UCI University of California, Irvine

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August 7, 2019

RE: Evaluation of the habilitation thesis of **Dr. Viktor Johánek** of the Charles University Faculty of Mathematics and Physics.

I am pleased to provide this brief assessment of the habilitation thesis of **Dr. Viktor Johánek** of the Charles University. Dr. Johánek was a postdoctoral fellow in the laboratory of my colleague Professor John Hemminger from 2003 – 2007 and I know him informally from this period, some years ago now. I should also provide the following qualifier: I am an electrochemist with interests in condensed phase surface chemistry and physics, however my familiarity with the many nuances of ultrahigh vacuum surface physics and gas phase catalysis - the 'bread and butter' of Dr. Johánek program - is limited. I nevertheless am happy to provide my perspective on this extraordinary body of work. Finally, I do apologize for the tardiness of this letter, which I committed to writing in April, 2019.

The first thing to say is that this is a very impressive document, in terms of the clarity with which Dr. Johánek has provided regarding the overarching goals of his research program, the comprehensive scope of the program itself, the quality and unique capabilities of the custom-built instrumentation he and his coworkers have designed and assembled, the depth of coverage of the science he and his coworkers have already produced, and the impressive level of scholarship (600+ references), all of which are of the highest quality.

The remainder of the letter is devoted to an analysis of its three major sections, paralleling the organization of the thesis. These are: 1) CO_x and NO_x surface chemistry, 2) Water surface chemistry, and 3) Surface chemistry of organic molecules.

1. ***Ch 3* - CO_x and NO_x surface chemistry.** This body of work carried out by Dr. Johánek with coworkers at the Fritz Haber Institute under the direction of Libuda and Freund has proven to be both seminal and impactful. The field of UHV surface science is small, and high impact publications (>100 cites) within this field are understandably rare. Dr. Johánek coauthored four such papers during this period, a remarkable number.

   Included in this list is a first author publication in *Science* in 2004 (ref. 3, 128 cites) that describes experiments focusing on CO oxidation on a Pd model catalyst in which microscopic fluctuations of the CO coverage translate into macroscopically observable changes in activity across three different model systems (Fig 21). These experimental

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results were supported by simulations that collectively provide that, "… the presence of coverage fluctuations on nanoscale particles should influence the global reaction kinetics even in the absence of kinetic phase transitions."

Another first-author paper in *Angewendte Chemie* (2003) with Libuda and Freund exploited surface IR spectroscopy (RAIRS) to probe the dynamics of NO dissociation on alumina-supported Pd nanoparticles. Exposure to a pulsed CO molecular beam is used to modulate the O_{ads} coverage resulting in observable changed to the NO dissociation rate (Fig 23). An exciting conclusion of this study is the disproportionate activity for adsorbing NO dissociation products at edge defects and (100) facets on these supported Pd nanoparticles. Beyond these two high profile papers, Dr. Johánek published a number of other first-author papers in this period pertaining to this general subject of NO_x and CO_x catalytic oxidation. This is one of several topical areas where Dr. Johánek's work has had a lasting impact on the field.

2. *Ch 4* - Water surface chemistry. A second topical area where Dr. Johánek's research is shaping the field of surface chemistry is in the area of water adsorption and reactivity on cerium oxides (collectively, "ceria" or CeO_x). His contributions in this area represent activity of he and his group in Prague in the 2012 – 2019 time frame. While electrochemical water splitting is energy intensive and generally requires metals like Pt and Ir that spontaneously dissociate adsorbed water, ceria can also spontaneously dissociate water to produce hydroxyls. Could CeO_x provide an earth-abundant "window" to efficient water splitting?

   This is a complex question. For example, stoichiometric CeO_2 evidently doesn't do this chemistry, just the more reduced CeO_x where $x < 2$. Dr. Johánek has engaged in studies of a series of water-related compounds on CeO_x including formic acid, acetic acid, and methanol that are aimed at broadening our understanding of ceria surface reactivity. The influential nature of this work is indicated by citation analysis. It is unusual to see publications in *J. Phys Chem C* receive a large number of citations, but a recent 2012 publication coauthored by Dr. Johánek, titled, "Water Chemistry on Model Ceria and Pt/Ceria Catalysts" (ref. 12) has already received 63 cites – an impressive ≈10/year. A coauthored second paper in *Catalysis Today* 2012 (ref 32) did almost as well with 56 citations. In this new and especially hot area of surface chemistry, the impact of Dr. Johánek and his coworkers recent work is already apparent.

3. *Ch 5* - Surface chemistry of organic molecules. Dr. Johánek's efforts relating to this topic have been distributed across decades, and date to his days in the Hemminger laboratory at UC Irvine where he constructed an amazing UHV STM/laser desorption mass

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spectrometry instrument. His heroic efforts to build up this instrument consumed all his time and impeded his publication productivity, but somehow he still managed to push out ten excellent papers or so during this period in the late 2000's. Some of these papers reported investigations of the reactions of unsaturated carbons on platinum surfaces and the formation of graphite nanostructures at high temperatures.

Since then, often in a collaboration with Ian Harrison at the University of Virginia, he has studied graphene formation on platinum. He has also been corresponding author on much of this work. There is much left to learn about controlling graphene growth on surfaces to tailor properties, number of layers, substituents, doping, and so on. This is an exciting growth area where his work has already having significant citation impact and it is very early.

Not included in his dossier are papers published since 2018 and I note that Dr. Johánek has already had an incredibly productive 2019 with five new manuscripts (2 of these first author) already published according to ISI. It is particularly nice to see a recent paper on electrochemistry pertaining to the direct methanol fuel cell, which has never work particularly well for electrochemists so it is certainly past time for superb surface scientists like him to become productively involved.

In summary, Dr. Johánek has established a world-class UHV science and catalysis laboratory and research program. Especially in the highly instrumentation-intensive discipline of UHV surface science, the barriers to establishing such a laboratory are enormous, in terms of time, expertise, and fund-raising. His impact across three disparate fields, in collaborations with multiple research groups at multiple institutions for 15 years, is well documented in the habilitation thesis. He is the common denominator in all this beautiful science. In the U.S. system, he would have received tenure and promotion to Associate Professor years ago. His research accomplishments, publication record, and other scholarly activities are fully commensurate with an appointment to the rank of Full Professor. He would certainly be a strong candidate to be promoted to this rank at my Department.

Sincerely yours,

[redacted]

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