3. PROPOSED RESEARCH

The studies outlined in this proposal will investigate the role of ion modification, in air at ambient pressure, and the introduction of chemical orthogonality in mobility spectrometry, specifically tandem DMS measurements. These studies will confirm if resolving power in small mobility analyzers can be improved when the physics of ion motion is supplemented with chemical methods of cluster formation and ion fragmentation. Orthogonality will be probed using pharmaceuticals and pesticides with range of 200 to 600 Da (with ions derived from a [63]Ni ion sources) and vapors of alcohols, ketones, and chlorocarbons with carbon numbers from 3 to 6. The pattern in Fig. 8 from an DMS/IMS experiment in purified gases shows a pattern of or protonated monomers of ketones from acetone to nonanone (absent butanone and octanone) where the ion peak positions were predictable, lacking any orthogonal character. This was observed for ions of other substances such that a DMS/IMS was a sequential measurement only. Consequently, a first measurement predicts roughly the second making the second measurement redundant. An orthogonal measurement would show ion peak positions in "unpredictable: positions, that is locations not obviously derived from the first dimension of mobility.

Our preliminary results described in Section 2 provide evidence that mobility behavior can be altered, in-filling the area of a plot of mobility in two dimensions using ion-molecule chemistry introduced between two stages of mobility. Ions of high mobility in the first section can be selectively decreased in mobility by adduct formation. Ion of low mobility can be selectively increased in mobility by ion fragmentation. This concept depends upon analyte selective cluster-formation and ion fragmentation. Specifically, chemical orthogonality can be probed well only when: 1) the gas purity is controlled in the first mobility stage. In the DMS/IMS instrument (Fig 8) or the DMS/DMS instrument (Fig. 4), ions enter the first mobility stage along with sample neutrals from the ion source. These vapor neutrals must be removed between the ion source and first stage in order to control ion molecule chemistry between the mobility stages. 2) a tandem mobility configuration is temperature regulated where cluster formation and fragmentation reactions are controllable. A refined DMS/DMS drift tube will be built with independent
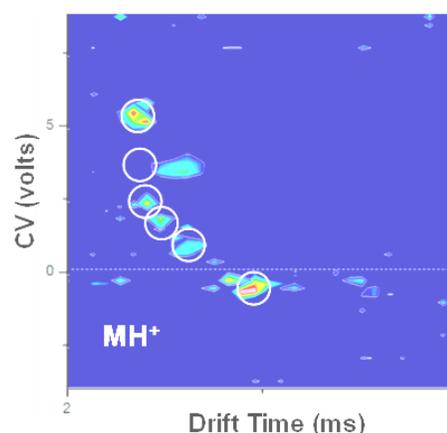

Figure 8. Result from tandem DMS/IMS measurement of five ketones; results are overlaid in this plot. The pattern of CV vs drift time showed little to no orthogonality in ion characterization by K and ΔK, i.e.; using physics of ion motion alone.

temperature monitoring in each stage and regulation. Additionally, pre-heating of all gases, before entering the drift tubes, is needed. 3) a suite of vapors is selected and concentrations from vapor generators are known over a suitable range (est. 1 ppm to 500 ppm). and, 4) an ion fragmenter to be placed as a component between two DMS stages or perhaps a triple stage mobility drift tube. This will be a high frequency RF device where ions can be fragmented by field heating. An option will be reserved for photo-dissociation with a pulsed UV laser.

To better understand chemical orthogonality in tandem mobility measurements, our initial efforts will be to refine and stabilize the existing DMS/DMS instrument (Fig. 9). Refinement means computer control of utilities of temperature, gas flows, vapor concentrations, and field strength for ion fragmentation. A method to describe and quantitatively measure orthogonality is needed early in this project. These two developments are critical for any further investigations. The instrument, derived from our existing DMS/DMS, will need extensive documentation of performance and discovery of any design flaws. Our laboratory philosophy on instrument building is design/model first and build second.

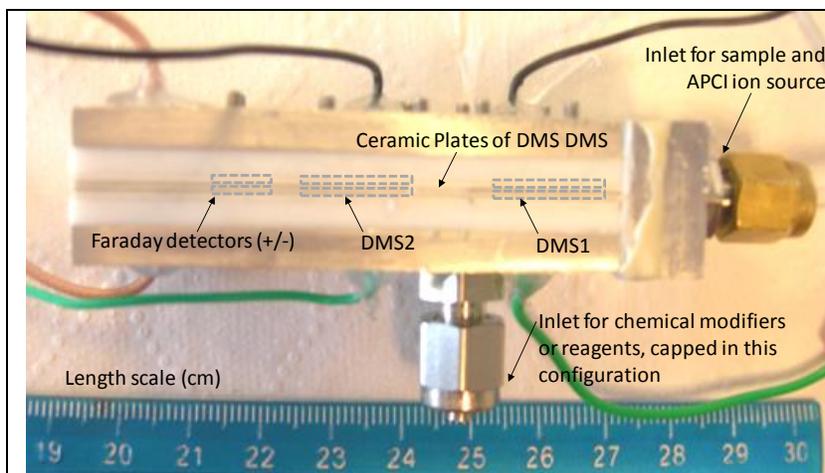Figure 9. Photograph of tandem DMS drift tube showing inlet for sample, ion source (2 mCi ^{63}Ni) and inlet for reagents introduced between DMS1 and DMS2. Gas flows right to left venting at end of drift tube body. Locations of active elements are shown in grey dotted boxes.

Thus, future designs will be examined by COMSOL for flow and heat behaviors and by DMx, a proprietary software purchased from Sionex Corporation in 2008, for ion trajectories.

The central part of these studies is systematic investigation of a) cluster formation between an analyte ion and a selection of vapor neutrals and of b) ion fragmentation, particularly the importance of ion mass and functionality in efficiency of fragmentation. Ion cluster formation and strength of displacement on the CV scale will be studied as a function of 1) molecular descriptors of basicity, polarizability, dipole strength, 2) molecular weight, 3) vapor concentration, 4) temperature, and 5) moisture. These studies will be distinctive in depth of quantitative discovery in items 3 to 5, building upon directions provided by Schneider, et al[34] and Yost, et al.[37] Our studies in ion chemistry are backed using *ab-initio* calculation of structures and thermochemical values of ion-adducts with Spartan and Gaussian. Ion fragmentation in this laboratory has been limited to field strengths near 120 Td and has been limited by electronics and design of the instrument. We will seek to reach 300 Td by employing Owlstone Nanotech which offers a ultraFAIMS chip used already in FAIMS/MS studies. This ultraFAIMS device has electric fields so large that fragmentation is a regular, and often singular, effect on gas ions. This will allow ion fragmentation and dissociation to be studied over a range of 1) field strengths, 2) cluster structure, 3) gas temperatures, and 4) moisture in the supporting gas atmosphere. Another distinctive of these measurements is our ability to determine the shift in mobility behavior precisely and conveniently since the ion is characterize in a first mobility stage, modified and characterized in second or third mobility stage. This will provide high speed, precise measures of such influences uniquely contributing to expanded understanding and practice of chemical modifiers and ion fragmentations. In an final effort, we will seek to isolate an ion in DMS1, fragment the ion, separate ions in DMS2, cluster and separation ion fragment clusters in DMS3.