Wireless Three-Dimensional (3D) Nanorod Composite Arrays-Based High-Temperature Surface Acoustic Wave Sensors for Selective Gas Detection through Machine Learning Algorithms

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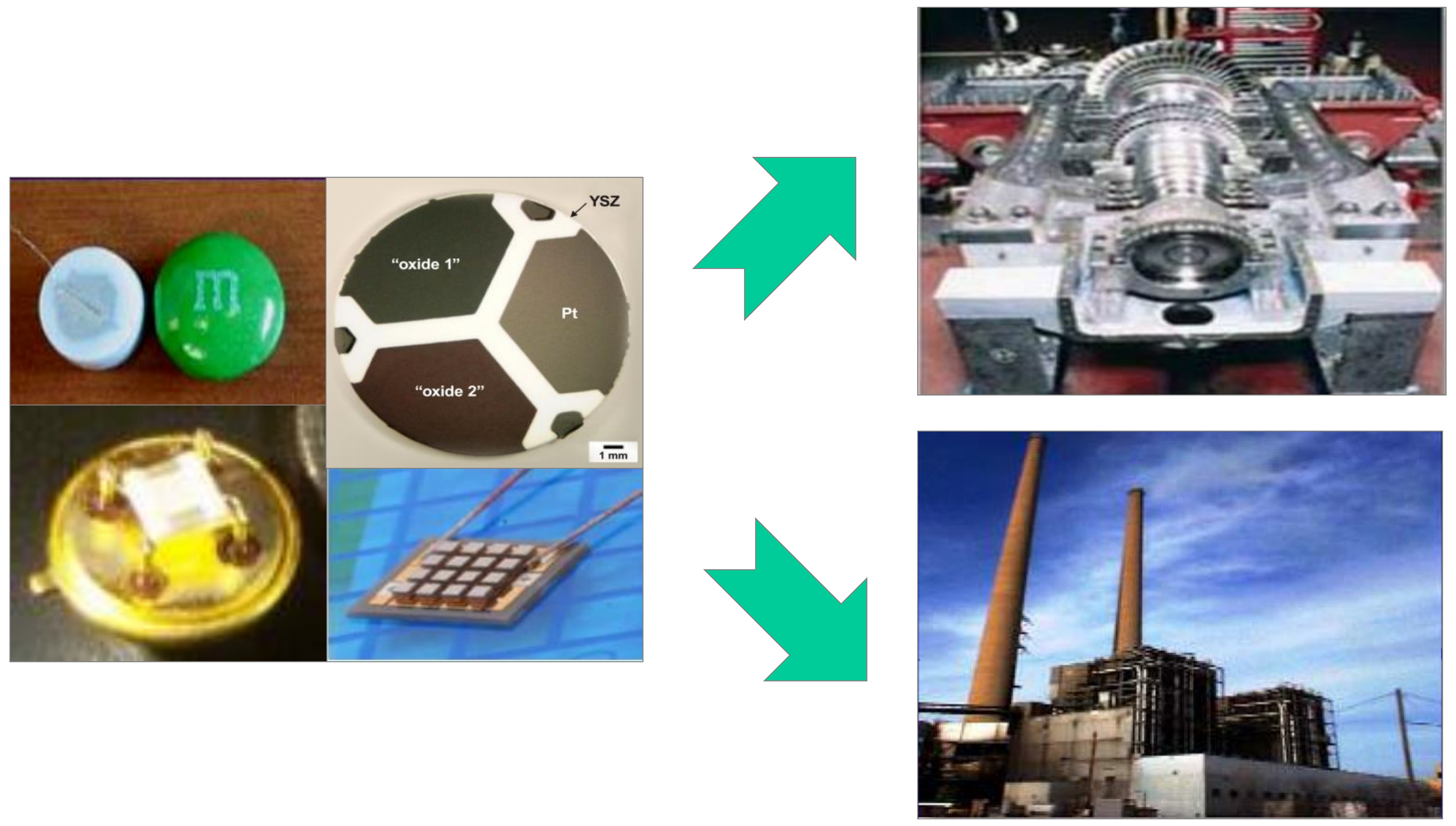
INTRODUCTION

• High-temperature gas sensors have recently garnered significant attention in industrial and research fields as concerns about the environment and energy consumption have been rising.

