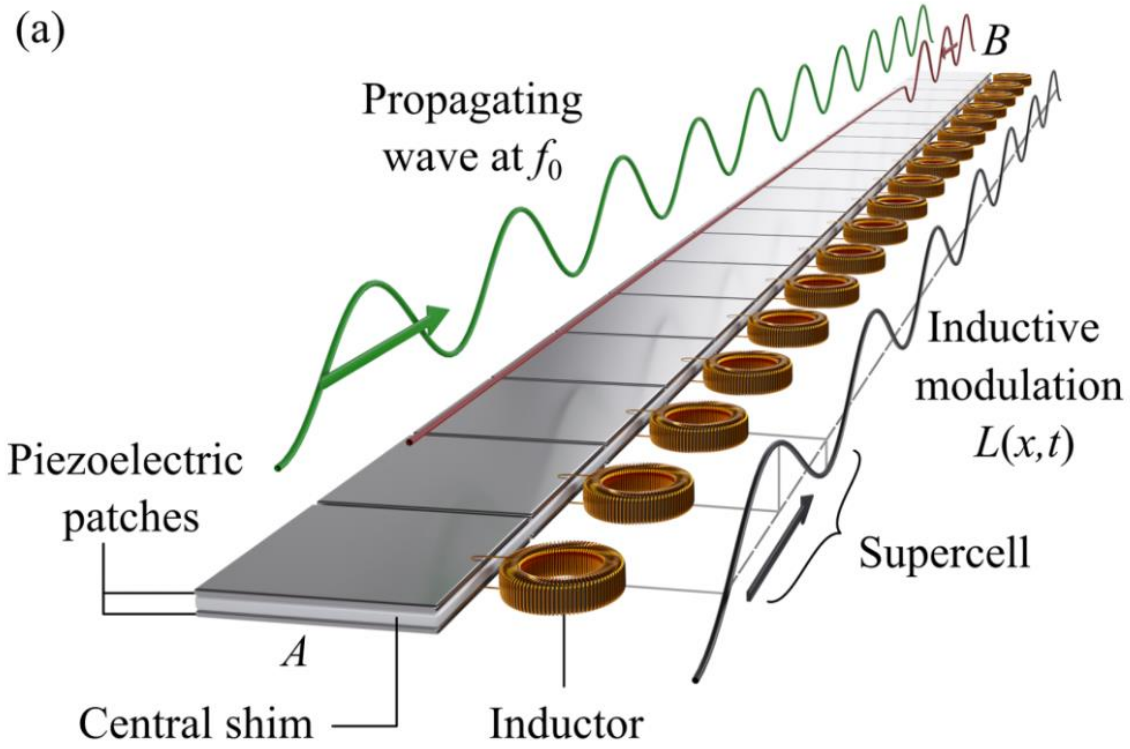
Metaestruturas Eletromecânicas



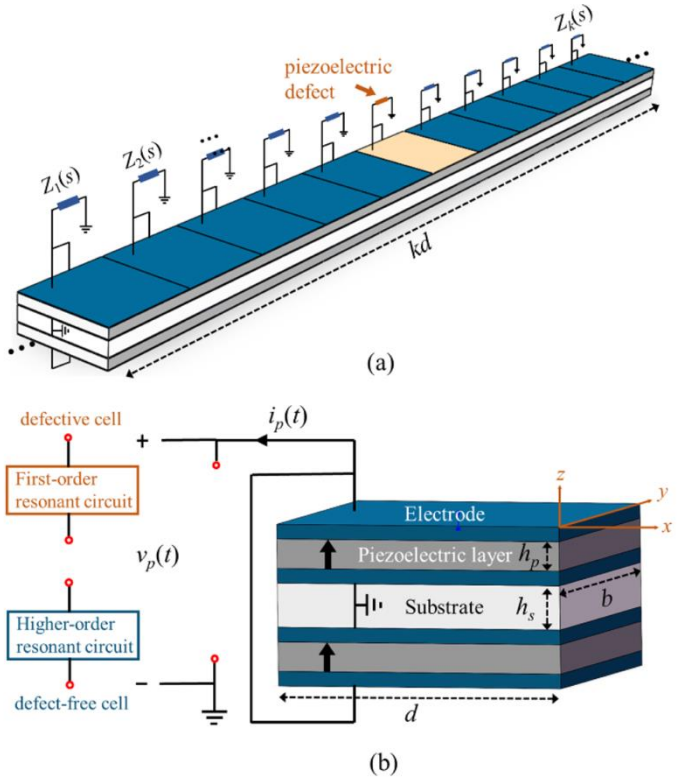
Jian et al. (2024)

Materiais Piezoelétricos – Controle e Atenuação de Vibração

Metaestruturas Eletromecânicas



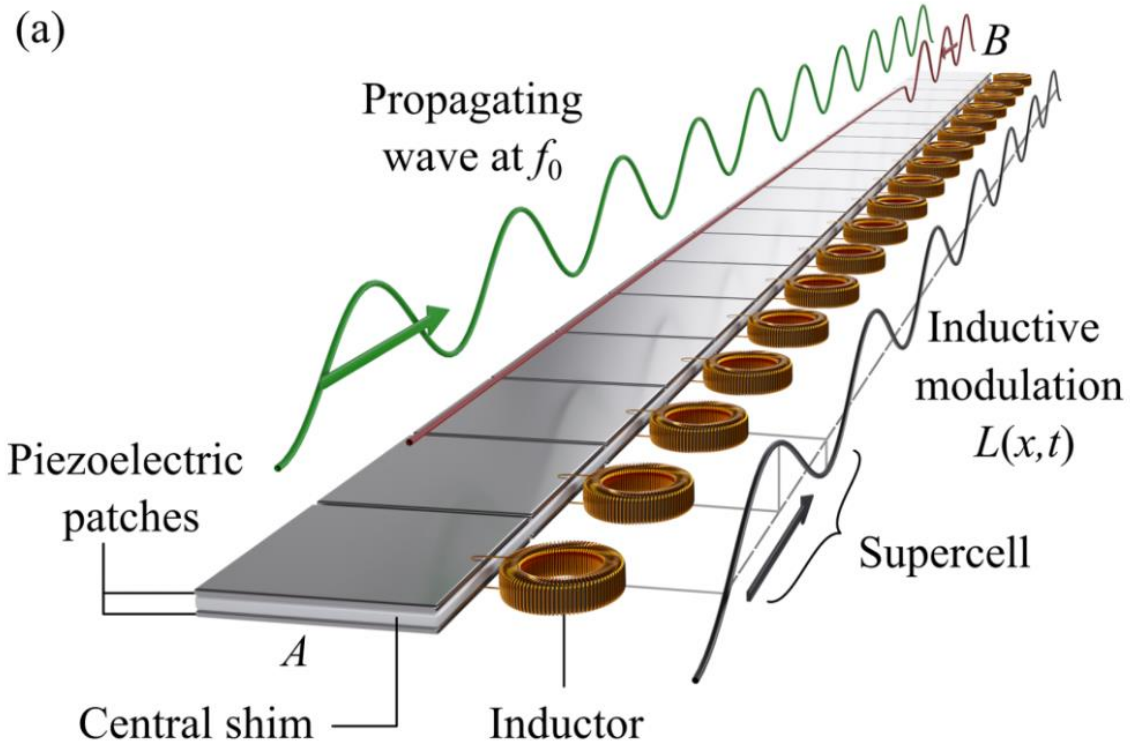
Alshaqaq et al. (2023)



