Research Assessment Exercise 2020

Impact Case Study

University: City University of Hong Kong

Unit of Assessment (UoA): 7 Physics & Astronomy

Title of case study: Neutron scattering study of condensed matters

(1) Summary of the impact

At City University of Hong Kong, a neutron scattering group has formed with strong knowledge in neutron scattering science and technology. The neutron research group has obtained a number of significant research results in the past several years. The major impacts of these results are: (i) influence on public policy leading to significant infrastructure investments, (ii) the elevation of the public awareness of the Hong Kong and Dongguan society of the importance of China Spallation Neutron Source (CSNS), a world-class neutron facility in Dongguan, a nearby city about 70 km north of Hong Kong. In addition to conducting cutting-edge research in materials physics, the group also has strong expertise in instrument design, and has made essential contribution to the construction of a total scattering instrument at CSNS. The impact is evident from the significant increase in the government investment in building new neutron scattering instruments in the facility, media coverage, and the increase in research activities and support in this area. The group was recently awarded a $8.65 million HKD funding from the Research Grant Council of Hong Kong SAR, under the title, "Hong Kong's participation at China Spallation Neutron Source." The funding will be used to support the construction of a total scattering diffractometer in exchange for a beamtime share for access to a suite of instruments at the CSNS. The dedicated beamtime will significantly enhance education and research activities in Hong Kong and encourage a rapid growth of a strong user community, to take advantage of state-of-the-art facilities at CSNS for scientific discovery and technology development.

(2) Underpinning research

When China Spallation Neutron Source started its operation in March 2018 in Dongguan, China joined US, UK, and Japan as the only nations which provide pulsed neutron facility for materials research. Neutron scattering is a powerful and versatile method to characterize the structure and dynamics of materials. In Hong Kong, there have been steady efforts to promote the use of neutron scattering since 2013. For example, with support from the Croucher Foundation in Hong Kong, a biennial summer school was launched at the City University of Hong Kong to train highly promising postgraduate students and early career scientists on the use of neutron scattering. In addition, a joint laboratory was founded by CAS and City University of Hong Kong, to collaborate on neutron scattering science and technology. The joint laboratory has received steady support from the Croucher Foundation, and recently from the Research Grant Council of Hogn Kong SAR.

Neutrons are one of the fundamental particles that make up matter. Neutrons are abundant in the universe, making up more than half of all visible matter. They are also ideal for certain types of research. Neutron scattering provides information about the positions, motions, and magnetic properties of solids. When a beam of neutrons is aimed at a sample, many neutrons will pass through the material. However, some will interact directly with atomic nuclei and "bounce" away at an angle, like colliding balls in a game of pool. This behaviour is called neutron diffraction, or neutron scattering. Using special detectors, scientists collect and count scattered neutrons, measure their

energies and the angles at which they scatter, and map their final position. This makes it possible for scientists to glean details about the nature of materials ranging from liquid crystals to superconducting ceramics, from proteins to plastics, and from metals to metallic glass magnets.

Over the years, neutron scattering studies have made enormous impact in many areas of physics, chemistry, biology, materials science, and materials engineering. For example, neutron scattering experiments played a crucial role in elucidating the interplay between spin fluctuations and superconductivity in high-temperature superconductors. Because of their characteristic energy scales, cold neutrons are uniquely positioned to probe dynamic processes in soft matter, whose applications range from consumer products to photovoltaic materials to drug delivery. The study of mechanical behaviours represents a new application of neutron scattering. In addition to offering fundamental insights of deformation at microscopic level, the technique has also provided critical data for assessment of the structure integrity of key equipment (e.g., high speed trains or nuclear reactors) and national infrastructures (e.g., bridges).

At CityU, the neutron scattering group led by Prof Xun Li Wang has focused on phase transformation and deformation in complex metallic alloys based on in-situ neutron diffraction measurements. In a study of Pd-Ni-P metallic glass [1], Professor Wang's group uncovered a 40-year old scientific mystery of a broad exothermal peak found in the scanning calorimetric study of metallic glasses between the glass and crystallization temperatures. This anomaly has puzzled the field for a long time. The study of Pd-Ni-Pd system by the neutron scattering technique undertaken by Prof Wang's group revealed the existence of a new amorphous phase in the supercooled liquid region. The exothermal peak is due to the polymorphous phase transition between two supercooled liquid states.

