Controlling Spatial Resolution and Sensitivity in Nanoscale Chemical Imaging by Photothermal-Induced Resonance Spectroscopy

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Short abstract: We introduce an analytical expression, modeling the photothermal expansion process and validating it with finite element simulations and AFM-IR experiments. These results enable experimentalists to achieve high signal intensity and high spatial resolution in AFM-IR experiments through selection of excitation laser parameters and accounting for material properties and sample geometries in both 2D and 3D chemical imaging.

Atomic force microscopy-infrared (AFM-IR) spectroscopy is an atomic force microscopy (AFM) based technique which combines nanoscale high-spatial resolution with the chemical analysis power of mid-infrared spectroscopy. The technique of AFM-IR relies on the detection of the pulsed wavelength tunable IR laser induced thermal expansion of the sample area underneath the AFM tip. However, the limitation on spatial resolution and sensitivity of the technique are not yet fully understood. In the analytical and numerical models of AFM-IR, we took into account laser heating, thermal and mechanical properties of materials and found good agreement with finite element simulations and AFM-IR experimental measurements with polymethyl methacrylate (PMMA) and polystyrene.

Building on our recently developed theoretical model of the AFM-IR signal, we now use a series of nanostructured polymer samples of mixed polymers with different features sizes and thicknesses to gain an understanding of how to control the spatial resolution and sensitivity in AFM-IR experiments. To achieve the goal, we make use of the advanced clean room technique to fabricate desired patterns on the chip, in addition, this technique allows us to precisely control the size, thickness and position of the features. As results, we have successfully fabricated three samples with 1 µm thick SU-8 covered by 100, 200 and 300 nm thick PMMA, respectively. The preliminary experimental results show clear chemical absorption spectra of two polymers and chemical images about designed patterns.
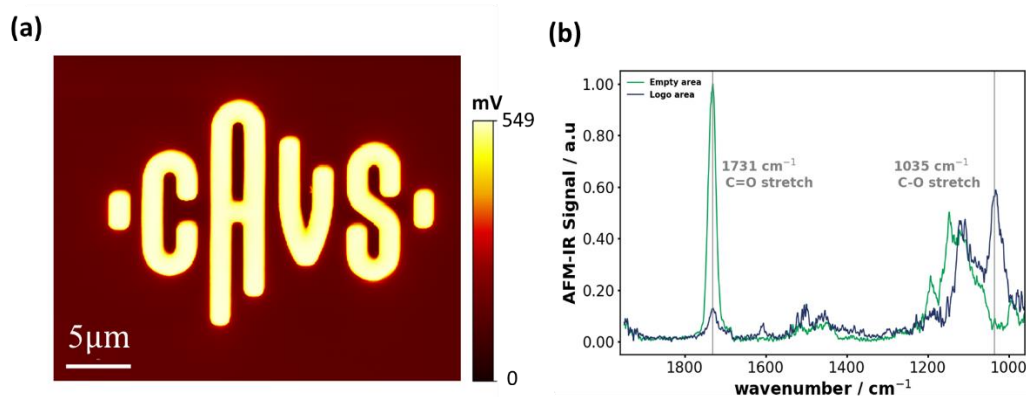
Fig. 1 (a) AFM-IR chemical map at 1035cm^{-1}. The bright logo part is designed by 1 µm thick SU-8 covered by 200nm PMMA, the empty area is designed only with 200nm thick PMMA. (b) AFM-IR spectra obtained on the position on the logo and empty area, respectively. The AFM-IR intensity is normalized at 1731cm^{-1}.