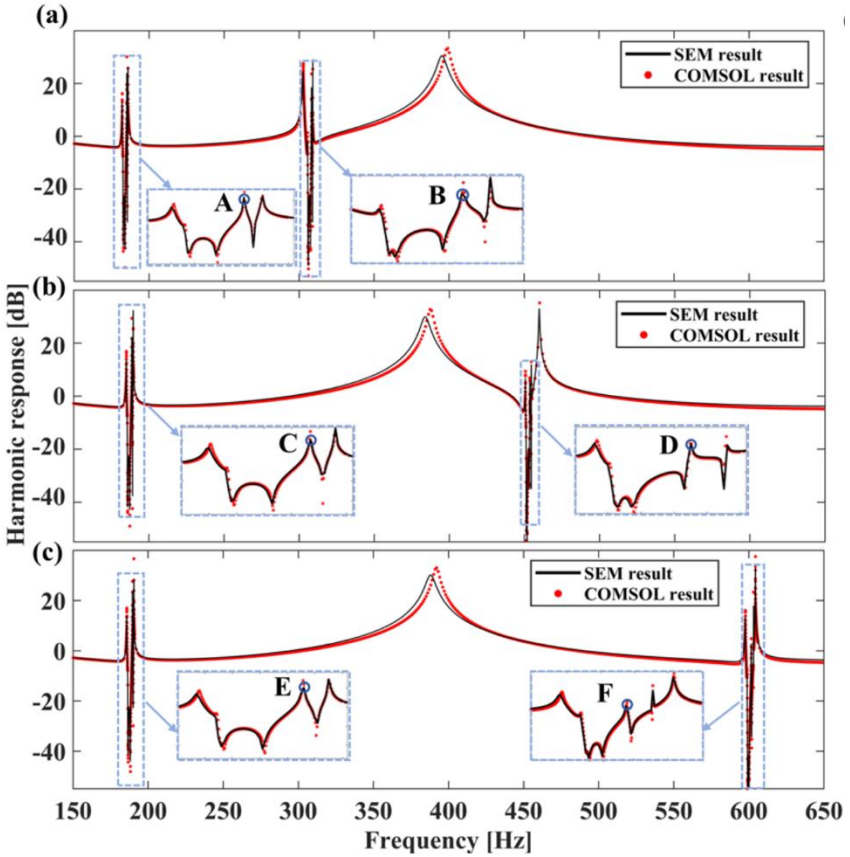
Jian et al. (2025)

Materiais Piezoelétricos – Controle e Atenuação de Vibração

Metaestruturas Eletromecânicas

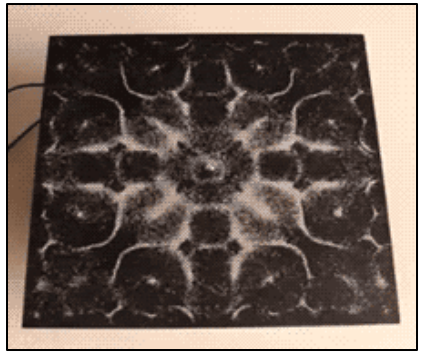


Alshaqaq et al. (2023)



Materiais Piezoelétricos – Colheita de Energia

Fontes de Energia Mecânica



Materiais Piezoelétricos – Colheita de Energia

Fontes de Energia Mecânica

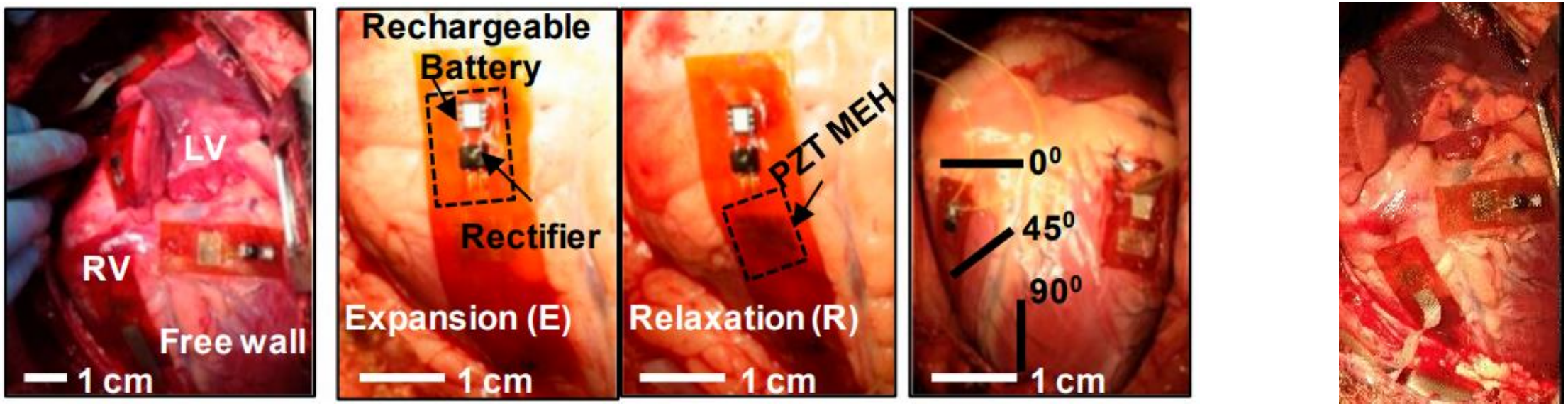
Materiais Piezoelétricos – Colheita de Energia

Infraestrutura Civil

Erturk (2011) | Peigney & Siegert (2013) | Zuo & Tang (2013) | Xiang et al. (2014) | Elhalwagy et al. (2017)
Wang et al. (2018)

Materiais Piezoelétricos – Colheita de Energia

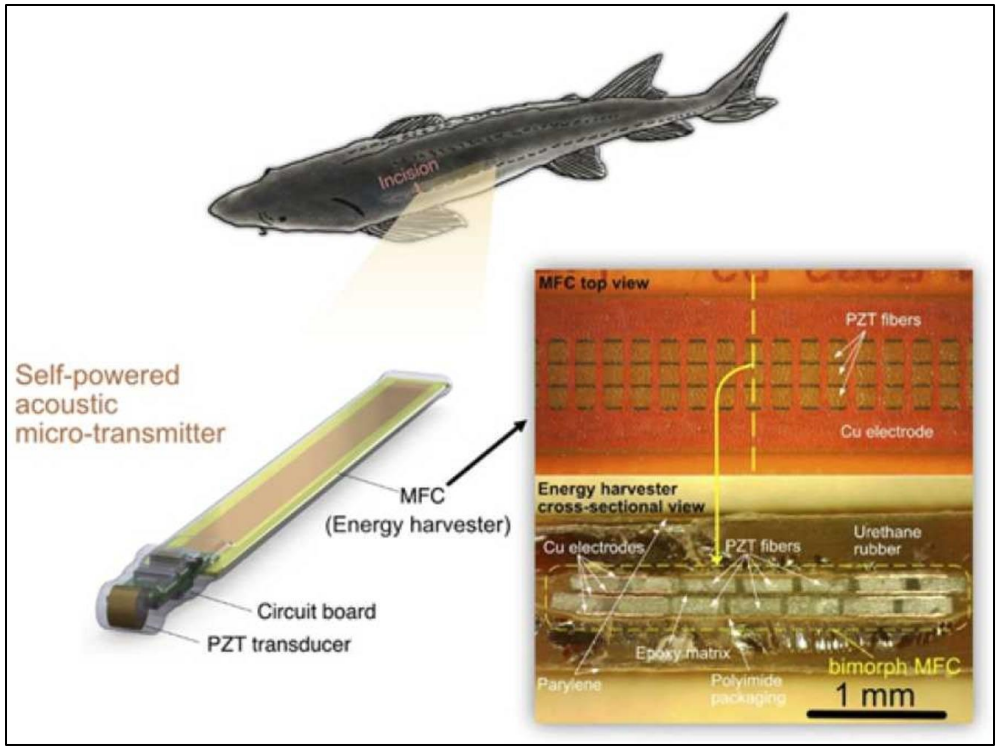
Movimento Biomecânico de Órgãos



Dagdeviren et al. (2014)

