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Atomically Precise Manufacturing of Membranes for Water Purification and Desalination

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Abstract: In order to realize the goal of atomically precise manufacturing (APM) while creating near-term, commercially viable products, we have taken a building block-based, self-assembly route to manufacturing. We have developed a family of atomically precise, self-assembling, organic, two-dimensional building block structures. These porous molecular building blocks fit together to make a highly porous nanomembrane. When placed on a suitable substrate, the nanomembrane provides extremely high flux as compared to Aquaporins or conventional polymeric membranes. The long term goal of separation science has been to achieve high specificity in filtration at low energy: this nanomembrane-based system is anticipated to operate at ~1 psi for low TDS water, reducing the energy costs of water purification. The atomically-precise building block structure allows specific modification such that classes of impurities can be excluded with extreme specificity. The synthetic adaptability of the building blocks also allows for surface modifications such that fouling prevention for a specific water source can be “dialed in” during manufacturing. We are currently building the laboratory-scale manufacturing apparatus, and will use the membranes from this device to determine membrane flow, selectivity and lifetime parameters. The first use of this membrane will be in the California Central Valley where multi-year agreements have been signed to produce agricultural water from “salvageable water.” Due to the small footprint of our purification system, which is a direct result of using a nanomembrane construct, we anticipate providing a similar volume of water at a fraction of the cost and physical area as the Western Hemisphere's largest desalination plant at Carlsbad, California. The self-assembling APM building block manufacturing concept and implementation provides a mechanism to resolve pressing national water needs at low dollar and energy costs, thus allowing the use of previously unusable, contaminated water as feedstock. In addition to the near-term applications of atomically precise manufacturing for water applications, the building blocks are the basis for other transformational products across a range of industrial and medical applications, such as low energy 02/CO2 separation devices, a wearable renal replacement device that can operate using venous blood pressure, and medical diagnostic devices. Using this technology as a basis for further APM development, an early stage grant from DOE is also enabling Covalent to examine synergies between elements of the self-assembling AP technology and direct positional assembly.

Bio Note: Martin Edelstein is the cofounder and Chief Scientific Officer of Covalent. Martin leads the efforts from initial chemistry concepts through manufacturing of commercial products. Martin received a B.S. in chemistry at Northeastern University and a Ph.D. at Texas A&M University in the laboratories of F.A. Cotton and E.E. Hazen Jr. His dissertation was one of the first attempts at de-novo design and synthesis of a protein supramolecular structure. He did an NIH-funded postdoctoral fellowship at Baylor College of Medicine. Prior to co-founding Covalent, he worked in the pharmaceutical industry at SmithKline- Beckman, Berlex Laboratories and Athena Neurosciences developing cancer drugs to treat acute lymphocytic leukemia such as Fludara (Fludarabine) and multiple sclerosis drugs such as Betaseron (Interferon beta-1b) and Tysabri (Natalizumab). His experience has spanned research through pilot manufacturing and taking drugs through the FDA.