Detecting nerve gases VX and Tabun with a handheld device

Threats from nerve gases, or more accurately termed chemical warfare agents, constitute a serious security issue of increasing global concern because of surging terrorist activities. A big problem with nerve gases are that they are very challenging to detect using today's analytical techniques and especially outside dedicated laboratories. This study demonstrate that surface-enhanced Raman scattering (SERS) can be used for ultra-sensitive detection of two nerve gases, VX and Tabun, using a handheld Raman device and special nanoscale patterned sensors with superhydrophobic yet highly adhesive properties. The results opens for life-saving detection of chemical warfare agents in the field and at strategic locations such as airports and subways.

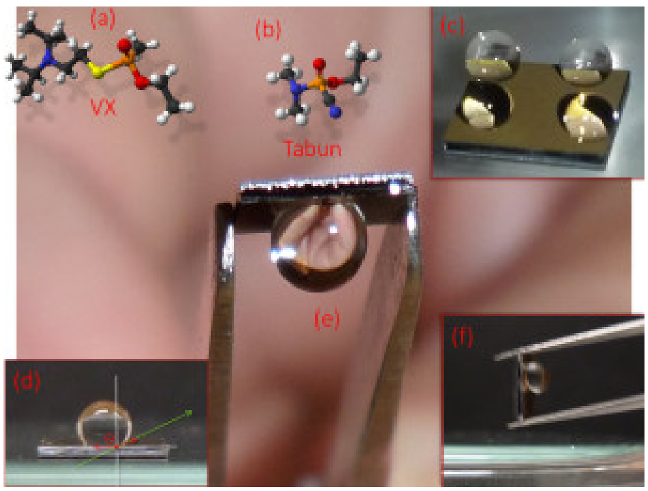

Fig. 1 Molecular models of the nerve gases (a-b) and sensor surfaces (ca. 5×5 mm) with 2 µl water droplets on, demonstrating the surface/wetting properties (c-f)

Nerve gases blocks the enzyme that breaks down acetylcholine in the body, which leads to nervous system break down, paralysis and eventually death. A single droplet of VX can cause human death in 15 minutes, even through the skin. It is approximately ten times more deadly than the infamous Sarin, which has similar toxicity as Tabun. Surface-enhanced Raman scattering (SERS) based molecular analysis methods display highly attractive properties in terms of sensitivity, speed, cost, multiplexing and portability. However, for the difficult nerve gases SERS has previously only been demonstrated at very high concentrations, 1–5% range, which is far from life-saving field measurements.

The SERS sensors were in layman's terms fabricated by deposition of a nanoscale layer of gold on flexible silicon nanopillars. An interesting thing with these sensor surfaces are that they are superhydrophobic, i.e. highly water repellant, yet also being highly adhesive when a water droplet finally sticks (Fig. 1). This has attractive features for hydrophilic molecules (such as VX and tabun) in water based samples, in terms of getting the molecules near the nanoscale surface and sample pre-concentration. Additionally, due to the flexibility of the silicon, the nanopillars are pulled together where the water has penetrated the sensor surface giving even more concentration effect and also a much higher surface-enhanced Raman scattering signal.