Materiais Piezoelétricos – Colheita de Energia

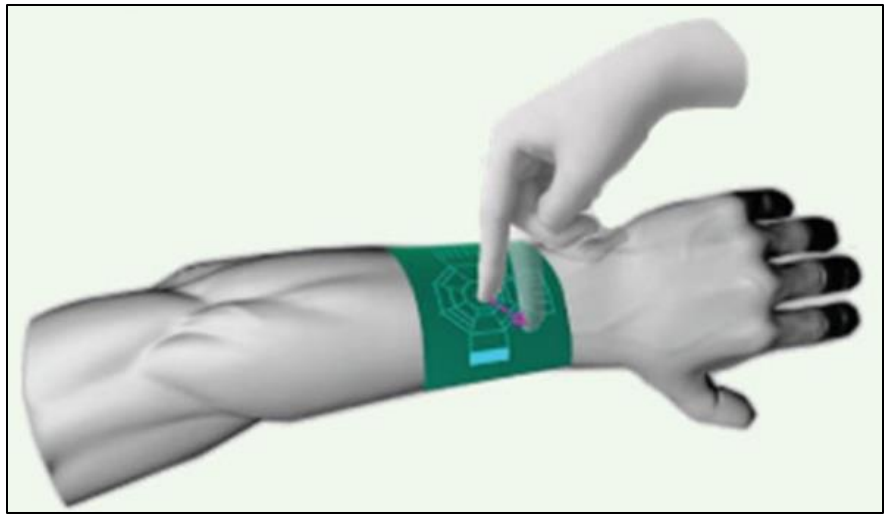
Biologia: Monitoramento de Vida Selvagem

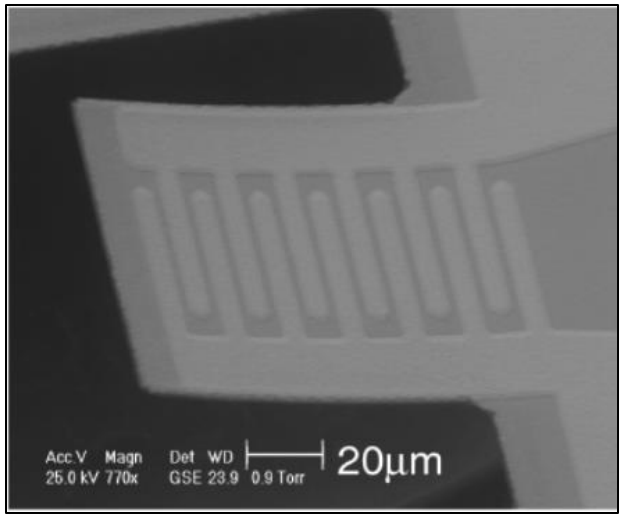


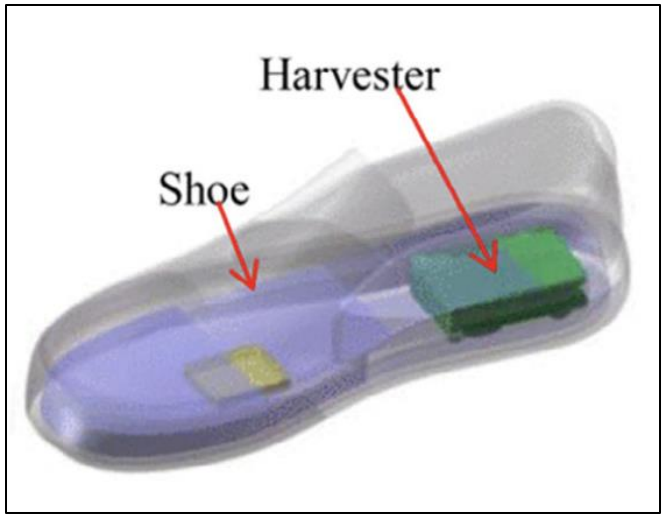
Reissman et al. (2011) | Aktakka et al. (2011) | Shafter et al. (2015) | Li et al. (2022)

Materiais Piezoelétricos – Colheita de Energia

Sensores Sem Fio Auto-Alimentados, MEMS, Dispositivos Vestíveis

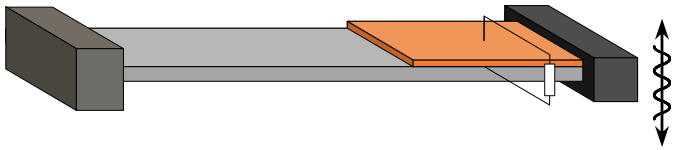




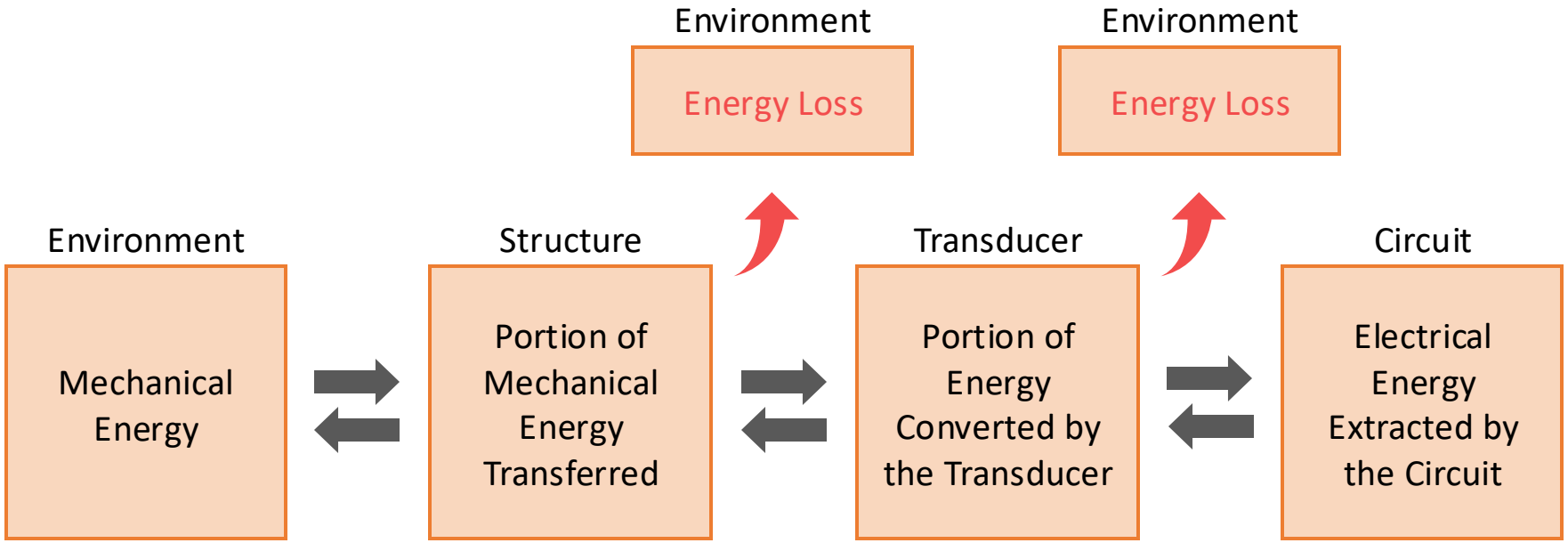


duToit et al. (2006) | Lee and Choi (2014)

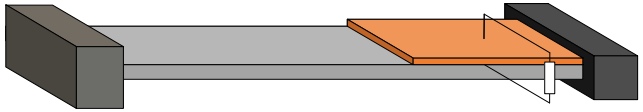
Materiais Piezoelétricos – Colheita de Energia



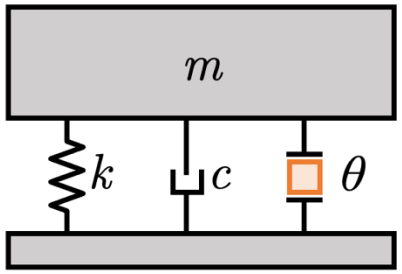
Base Host Structure Transducer Tip Mass Circuit

