NONLINEAR MICROWAVE IMPEDANCE MICROSCOPY

Tech ID: 33962 / UC Case 2025-102-0

PATENT STATUS

Patent Pending

BRIEF DESCRIPTION

Microwave impedance microscopy (MIM) is an emerging scanning probe technique that enables non-contact, nanoscale measurement of local complex permittivity. By integrating an ultrasensitive, phase-resolved microwave sensor with a near-field probe, MIM has made significant contributions to diverse fundamental and applied fields. These include strongly correlated and topological materials, two-dimensional and biological systems, as well as semiconductor, acoustic, and MEMS devices. Concurrently, notable progress has been made in refining the MIM technique itself and broadening its capabilities. However, existing literature has focused exclusively on linear MIM based on homodyne architectures, where reflected or transmitted microwave is demodulated and detected at the incident frequency. As such, linear MIM lacks the ability to probe local electrical nonlinearity, which is widely present, for example, in dielectrics, semiconductors, and superconductors. Elucidating such nonlinearity with nanoscale spatial resolution would provide critical insights into semiconductor processing and diagnostics as well as fundamental phenomena like local symmetry breaking and phase separation.

To address this shortcoming, UC Berkeley researchers have introduced a novel methodology and apparatus for performing multi-harmonic MIM to locally probe electrical nonlinearities at the nanoscale. The technique achieves unprecedented spatial and spectral resolution in characterizing complex materials. It encompasses both hardware configurations enabling multi-harmonic data acquisition and the theoretical and calibration protocols to transform raw signals into accurate measures of intrinsic nonlinear permittivity and conductivity. The advance extends existing linear MIM into the nonlinear domain, providing a powerful, versatile, and minimally invasive tool for semiconductor diagnostics, materials research, and device development.

SUGGESTED USES

- Minimally invasive measurement of intrinsic nonlinear permittivity and conductivity
- Semiconductor diagnostics, materials research, and device development

ADVANTAGES

- Sensitive to local electrical nonlinearity in dielectrics, semiconductors, and superconductors
- Nanoscale spatial and high spectral resolution

RELATED MATERIALS

- Amogh Yogesh Waghmare, Joshua Bromley, Jun-Yi Shan, Eric Y. Ma; Nonlinear response of microwave impedance microscopy. Appl. Phys. Lett. 31 March 2025; 126 (13): 133505.

CONTACT

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INVENTORS

- Ma, Yue "Eric"

OTHER INFORMATION

CATEGORIZED AS

- **Optics and Photonics**
  - All Optics and Photonics
- **Energy**
  - Other
  - Storage/Battery
- **Engineering**
  - Engineering
- **Materials & Chemicals**
  - Electronics Packaging
  - Nanomaterials
  - Other
  - Storage
  - Superconductors
  - Thin Films
- **Nanotechnology**
  - Electronics
  - Materials
  - Other
  - Tools and Devices
- **Research Tools**

- » Other
- » **Security and Defense**
  - » Other
- » **Semiconductors**
  - » Assembly and Packaging
  - » Materials
  - » Other
  - » Processing and Production
  - » Testing
- » **Sensors & Instrumentation**
  - » Other
  - » Physical Measurement
  - » Scientific/Research

RELATED CASES

2025-102-0

ADDITIONAL TECHNOLOGIES BY THESE INVENTORS

- ▶ Resonant Distance Spectroscopic Scanning Probe Microscopy

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