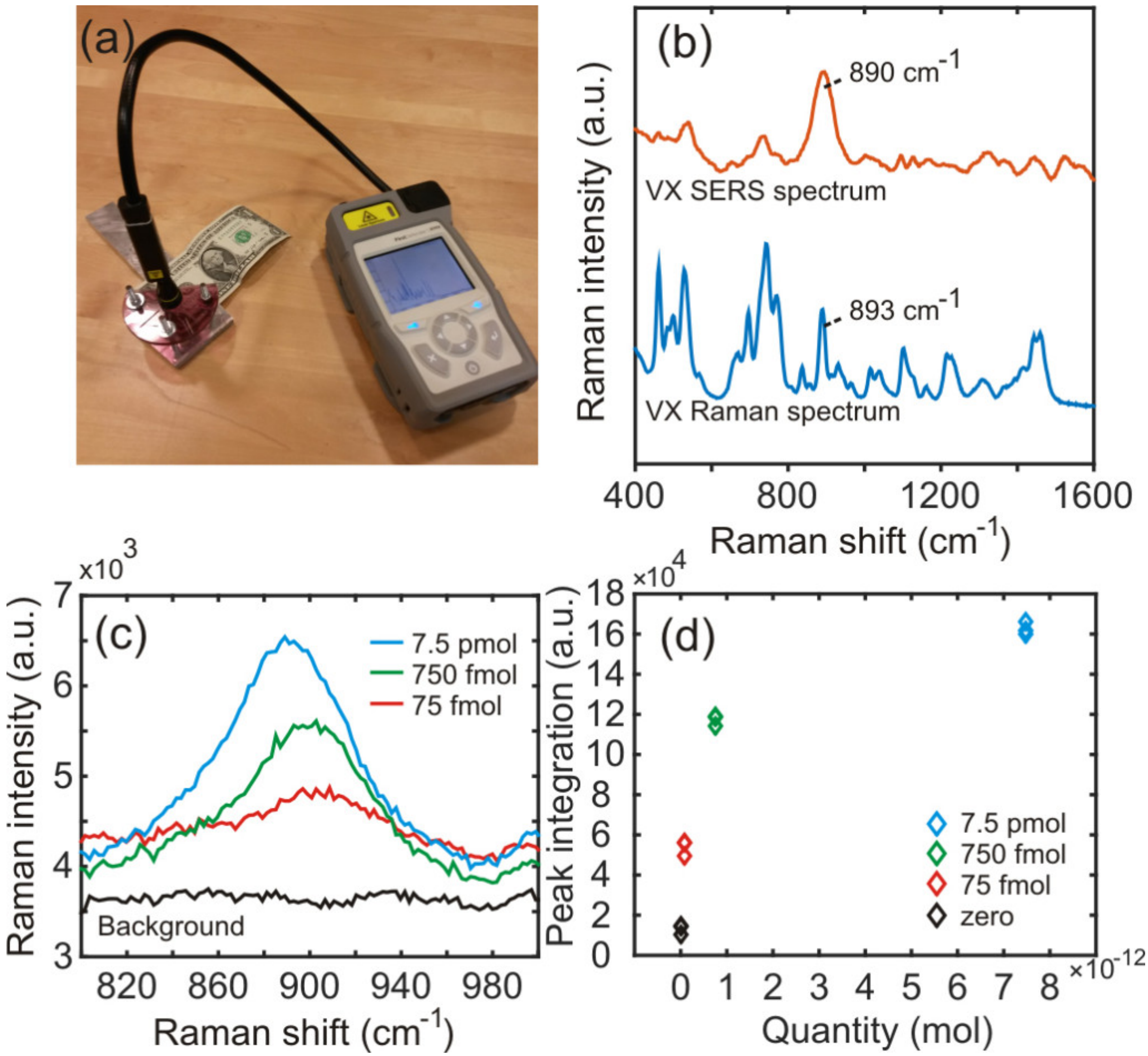

Fig. 2 a) The handheld Raman device, including a US dollar illustrating its small size. b) VX SERS and Raman spectrum. c) Low VX amount SERS measurements. d) Calibration curve.

It was concluded that the wetting properties of the sensors lead to a significant accumulation of molecules, not only at the macroscopic scale after droplet evaporation, but more importantly within nanoscopic SERS hot-spots formed locally by the elasto-capillarity aggregated nanopillars. As little as 0.000002 µg (75 femto mol) of VX was explicitly detected with the handheld device, from a 2 µl droplet of 10 parts per billion (ppb) VX concentration.

Aron Hakonen
Department of Applied Physics, Chalmers University of Technology, Gothenburg, Sweden

Publication

Detection of nerve gases using surface-enhanced Raman scattering substrates with high droplet adhesion.
Hakonen A, Rindzevicius T, Schmidt MS, Andersson PO, Juhlin L, Svedendahl M, Boisen A, Käll M
Nanoscale. 2016 Jan 7