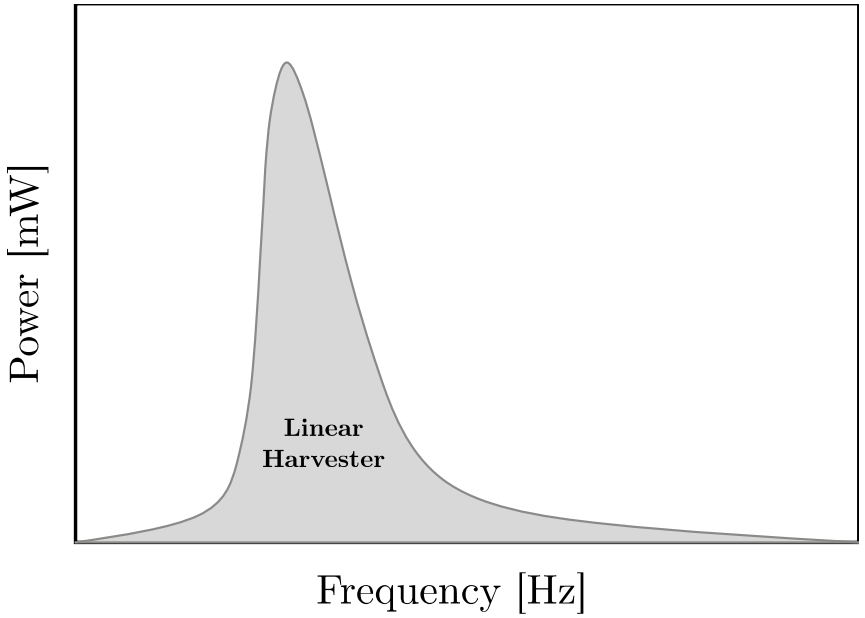


Materiais Piezoelétricos – Colheita de Energia

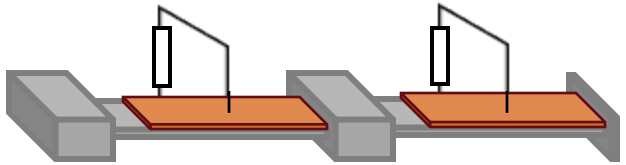


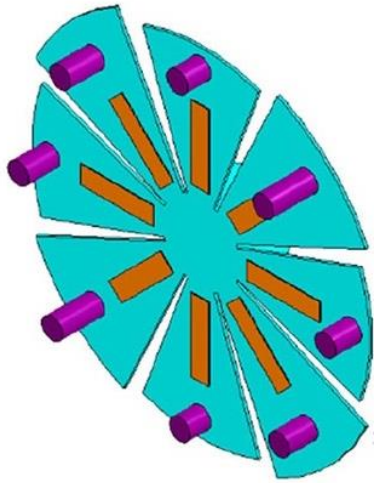
Base Host Structure Transducer Tip Mass Circuit

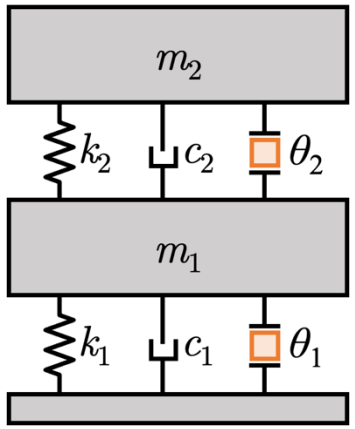


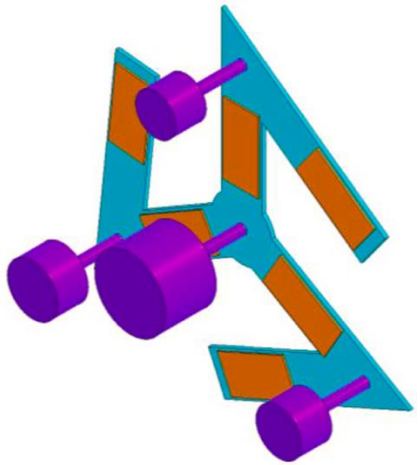


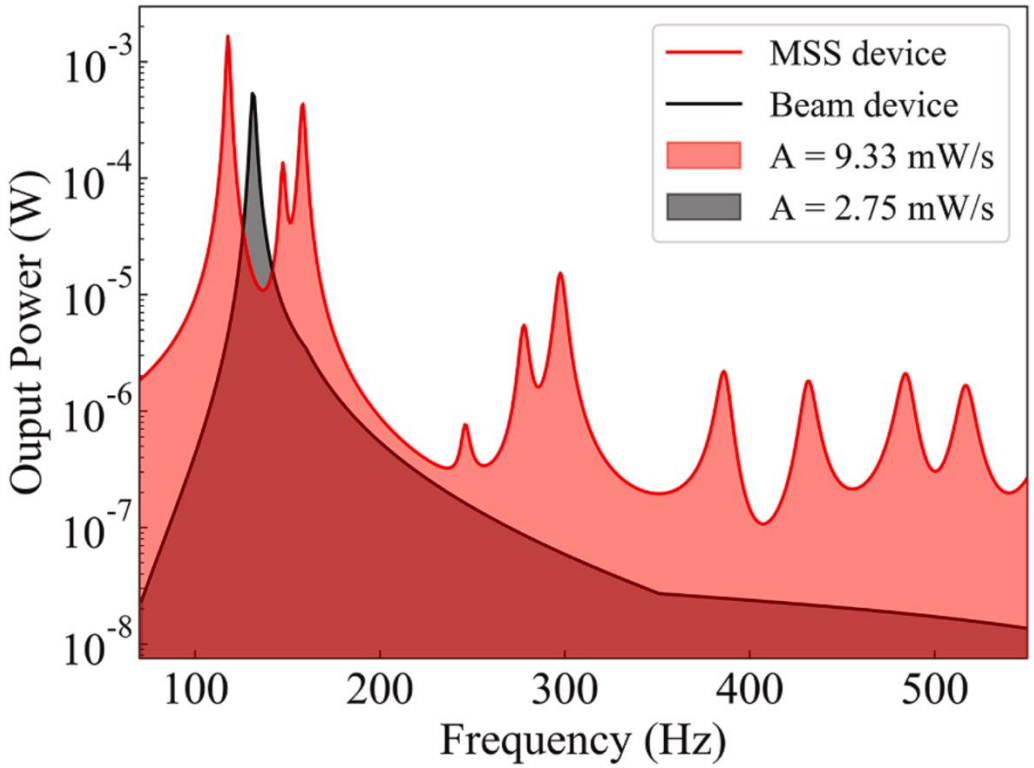
Materiais Piezoelétricos – Colheita de Energia





