

size for solid sample preparation, routinely produces a sample current from our ion source of 100-150 pA and a ^{14}C count rate of about 300 Hz. Applicants measure a sample for at least 4 cycles of at least 15,000 counts for 60,000 total ^{14}C counts. This is done in 200 seconds with approximately 10% added time for the ion current to come to a stable output and for data acquisition overhead. Thus, a measurement of a 1 Modern sample takes about 4 minutes, during which 30 milliCoulombs of carbon are extracted as negative ions in a process that is on the order of a few percent efficient, requiring 6.2 pmol carbon atoms: 75 pg of carbon, or 15% of the total carbon. The gas-fed source has about twice the efficiency in ionizing the sample to negative carbon ions, but has an output of only 10% that of the solid source. The same 75 pg will require about 80 minutes of measurement to obtain similar statistics of counting. Thus, the gas-ion source is not suitable to high throughput of large samples or high precision measurements. The gas source is valuable, however, for very small samples that pass through the system rapidly, as is found for materials directly combusted coming from an HPLC.

The Radiocarbon Accelerator Unit at the University of Oxford is currently the only AMS group that routinely performs ^{14}C -AMS analyses using CO_2 for accurate and precise carbon isotope chronometry. In the past few years, several AMS research laboratories have acquired or developed gas-accepting ion sources and have begun to develop samples introduction interfaces. The National Ocean Sciences AMS (NOSAMS) Facility at the Woods Hole Oceanographic Institution is developing a gas-accepting ion source that uses a microwave-driven plasma to generate positive ions. A magnesium oven charge-exchange canal is used to convert positive ions to negative ions for injection into the spectrometer. They have developed an interface to directly couple the output of a gas chromatograph to their ion source (McIntyre et al., 2009). For these laboratories, the emphasis has been on the quantification of ^{14}C from GC-separated compounds from natural sources to understand carbon cycling in the environment or on carbon dating applications from small samples.

The BEAMS lab, located at the Massachusetts Institute of Technology, uses a modified cesium-sputter ion source to accept gaseous CO_2 and H_2 (Hughey et al., 1997, 2000). They have also developed LC and GC interfaces for ^{14}C - and ^3H -AMS quantification of biochemicals. Their interface for the analysis of nonvolatile biochemicals relies on the analysis of discrete samples. Individual fractions from an HPLC are deposited into a well filled with CuO . After the solvent has evaporated, the dried sample is combusted by an infrared laser to produce CO_2 which is then transported to the ion source in a helium carrier gas. Only total ^{14}C counts are recorded, (i.e., not isotope ratios) essentially limiting the use of this system as a radiocarbon detector. This system can analyze samples containing picogram quantities of carbon without the addition of carrier carbon, assuming that the degree of ^{14}C -labeling is great enough. However, sensitivity and throughput are low, mainly due to the limitations of their accelerator, which is custom-built from an in-house design.

National Electrostatics Corporation (Middleton, Wis.), developed and markets a gas-accepting ion source for use with AMS spectrometers. It is a modification of their cesium-sputter ion source for solid samples, and has been designed to accept both solid and gaseous samples. Applicants performed ion-optics calculations and designed a beam line to transport both carbon and hydrogen isotopes, as well as matching the phase space of the ion beam to the acceptance of the accel-

erator. Based on these calculations, Applicants purchased such a gas-accepting ion source and associated beam line components.

This ion source, as purchased from National Electrostatics Corporation in 2002, required significant modifications to improve its overall ionization efficiency and serviceability. Subsequently, Applicants redesigned the interior of the ion source, primarily in the cesium feed and cesium ionization region. Applicants also modified the ion extraction region and increased the vacuum pumping capabilities. These redesigns were based on the successes that Applicants have had in improving the output of the LLNL ion sources, as well as on the work of others in improving the output of the NEC-designed ion sources. Applicants assembled the ion source and its injection beamline onto the 1-MV AMS system through an existing port of a 45° electrostatic analyzer (ESA). The field plates on the ESA can be rotated to transmit ions from either this ion source or from our existing ion source. Typical $^{12}\text{C}^-$ ion currents are approximately 150 icoamps and overall ion transmission through the system is approximately 30% as measured with solid graphitic samples.

Referring now to the drawings and in particular to FIG. 1, an embodiment of a system for analysis of liquid sample having carbon content by an accelerator mass spectrometer is illustrated. The system is designated generally by the reference numeral **100**. The system **100** provides the deposit of liquid samples on an indented moving wire. The moving wire is passed through a system to convert the carbon content of the samples to carbon dioxide gas in a helium stream. The gas is then directed to a high efficiency gas-accepting ion source for AMS analysis.

The system **100** includes an AMS unit **102** and a moving wire interface **104**. The moving wire interface **104** includes the following components: wire **106**, a wire indenter **108**, indentations in the wire **110**, a droplet maker **112**, sample droplets **114**, a drive motor **116** that moves the wire **106**, a system **118** that converts the carbon content of the droplets **114** of the liquid sample to carbon dioxide gas in a helium stream **120**, and a gas-accepting ion source **122** connected to the accelerator mass spectrometer **102** that receives said carbon dioxide gas of the sample in a helium stream **120** and introduces the carbon dioxide gas of the sample into the accelerator mass spectrometer **120**.

The moving wire interface **104** requires that the droplets **114** be placed on the wire **106** to stay at a fixed position such that they move with it. If a droplet **114** is allowed to slide along the wire **106**, it will collide with other droplets. At best this decreases resolution and at worst the combined droplets fall off the wire altogether. For fluids that bind weakly to the wire, such as methanol on nickel, this behavior results in a complete failure of the system if preventative steps are not taken. By introducing defects or indentations **110** to the wire at regular intervals this behavior can be prevented.

Referring now to FIGS. 2A through 2E, the defects, i.e. indentations **110**, in the wire **106** are shown in greater detail. The static force on either side of a droplet **114** is proportional to the surface area per unit of length where the edge of the droplet makes contact with the wire **106**. For a wire that is uniform along its length, the force on either side of a droplet is equal and opposite. In such a case ignoring friction, which may be very small as with methanol on nickel, there is no net force holding the droplet in place and it may slide freely along the length of the wire. If there is a defect on the wire, such that there is a change in surface area per a unit of length compared to a uniform section of wire, where the edge of one side of a droplet makes contact then there will be a net force on the