Professor Wang' recent research [2, 3] also elucidated deformation mechanism in high entropy alloys, which can be described as a three-stage deformation behavior. Despite the chemical complexity of the material, the deformation behavior is determined by the dislocation activities. Diffraction and microscopy data show the progress of deformation is from dislocation slips to serious entanglement. A critical review by Z Wu et al., [Current Opinion in Solid State and Materials Science 21 (2017) 267], highlighted Professor Wang's work [2], which is now serving as a standard reference in the field of high entropy alloys. Studies like these advance our understanding of the physics of important structural materials and have shown that neutron scattering is a very powerful technique in revealing outstanding scientific mysteries and thus generate high impact on the society.

Apart from scientific research work, Prof Wang's expertise in neutron scattering instrumentation has directly contributed to the build-up of the instrument suite at CSNS. While working at Oak Ridge National Laboratory (ORNL), Professor Xun-Li Wang served as Group Leader for the Powder Diffraction Group, which manages all neutron powder diffractometers at both the Spallation Neuron Source (SNS) and the High Flux Isotope Reactor, at ORNL. In particular, Professor Xun-Li Wang built VULCAN, the engineering diffractometer at the SNS. As lead scientist, he was responsible for the overall design, construction, and early commissioning of the highly successful instrument.

At CSNS, Professor Wang and Professor Hesheng Chen of CSNS were the main drivers of the 1st user instrument, the Multi Physics Instrument (MPI), funded by Dongguan Institute of Technology, a local university in Dongguan at 80 million RMB. MPI is designed to study disordered materials using the total scattering techniques. As Chief Scientist, Professor Wang led the design of the instrument [4]. The design, featuring innovative use of neutron guides and choice of water moderator, have been recently published.

(3) References to the research

[1] "Hidden amorphous phase and re-entrant supercooled liquid in Pd-Ni-P metallic glasses", S Lan, Y Ren, XY Wei, B Wang, EP Gilbert, T Shibayama, S Watanabe, et al, Nature Communications **8**, 14679 (2017)

[2] “Deformation of CoCrFeNi high entropy alloy at large strain”, B Wang, H He, M Naeem, S Lan, S Harjo, T Kawasaki, Y Nie, HW Kui, et al, Scripta Materialia **155**, 54-57 (2018)

[3] “In-situ neutron diffraction study of deformation behavior of a multi-component high-entropy alloy”, Y Wu, WH Liu, XL Wang, D Ma, AD Stoica, TG Nieh, ZB He, ZP Lu, Applied Physics Letters **104** (5), 051910 (2014)

[4] “Physical design of multipurpose physics neutron diffractometer for the CSNS”, J. P. Xu, L. W. Mei, W. Yin, X.-L. Wang, W. L. Cai, Z. D. Li, Tao Bo, H. C. Chen, B. T. Wang, Y. B. Chen, Nucl. Inst. Meth. A, **927**, 161-168 (2019)

(4) Details of the impact

The technical design research has led to an innovative design. Construction of the instrument is well underway and the instrument will be ready in 2021. The instrument, MPI, will support a vibrant community who will be able to carry out high-quality and high-impact total scattering research, according to a report from the International Review Committee. The new design is expected to yield exceptional flux, when normalized to the operating power of the accelerator. Professor Heshen Chen of CSNS is the PI and Professor Wang is Chief Scientist of the instrument.

The advent at CSNS, particularly the progress with MPI, has led to direct funding from Hong Kong government. In December 2018, The Research Grant Council (RGC) rewarded a $8.65 million HKD grant, along with required 100% matching from CityU, to a group led by Professor Wang to support the construction of MPI. The $17.3 million HKD funding will double the detector coverage of MPI, effectively doubling the performance of the instrument. The group consists of faculty members from all major universities in Hong Kong, including HKU, CUHK, HKUST, CityU, and also University of Macau.

As a versatile instrument, MPI has broad applications in Physics, Chemistry, materials science and engineering, and life sciences. A recent study in the UK demonstrated an application to the development of anti-HIV drugs.

The investment by RGC will obtain a fractional beamtime share for access to the entire suite of instruments at the CSNS, so as to accommodate a broad range of research interests in Hong Kong. The dedicated beamtime will greatly enhance education and research activities in Hong Kong, and encourages rapid growth of a strong user community, to take advantage of state-of-the-art facilities at CSNS for scientific discovery and technology development. More importantly, through this investment, Hong Kong’s scientifically will become engaged in the development of next generation instruments, and thus helping to shape the future of CSNS.