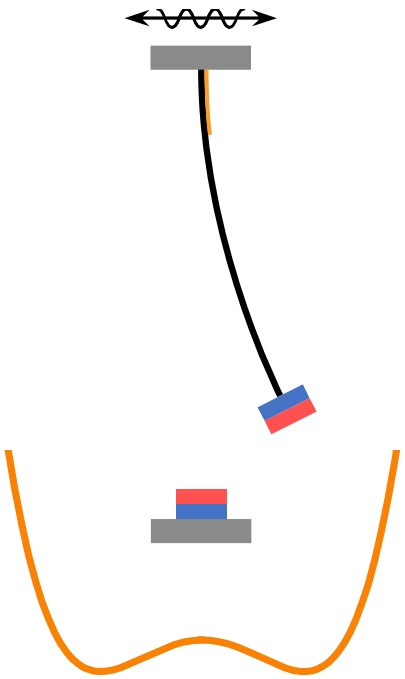




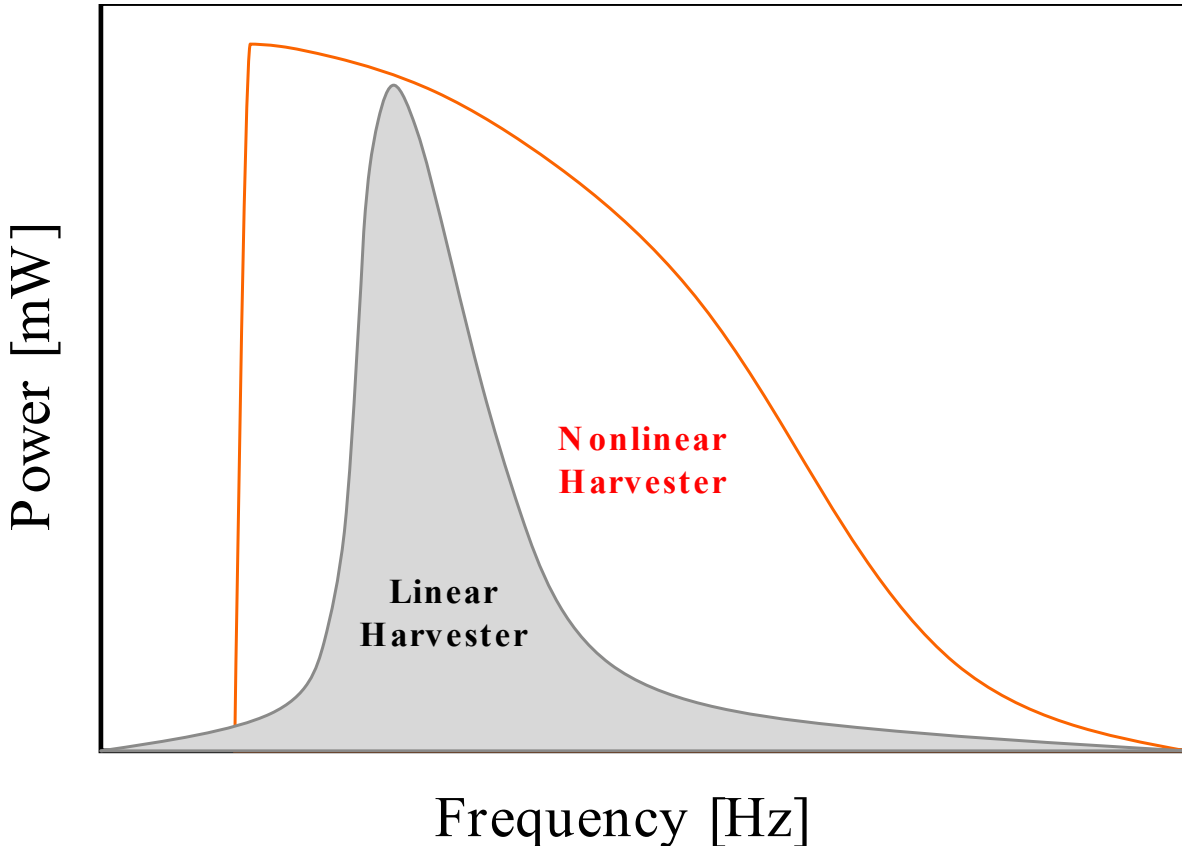


Materiais Piezoelétricos – Colheita de Energia

Sistemas Multiestáveis

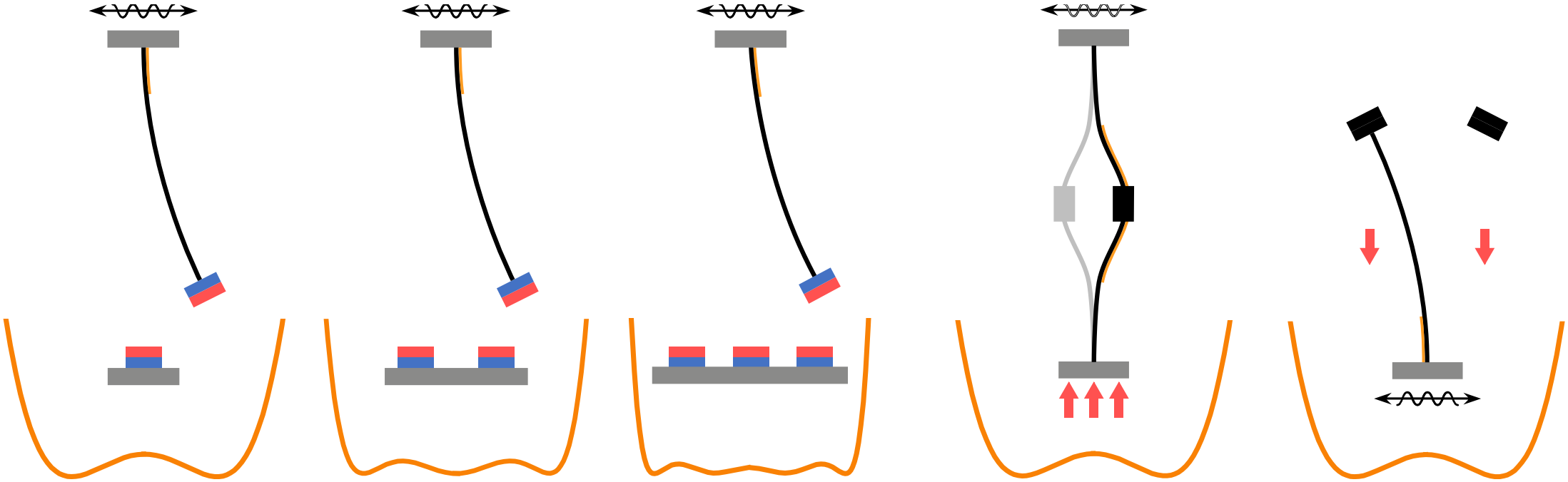


Erturk et al. (2009)



