**A new research and teaching collaboration with the University of Duisburg-Essen**

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1. **Applicant’s Qualification**.

Beaucage has 30-years’ experience in the nanocomposite field with 163 publications (Web of Science) and an H-index of 35. He pioneered the use of small-angle X-ray scattering to study hierarchical materials. He has worked closely with industry such as pigment polymer companies. This background and network will be leveraged in the proposed activities. Beaucage spent part of a Fulbright Fellowship at the University of Sheffield in the UK working on the use of silicon to replace graphite anodes to improve battery capacity. Beaucage is a Fellow of the American Chemical Society, a Fellow of the American Physical Society and a Graduate Fellow at the UC.

2. **Impact of Proposal**.

*Outcome/Deliverables:* Immediate: It is planned to develop a research proposal focusing on silicon nanoparticles in lithium-ion battery anodes as well as to seek industrial funding in the pigment industry which is prevalent both in Cincinnati and in the Ruhrgebeit. The DAAD Rise program will be used to fund undergraduate Chemical Engineering students to work at UDE on soft matter research projects with Profs. Winterer and Segets. A co-taught dual-level course will be planned on soft materials using Zoom that will be offered as a graduate and undergraduate elective at UC and at UDE.

Long-Term: We expect long-term research and teaching interaction with the Segets and Winterer groups. This may serve as a seed for the development of further interactions between UC and the CeNIDE Center at UDE.

*UC Partnership Advancement:* The proposed trip will take advantage of an existing strategic-partner relationship to develop new research and teaching interactions with the University of Duisburg-Essen. The University of Cincinnati has expertise in nanoparticle synthesis, processing, and characterization, especially in polymer nanocomposites, that compliments expertise at the University of Duisburg-Essen and the CeNIDE center which includes 45 research groups including those of Markus Winterer and Doris Segets. The interaction in nanoparticle research could involve several other faculty members at UC in Chemistry, Chemical, Mechanical, Materials, and Environmental Engineering. The work on lithium-ion batteries also involves the University of Sheffield in the UK where Beaucage spent a Fulbright Global Scholar Fellowship and which could easily be developed into a new UC strategic-partner. Sheffield has the The Centre for Research into Electrical Energy Storage and Applications (CREESA) and the Kroto Innovation Centre which overlap with this work. Beaucage was a visiting faculty in the Chemical Engineering Department in 2018-19.

3. **Proposal.**

The proposed interaction with UDE involves two facets, new collaborative research and funding, and joint educational opportunities. Nanoparticles are rarely used in dilute conditions and generally rely on the self-assembly of complex networks in composites to produce properties such as tear strength, electrical and ionic conductivity, ion storage capacity, optical, and mechanical properties. Due to their high surface to volume ratio, nanoparticles display high transport properties and are effectively crack proof because they are smaller than the critical flaw size. For silicon absorbing lithium ions this means that nanoparticles can swell to three times their volume while retaining structural integrity with rapid absorption and desorption giving silicon anodes 10 times the storage capacity of current graphite anode batteries. Network structures can emerge during processing of nanoparticle composite films such as during drying or curing. This is as true of lithium-ion battery anodes as it is of paint and inks. The emergent network structure is tied to important properties in both cases, conductivity, permeability for lithium ions, mechanical integrity, and optical properties for pigments. The focus of the new collaboration is to understand and control the mechanisms for the emergence of optimal network structures on drying of materials such as pigment /polymer /solvent dispersions, i.e., paint, ink, and production of silicon anodes for Li+ batteries. Collaborative work involves synthesis of model nanoparticles, production of composite coatings, in situ synchrotron static and dynamic X-ray measurements, coarse grain molecular dynamics simulations, experimental measurement of properties using dynamic dielectric and rheological tests. Target funding for this work is the National Science Foundation (NSF) in the US and the German Deutsche Forschungsgemeinschaft (DFG). For example, the Partnerships for International Research and Education (PIRE) program is funded at $1.5M. Germany also has regional funding from the German state of North Rhein-Westfalia. In addition, there are several pigment companies with whom Beaucage has worked that might be interested in participating, for example, Sun Chemical (with facilities in Cincinnati and in Cologne), Shepherd Pigments, and Sherwin-Williams in Wupperthal and Cleveland. Currently, Beaucage is working with a group at the University of Sheffield in the UK that synthesizes nanoaggregates of silicon. In the work with Duisburg-Essen we would study the process of coating elastomer/silicon on battery anodes, the development of network structure and its impact on battery performance. This travel funding would be used to assess the areas of complimentary expertise, initiate initial studies, and to develop several research proposals around hierarchical structural emergence in nanoparticle dispersions from national and industrial funding sources in Germany and in the US.

There is also an opportunity to expand educational offerings at UC and at UDE. Prof. Winterer has pointed out that the German government funds US undergraduate researchers to study with a German graduate student through DAAD Rise. Applications are made by a German PhD student in the fall followed by selection of students. Prof. Winterer also suggested application for a Humboldt Fellowship that supports extended faculty visits to UDE, this is like the Fulbright program in the US. During the visit to UDE Beaucage would teach a short course on X-ray and neutron scattering from nanomaterials. Plans for Zoom® based interactions like a joint semester-long course on soft matter (including nanoparticles, fractal aggregates, polymers, biomaterials, self-assembly etc.) or a joint seminar series in this area will be discussed. New approaches such as international joint classes that take advantage of expertise in different countries would add to the diversity of elective courses at both campuses.

4. **Cost Sharing:**The Department of Chemical and Materials Engineering strongly supports the interaction with the UDE (and Sheffield) and will contribute $1,000 towards this trip through travel funds. The Department sees this interaction in Soft Matter as one of its strategic goals with the parallel interests of seven research groups who might participate in interactions with UDE including new faculty hires Asst. Prof. Ben Yavitt.