# E-nose sensing of low-ppb formaldehyde in gas mixtures at high relative humidity for breath screening of lung cancer and indoor air quality monitoring

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Formaldehyde (FA) is a potential breath marker for non-invasive detection of lung cancer (Fuchs, 2010) and a tracer for indoor air quality monitoring due to its carcinogenic nature (Salthammer, 2010). Its typical concentrations are below 100 ppb posing a *sensitivity* and *selectivity* challenge to current portable sensors.

Inexpensive, portable and simple-in-use chemo-resistive FA sensors based on semiconductive metal-oxides (MOx) are quite attractive. They can detect sufficiently low FA levels, offer fast response and recovery times (Güntner, 2016) suitable for on-line monitoring, and a compact design already applied in portable samplers. (Righettoni, 2015) To overcome the selectivity challenge, a viable option is to combine broadly sensitive but differently selective sensors in arrays, so-called electronic noses (E-nose), that mimic the mammalian olfactory system. (Persaud, 1982) Statistical response analysis is applied to *selectively* detect the concentration of target analytes in mixtures.

Here, we present a highly sensitive, selective and compact electronic nose (E-nose) for real-time quantification of FA at realistic conditions. As shown in Figure 1, this E-nose consists of four nanostructured and highly porous Pt:, Si:, Pd: and Ti:$SnO_2$ sensing films directly deposited onto silicon wafer-based microsubstrates by flame spray pyrolysis (FSP).

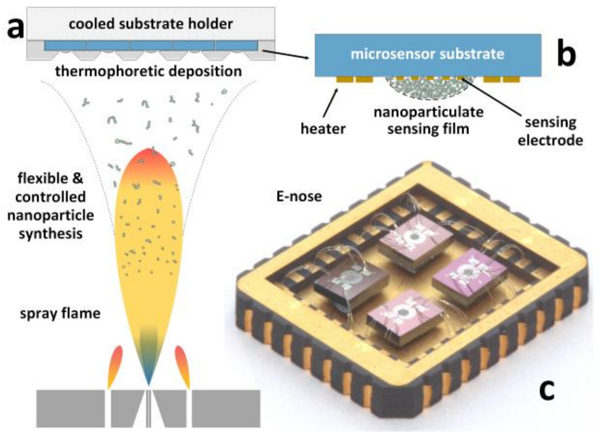


Figure 1. (a) Flame aerosol-made sensing particles are deposited (b) onto Si wafer-based microsensors. (c) Pt:, Si:, Pd:, & Ti:$SnO_2$ sensors are combined as E-nose.

The constituent sensors can detect FA down to 3 ppb (signal-to-noise ratio > 25) at breath-realistic 90% relative humidity (Figure 2a). Each dopant induces different analyte selectivity enabling *selective* detection of FA in 3- and 4-analyte mixtures by multivariate linear regression (Figure 2b). In simulated breath (FA with higher acetone, $NH_3$ and ethanol concentrations), FA is detected with an average error ≤ 9 ppb using the present E-nose and overcoming selectivity issues of single sensors. This device could facilitate easy screening of lung cancer patients and monitoring of indoor FA levels.

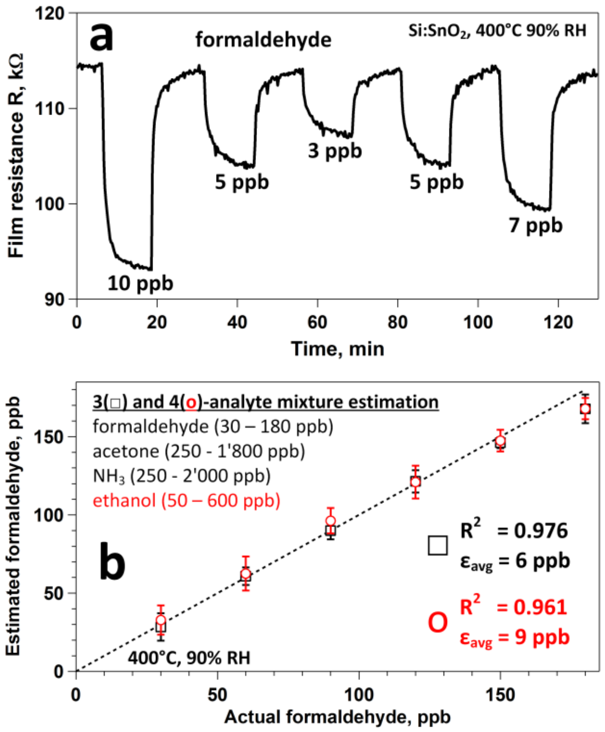


Figure 2. (a) Film resistance of a Si:$SnO_2$ (400 °C, 90% RH) sensor upon exposure to 10, 7, 5 and 3 ppb of FA. (b) E-nose estimation of FA in 3- & 4-analyte mixtures.

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