Materiais Piezoelétricos – Colheita de Energia

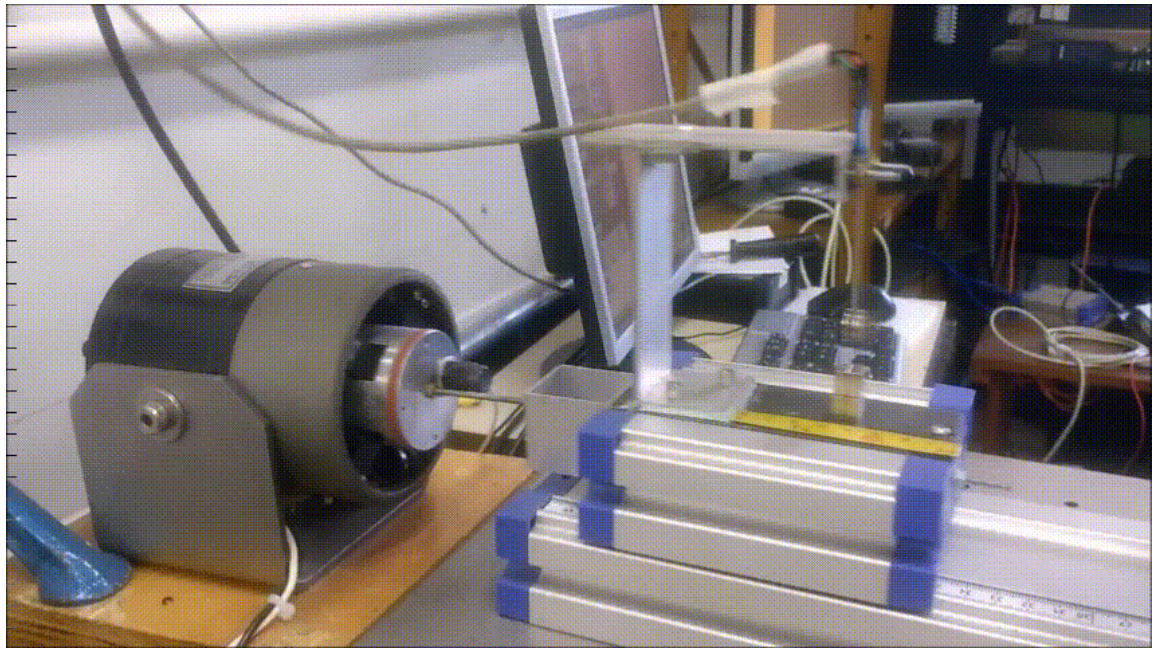
Sistemas Multiestáveis



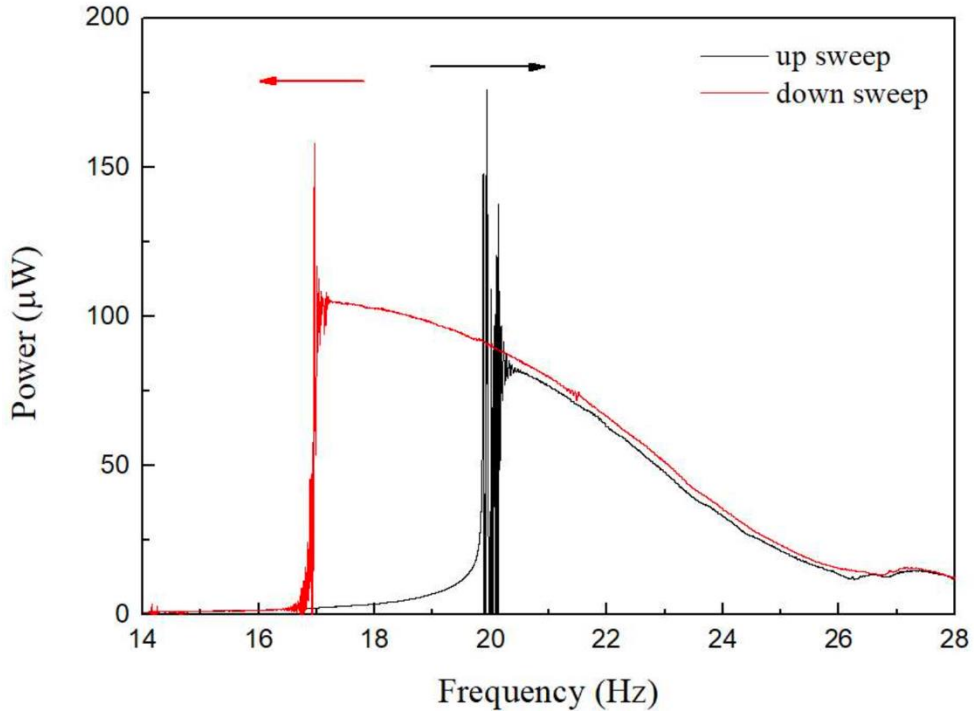
Erturk et al. (2009) | Kumar et al. (2015) | Zhou et al. (2017) | Masana & Daqaq (2011) | Friswell et al. (2012)

Materiais Piezoelétricos – Colheita de Energia

Sistemas Multiestáveis



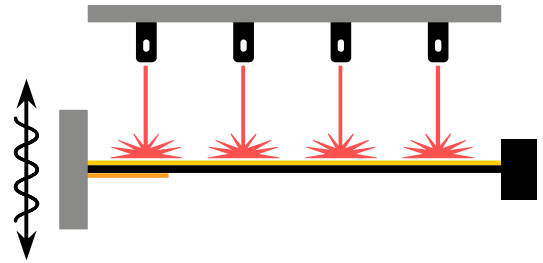
Borges et al. (2019)



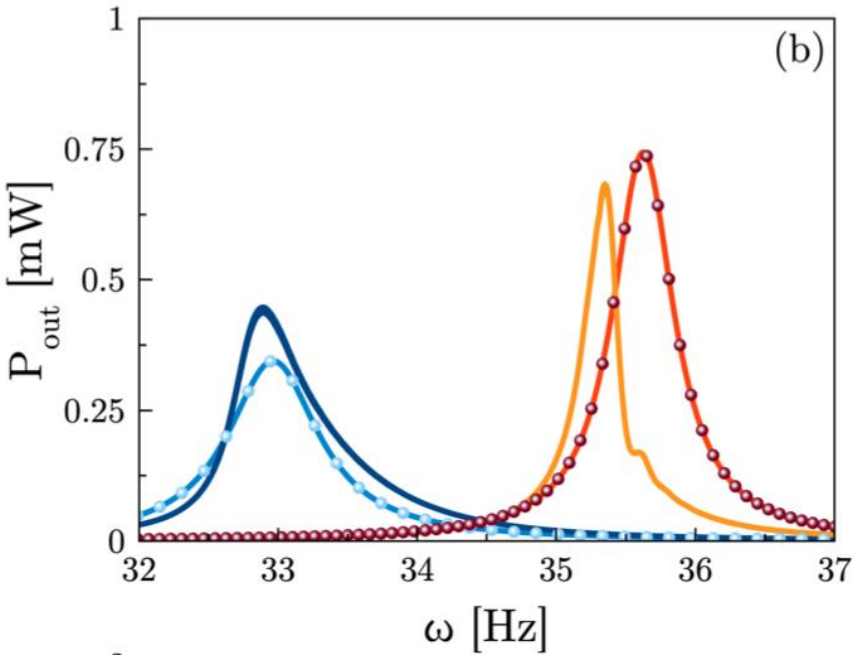
Materiais Piezoelétricos – Colheita de Energia

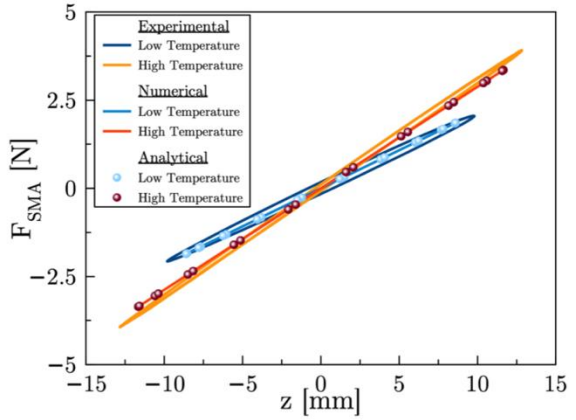
Sistemas Adaptativos

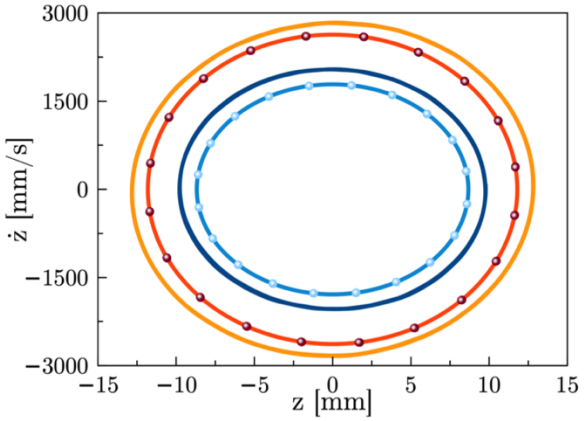
Adeodato et al. (2021)



Yuan et al. (2019)

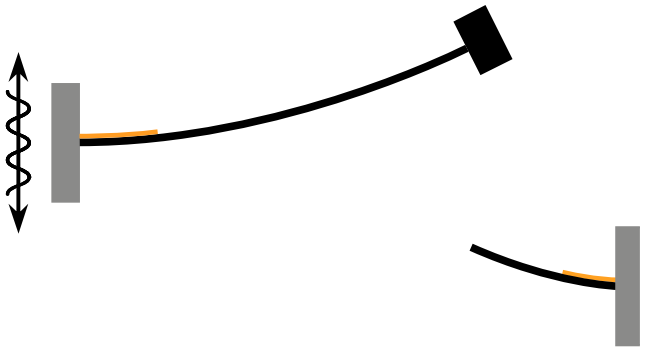




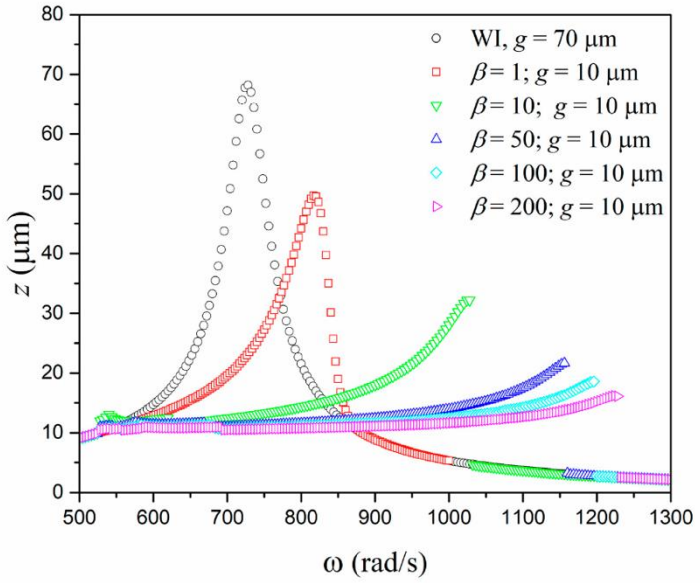


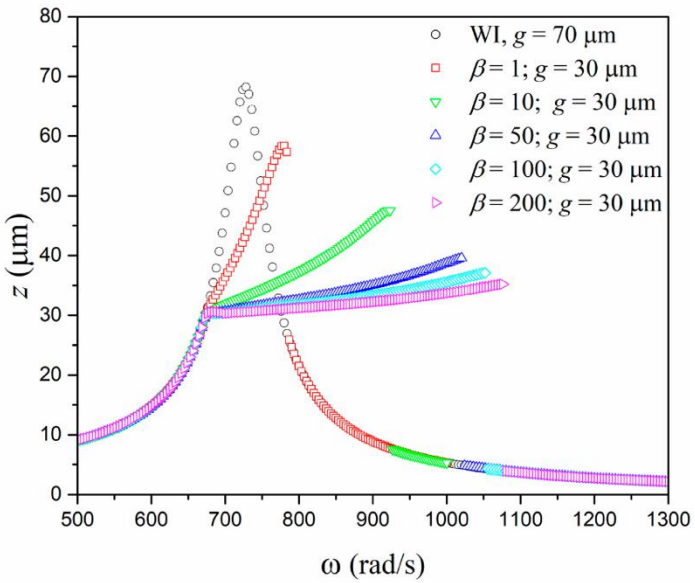
Materiais Piezoelétricos – Colheita de Energia