Additionally, Professor Wang has also organized conferences and workshops, which help promote the importance of neutron scattering research in Hong Kong and nearby region. The Croucher Foundation sponsored the Croucher Summer Course on Neutron Scattering, which has been held biennially since 2014. A Gordon Research Conference on Neutron Scattering was launched in 2015 and continued as a biennial conference series. Professor Wang served as the chair of the inaugural conference. The collaboration with China Spallation Neutron Source has led to a featured article in Nature Materials [A], which report these important developments in Dongguan and Hong Kong for the international scientific community.

The funding from RGC, to invest directly into a scientific facility in mainland, is unprecedented. The neutron scattering research undertaken in the past few years by Prof Wang’s group has changing Hong Kong and Dongguan’s views and subsequently policies towards large-scale research facilities. Both societies realized that the results obtained from these facilities could have transformational impact on science, technology and eventually the society as evident from the research results obtained by Prof Wang’s group (solving a long-term scientific mystery and elucidation of deformation mechanism of important technological materials). Before the construction of CSNS started, scientific research in Hong Kong and Dongguan are mainly small scale and confined

to the universities. Dongguan has been known for its light industry which usually does not attract heavy investment. When CSNS broke ground in 2012, local people reacted with doubts and disbelief, because neutrons are a rather foreign concept to the local universities and the public at large. In general people are skeptical about the contribution of the facilities to the local society. However, Prof Wang and his collaborators' research and conference activities demonstrated the utility and potential of CSNS. So, Professor Wang's work has an important impact on the public policy through changing the mindset of the Dongguan and Hong Kong government about the prospect of the facilities and invest further money in building up more facilities. The details of the impact on the public policy are:

1. Dongguan University of Technology decided to invest in neutron scattering science, by setting up a center and providing major funding to support the construction of MPI. The investment for the MPI instrument is 80 million RMB.
2. Hong Kong RGC decided to invest in neutron scattering science by providing $8.65 million to support the construction of MPI (CityU provides same amount of matching fund).
3. Dongguan government plans to build a neutron science park consisting of CSNS and a materials research laboratory as a key component of its future development. Initial investment for the materials research laboratory was 5 billion RMB.
4. City University of Hong Kong explores setting up a new campus in Dongguan next to CSNS. The total cost is expected to be 3 billion RMB

To corroborate the impact, supporting letters from Director of the China Neutron Spallation Source [B] and the Vice-president [C] of CityU are attached.

These efforts by the Dongguan, and Hong Kong government will transform Dongguan and the vicinity from a manufacturing town to an international city for science and technology.

Through these efforts, there is a significant elevation of the public awareness of the importance of the neutron source in Dongguan and the associated scientific opportunities. News report of Hong Kong LEGICO members visiting CSNS [D], and recently the Finance Secretary of Hong Kong also visited CSNS [E], expressing strong support for collaboration between Hong Kong university and CSNS. These activities are widely reported in news media. CityU provided leadership for neutron scattering activities in Hong Kong and was frequently mentioned in those news report. In June 2017, Wen Wei Po, a major Chinese newspaper in Hong Kong published a series of articles on the impact of CSNS to Hong Kong, featuring Professor Xun-Li Wang of CityU [F,G].

Our efforts have built a brand name for neutron scattering activities in Hong Kong and these activities raised the society interest in building and using this kind of scientific facilities. A collaboration research was formed and successfully applied for research funding from Hong Kong Research Grant Council.

(5) Sources to corroborate the impact

[A] "China's first pulsed neutron source", H Chen, XL Wang Nature Materials **15** (7), 689-691, (2016)

[B] Supporting letter from Director of China Spallation Neutron Source

[C] Supporting letter from Vice-president of City University of Hong Kong

[D] News report of Legislative Councilors' visit to the neutron scattering facility at Dongguan in Ming Pao (21April 2018)

[E] News report of the Financial Secretary's visit to the neutron scattering facility at Dongguan in Wen Wei Pao (10 August 2018)

[F] News report of the neutron scattering facility at Dongguan in Wen Wei Pao (26 June 2018)

[G] News report of the neutron scattering facility at Dongguan in Wen Wei Pao (29 April 2019)