Ultrafast Early Warning of Heart Attack through Plasmon-Enhanced Raman using Collapsible Nanofingers

Zerui Liu[†‡], Guangxu Su[†‖], Deming Meng[†‡], Pan Hu[‡], Yunxiang Wang[‡], Junhan Wei[‖], Tianyi Yuan[§], Hao Yang[‡], Buyun Chen[‡], Tse-Hsien Ou[‡], Matthew Miller[‡], Sushmit Hossain[‡], Fanxin Liu*[‖], and Wei Wu*[‡]
[‡]*Department of Electrical Engineering, University of Southern California, Los Angeles, CA 90089*
[‖]*Department of Applied Physics, Zhejiang University of Technology, Hangzhou, Zhejiang 310023, China*
[§] *Beijing Etown Academy, Beijing, China*
**liufanxin@zjut.edu.cn,* wu.w@usc.edu*

The incidence of heart attacks, represented by acute myocardial infarction (AMI), is increasing year by year. The sudden onset and rapid progression of heart attack leads to its extremely high lethality. Over 30 million U.S. adults are threatened by AMI and 1 in 3 deaths in the U.S. is due to heart attack. The detection time of existing fastest heart attack detection system is more than 15 minutes which is too slow compared to the rapid passage of life. Early intervention is the best way for preventing mortality in the event of a heart attack. However, the existing detection systems are not fast enough to save lives from the heart attack. To solve this issue, we invent a machine-learning-driven system (figure 1) with a simple process, low cost, super short detection time (only 10 seconds) and high precision.

This novel heart attack early warning system compries collapsed nanofingers with unique molecular recpotors to distinguish biomarkers of heart attack. Figure 2a shows the scanning electron microscope (SEM) images of nanofingers after collapsed[1]. The extremely high sensitivity is a major advantage of this structure. Since the collapsed nanofingers produce super strong field, over 10^{11} fold enhancement factor[2], it can achieve detection at the single molecular level. In addition to its high sensitivity, the structure is also highly selective[3]. Only the target biomarkers of heart attack can be trapped in the field enhancement area for Raman signals after a simple surface treatment. The use of nanofinger with targeted receptors effectively captures the biaomarkers of heart attack from serum. Then, the mixed Raman spectra are collected.

Since the structure of heart attack biomarkers, such as brain natriuretic peptide (pro-BNP), Creatine kinase-MB (CK-MB), and Myoglobin (Mb), are complicated (figure 2b & 2c), there is too much noise in Raman signal, making it hardly to distinguish by the existing systems or well-trained personnel. We invited one student to identify the Raman signals. After a long training period, he recognized the Raman signal containing biaomarkers with only 76% accuracy. The analysis of mixed Raman signals using machine-learning-driven models enables dramatic improvement identification of heart attack. We analyze mixed Raman signal using decision tree model (DT), k-nearest neighbor model (KNN) and support vector machine model (SVM) respectively. As shown in figure 3, the prediction accuracy of all three models for heart attack are over 90%. Notably, even for healthy people the prediction accuracy of SVM is only 81%, the prediction accuracy of SVM for heart attack is 100%, which means every patient can be determined the cause of the heart attack accurately and quickly. This will greatly enhance the rescue time to save the patients' lives.

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† These authors contributed equally to this work.