Sistemas Não-Suaves



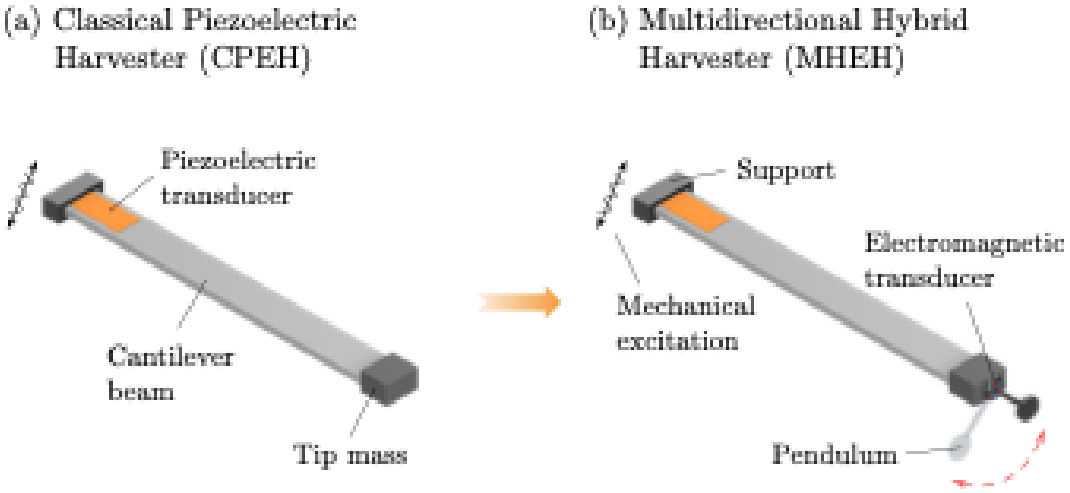
Ai et al. (2019)