• Specifically, the demand of wireless high-temperature surface acoustic wave (SAW) sensors has been increasing because they show promising sensing characteristics in harsh environments (e.g., high temperature, high pressure, high levels of radiation, electromagnetic interference, etc.).



OBJECTIVE

• To develop a new class of wireless 3D nanorod composite array-based high temperature surface acoustic wave gas sensors for selective and reliable detection through machine learning algorithms.

STRATEGY

• Combining the concept of a high-temperature stable passive wireless SAW sensor array with novel high-temperature stable perovskite coated three-dimensional (3D) metal oxide nanorod composites as well as machine learning algorithms to achieve highly selective and wireless detection of both gas species and concentration in a high temperature mixed gases environment.

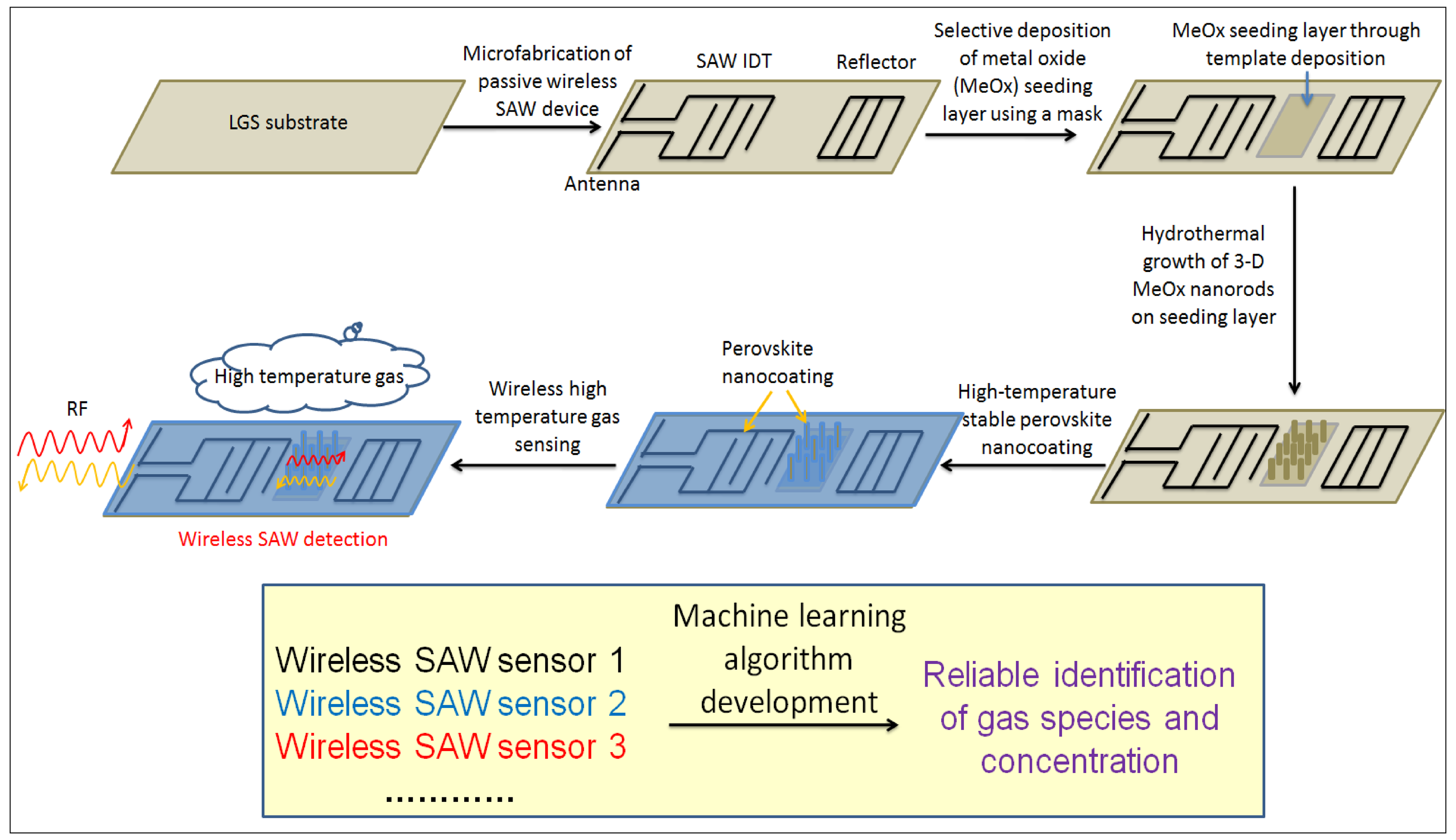


Fig.1. The proposed wireless high-temperature SAW gas sensors arrays with machine learning algorithm development.

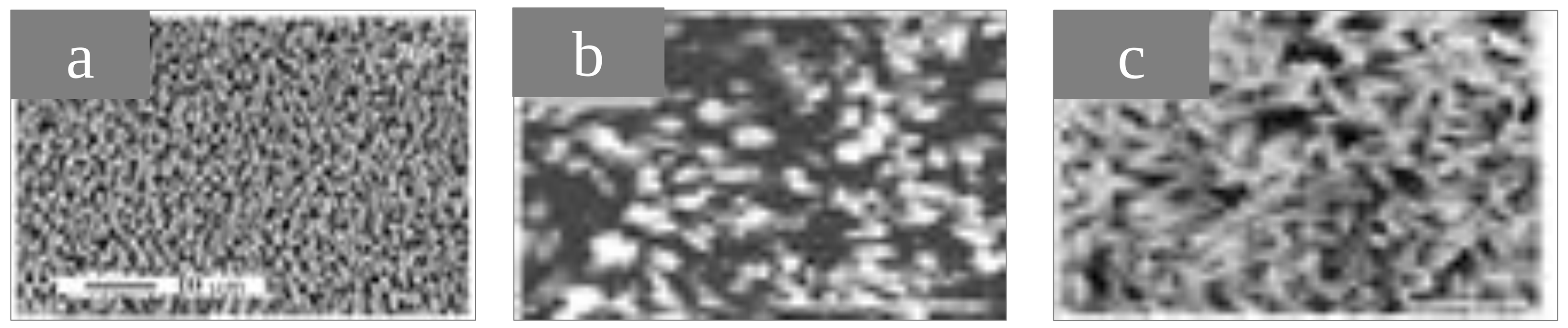


Fig.2. Top view of (a) ZnO, (b) TiO_2 and (c) CeO_2 nanorods grown by a hydrothermal approach.

SAW SENSOR DESIGN

• Langasite (LGS, $La_3Ga_5SiO_{14}$) is selected as the high-temperature SAW device substrate material since it has higher operating temperature limit (1470 ^oC) than other common SAW substrate materials, such as Lithium Niobate ($LiNbO_3$) and Lithium Tantalate ($LiTaO_3$), which have an operation temperature range from 400 ^oC to 500 ^oC. In addition, LGS also has a relatively high electromechanical coefficient (about 0.4 %) that enables the device to have higher sensitivity than other high-temperature SAW substrates.

• The selected materials for the interdigital transducer (IDT) electrode and the adhesion layer, which improves the bond between the LGS substrate and the IDT electrode, are Platinum (Pt) and Titanium (Ti), respectively.

• For the SAW IDT fabrication on LGS wafers, a lift-off technique is applied to create patterns of target materials (Pt and Ti) on the surface of a substrate.

• As used in the lift-off technique, an inverse chrome photo mask for lithography fabrication is designed using AutoCAD as follow.

MASK DESIGN (AutoCAD)