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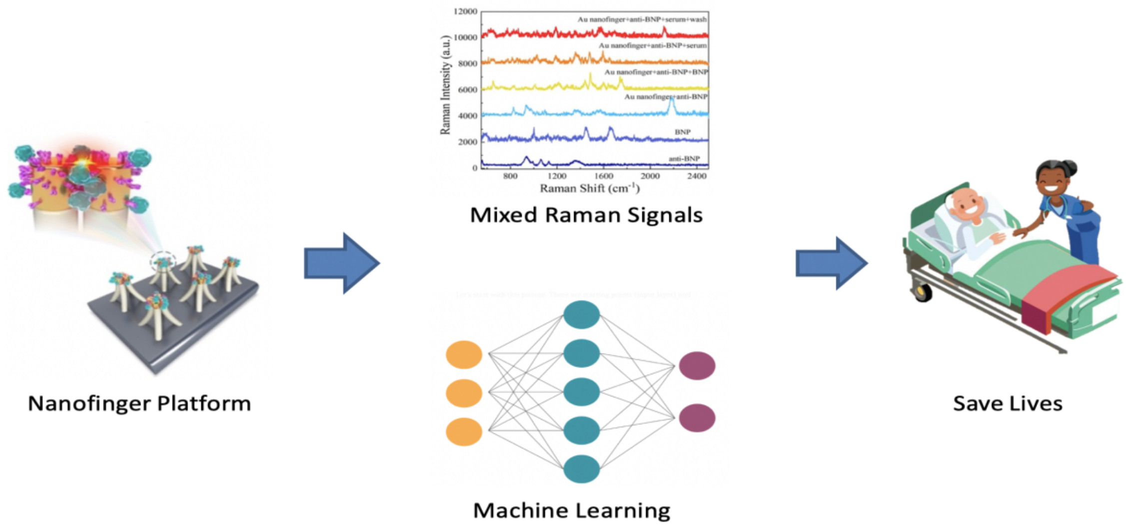
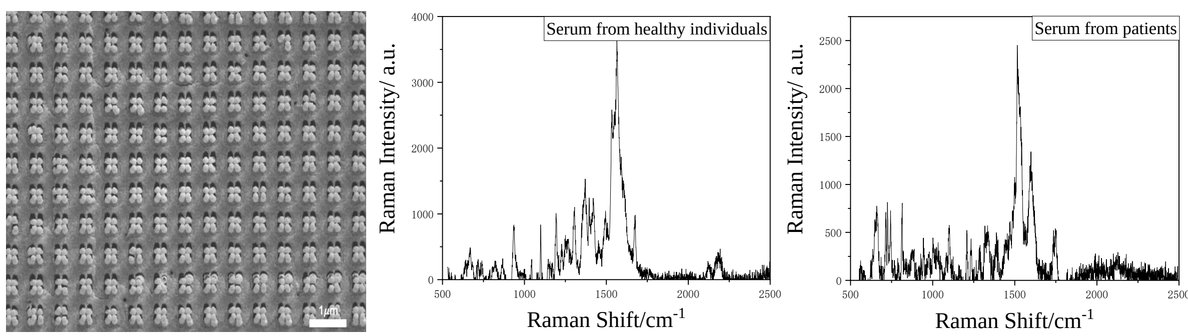
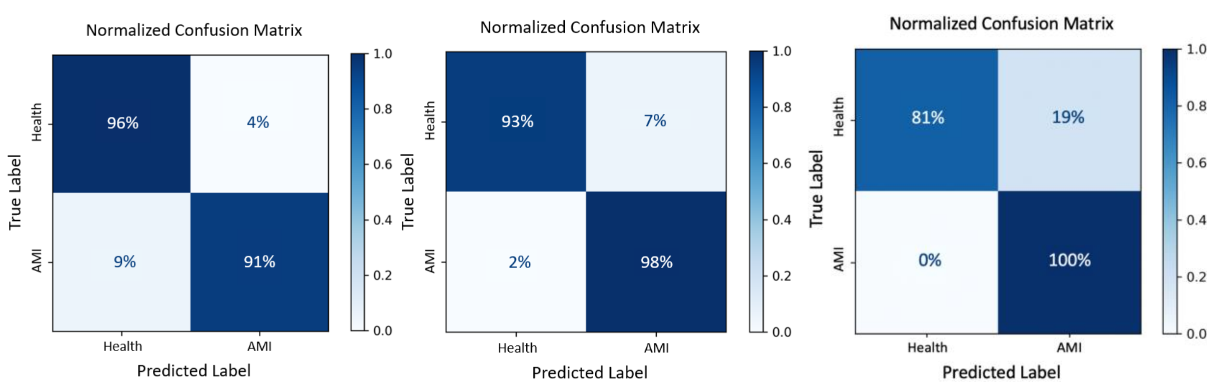


Figure 1. Designing a SERS based platform by collapsed nanofingers to construct Raman spectra for machine-learning-driven identification and early intervention of heart attack.



(a) (b) (c)

Figure 2. (a) SEM image of collapsed nanofingers. (b) Raman signal of serum from healthy individuals collected through nanofinger platform. This serum doesn't contain biomarker, BNP. (c) The Raman signal of the serum of individuals before the onset of heart attack. This serum contains BNP.



(a) (b) (c)

Figure 3. Normalized confusion matrix for three machine learning models. (a) Normalized confusion matrix for decision tree model with 91% accuracy. (b) Normalized confusion matrix for k-nearest neighbor model with 97% accuracy. (c) Normalized confusion matrix for support vector machine model with 100% accuracy.