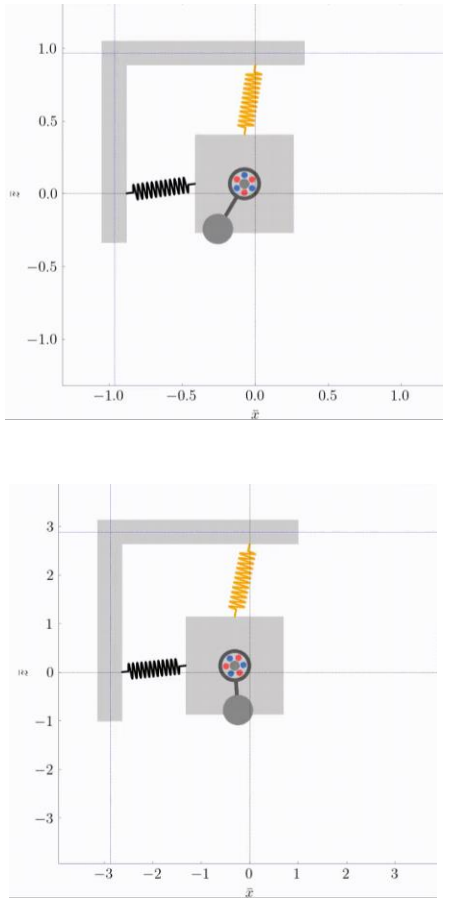


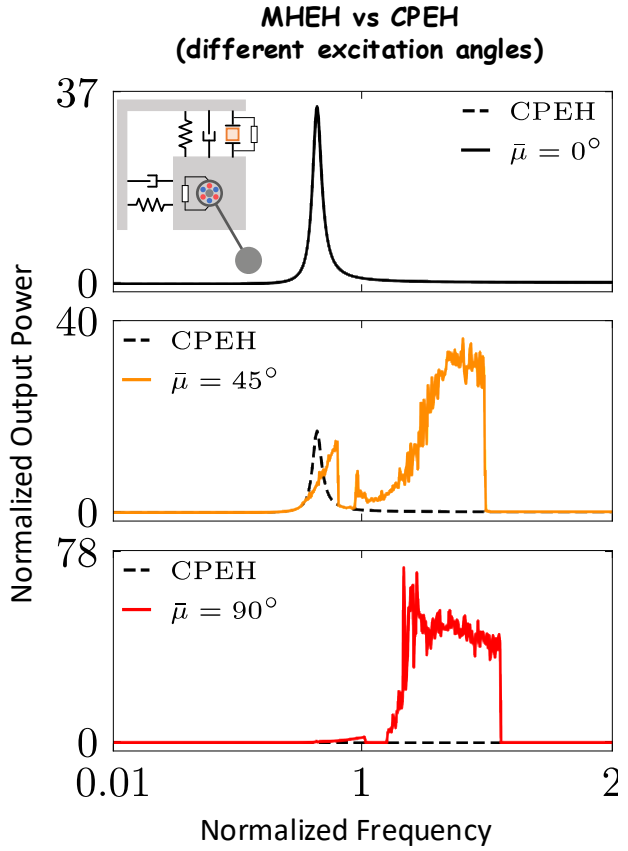


Materiais Piezoelétricos – Colheita de Energia

Sistemas com Estratégias de Melhoria Híbrida

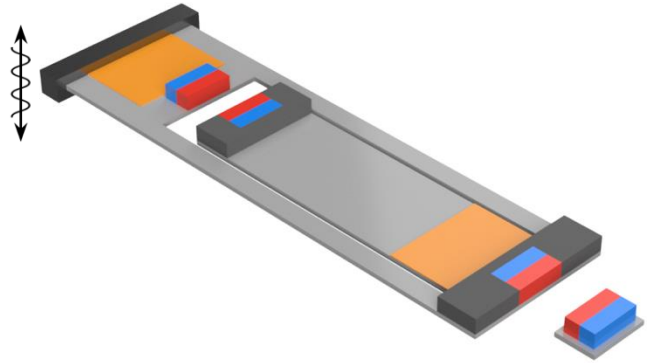


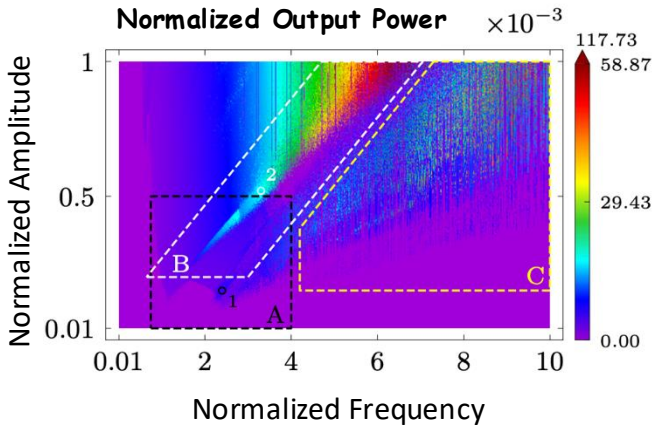


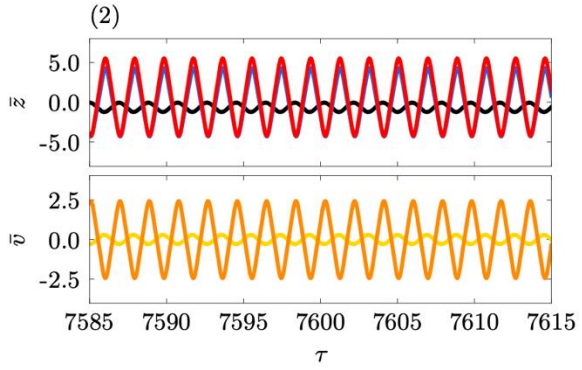


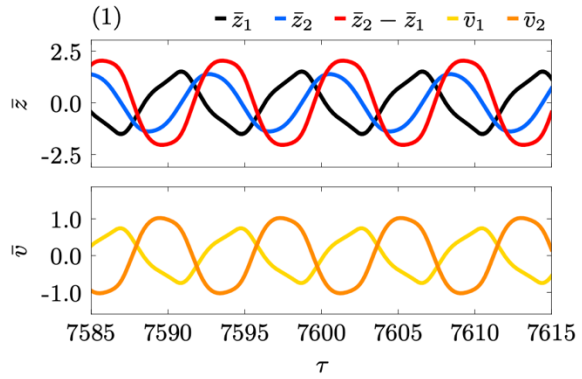
Materiais Piezoelétricos – Colheita de Energia

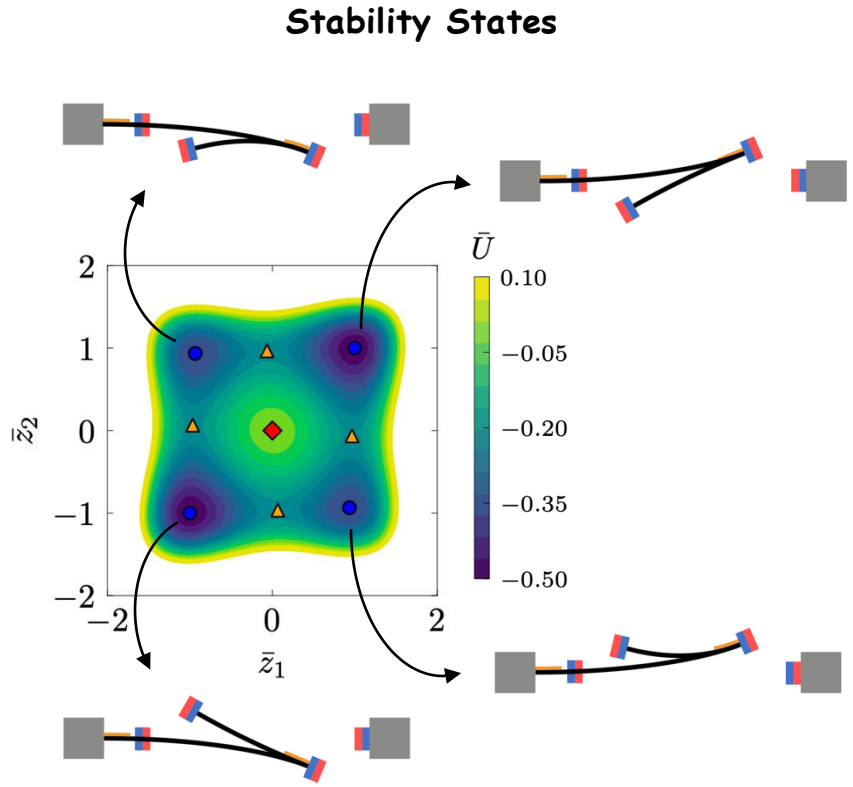
Sistemas com Estratégias Híbridas de Melhoria



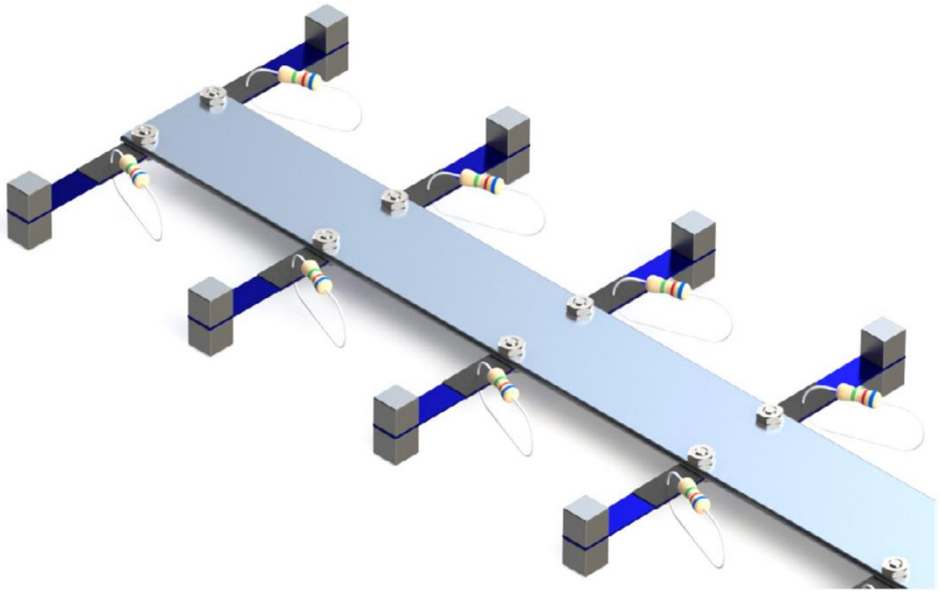




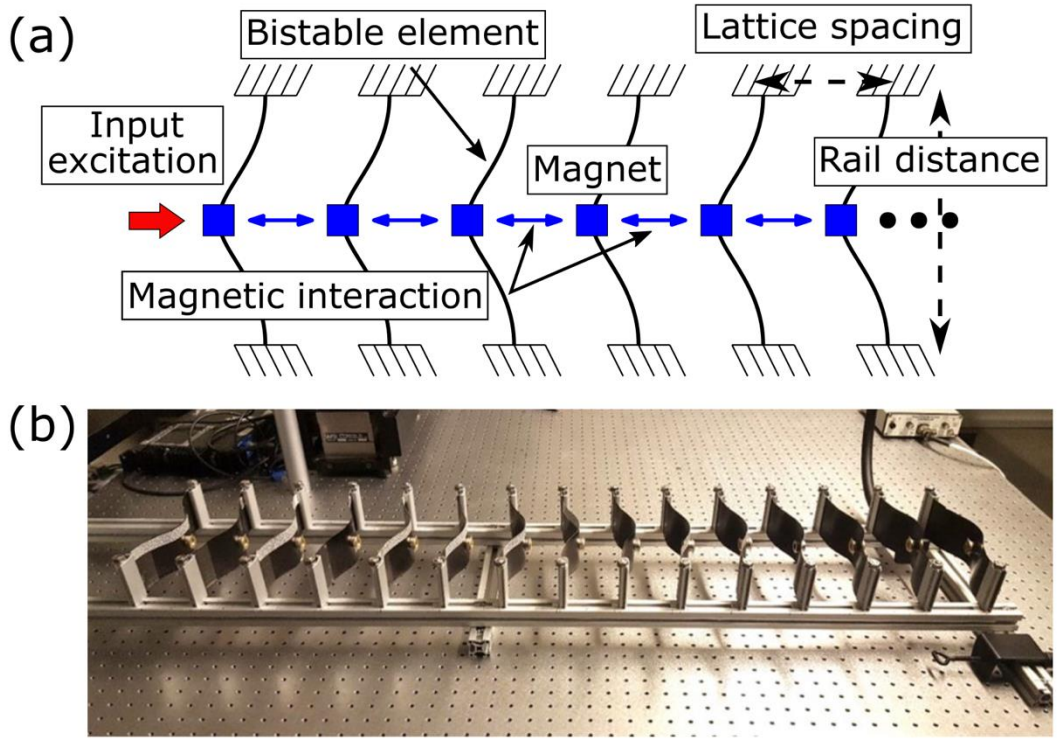




Materiais Piezoelétricos – Sistemas Multifuncionais



Sugino & Erturk (2018)



Hwang & Arrieta (2018)