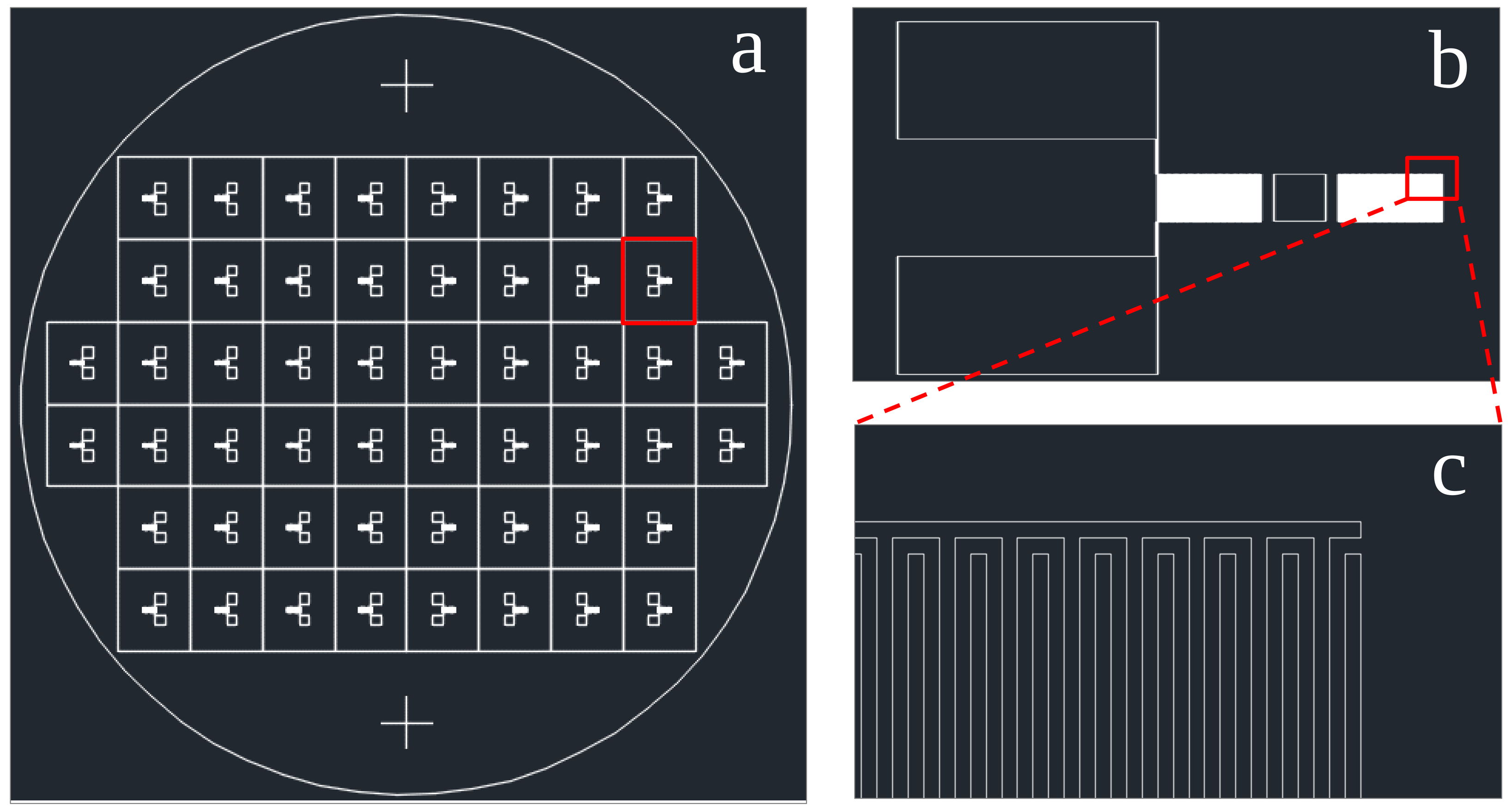


Fig.3. (a) A mask design for the configuration of wireless SAW devices on one LGS wafer, (b) A single wireless SAW device, (c) Zoomed-in IDT electrode areas.

FUTURE WORK

• Fabricating a passive wireless SAW array on the LGS substrate and 3D metal oxide nanorods on the active sensing area of SAW sensors.

• Characterizing surface morphology, electronic structure, high temperature stability, and chemical properties of the prepared nanorod composites by using a range of microscopy and spectroscopy techniques.

• Testing the wireless 3D nanorod composite SAW sensors under different controlled high temperature gaseous environments. The testing results will be used as the input to develop the machine learning algorithms.

• Confirming the wireless 3D nanorod composite SAW sensor arrays with integrated machine learning algorithms for monitoring methane combustion process under a lab environment.

ACKNOWLEDGEMENT

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