adhesion at the grain boundaries and resulted in the "ductilization" of previously useless, super strong but brittle alloys (see Nickel Aluminide). Other such applications of positron research abound, and progress in the field is gaining momentum.

Earlier, however, there had always been two major problems confronting positron researchers, both of which research funded by the Seed Money program helped to solve. First, in most practical applications (other than those requiring ultra-high vacuums) one could never get reliably enough positions for a useful diagnostic. Positrons are very rare; they live on the average of only one billionth of a second. Second, when one did get them, they were either too fast or of such widely varying energies that the resulting signals were nearly impossible to interpret meaningfully. What was needed was a reliable means of producing an abundant source of slow and relatively monoenergetic positrons in environments other than ultra-high vacuums.

In 1978 and 1979, researchers funded by Seed Money set out to solve these problems with a two-pronged attack. First, they investigated a number of different sources, particularly those known to be prolific and energetic positron emitters. This necessitated a containment system for safety and required the positrons to pass through a protective window, a process that would ordinarily diminish the resulting beam's strength. Ultimately, they found a window that was relatively transparent to fast positrons and devised a safe means of producing an intense beam.

Simultaneously, they explored a variety of materials that might be used to slow down, or moderate, fast positrons without consuming too many of them in the process. Ultimately, an efficient moderator was found to be tungsten. In addition, the researchers developed a heat treatment method for the tungsten that removed oxides and greatly reduced the concentration of surface defects, such as holes between molecules or atoms, which limited the number of slow positrons reemitted. As a result, the researchers were able to devise a reliable means of producing a beam of slow, monoenergetic positrons about the diameter of a pencil flowing at the rate of 100,000 positrons per second.

Although copper moderators developed elsewhere were known to be of higher efficiency, they had to be used under ultra-high vacuum conditions to prevent loss of efficiency due to rapid contamination and oxidation. The Seed Money tungsten moderator, by contrast, did not significantly oxidize when exposed to air. This attribute, aside from improving ease of use, also permitted its broader application to such areas as electron scattering in gases. A description of how electrons behave in gases is important in areas such as plasma physics, laser technology, and the chemistry of the upper atmosphere.

These breakthroughs proved to be significant steps in the further development of practical diagnostic tools, particularly in the area of analytical chemistry. It elevated positron research to a new and highly productive plane.

Shortly thereafter, using the Seed Money tungsten moderator, researchers at Brandeis University successfully performed the first laboratory demonstration of low energy positron diffraction, another useful surface analysis technique. This technique complements and may even surpass in overall utility and ease of use other more well-established methods.

Today, positron researchers around the world are investigating problems in many diverse areas, including annealing, wear, and fatigue in metals and alloys. Positrons are also being used to investigate the chemical properties of gases, solutions, and even such biological molecules as membrane proteins and enzymes. Many of these researchers are using tungsten moderators, or improvements thereon, which were originally researched by the Seed Money program.

The success of this research made a measurable contribution to a larger body of work and helped make positron spectroscopy more of a practical reality, with broadened applications.

Atom Science

Once in a while in the field of scientific instrumentation, there comes a device of such increased power and versatility that an entire spectrum of research based on traditional methods of measurement is revolutionized. Such is the story of a new and extraordinarily precise measuring technique, called resonance ionization spectroscopy (RIS). The origin of its development may be traced to three Seed Money projects funded in 1975, 1978, and 1982.

The power of this technique lies in its remarkable capability to search out, detect, count, and, if desired, extract for further use, a single atom of a specified type among literally billions of billions of atoms of any and all other types. In an analogy to an old saying, it's like finding a needle in a haystack; except with the RIS technique one has the added benefit (important to scientific research) of knowing that all the needles have been found and accounted for. Compared to previous techniques, RIS can improve the sensitivity of atom counting by an astonishing six orders of magnitude, or a million-fold.

Counting individual atoms, particularly those in rare amounts or unusual forms, is crucially important to many fields of fundamental research. It is also vital to commercial research and development in many burgeoning and competitive high-technology industries.

In the miniaturization of computers, for example, wherein a million transistors may be placed on a single silicon chip the size of a dime, the wires carrying the electrical signals have become so narrow (10 to 100 atoms wide) that