

## Faculty of Science and Engineering

### Profile report: Cognitive Devices (Cognitive devices)

- Discipline: Device Physics/ Nanoelectronics
- Level: Assistant professor
- Fte: Full time (1,0)

#### 1. Scientific discipline

Nanoelectronics comprises the understanding of electronic processes and development of electronic materials and devices at the nanoscale. The focus is on the application of devices that show adaptable and multi-valued electronic, magnetic, optical or mechanical properties (known as cognitive devices), as key elements for brain-inspired information processing.

#### 2. Vacancy

This position is opened by the Board of the Faculty (PT/gl/18/00140) as part of the Centre "CogniGron - Groningen Cognitive Systems and Materials", which aims to develop systems and materials for cognitive computing. The position will be embedded in the Zernike Institute for Advanced Materials, and falls within the framework of 'Career Paths in Science 4' ('Bèta's in Banen 4'). Please see link for [criteria and conditions](#).

#### 3. Selection committee (BAC)

Prof. dr. ir. C.H. van der Wal	Scientific director of the Zernike Institute for Advanced Materials and professor Physics of Quantum Devices (Chair);
Prof. dr. B. Noheda	Director Groningen Cognitive Systems and Materials and professor Nanostructures of Functional Oxides;
prof. dr. ir. B.J. Kooi	Education Director of the Zernike Institute for Advanced Material and professor Nanostructured Materials and Interfaces;
Prof. dr. E. Chicca	Professor Bio-inspired Circuits and Systems;
Prof. dr. T. Banerjee	Professor Spintronics of Functional Materials;
Prof. dr. Martin Ziegler	External member, professor Micro and Nanoelectronic Systems, Technische Universität Ilmenau (Germany);
S. Dijt	Student member.

#### *Advisors:*

Prof. dr. M.A. Loi	Professor Photophysics and Photoelectronics;
Prof. dr. N.A. Taatgen	Scientific director Bernoulli Institute for Mathematics, Computer Science and Artificial

Dr. J.H.M. van der Velde

HR advisor

Intelligence, and professor Artificial Intelligence and Cognitive Modeling;  
Scientific Coordinator Groningen Cognitive Systems and Materials center and secretary of the selection committee.  
HR advisor

Besides the members of the committee also the Board of Zernike Institute and the Board of CogniGron (Groningen Cognitive Systems and Materials) centre may be consulted regarding the eligibility of the candidate.

#### **4. Research area**

The general profile of the position is experimental research on *brain-inspired devices* and will involve the design, fabrication, characterization and testing of circuits and systems for cognitive computers based on new devices, with material systems that are unconventional for the computer industry. The field of cognitive materials and devices is believed to propel data processing forward with the development of more efficient, smaller and faster systems, taking advantage of new materials and devices that emulate synaptic behaviour (adaptability and plasticity) and neural behaviour (memory/multi-valued responses). This can be achieved by a way of computing that, inspired by the working mechanism of the brain, combines parallel processing, analogue signals and co-localization of processing and memory. These characteristics endow the brain with the capability to deal with large amounts of heterogeneous and complex (sensory) data, filtering, classifying and prioritizing in a very efficient manner. Thereby, this research area will respond to the need for devices in information processing that work *via* very different concepts than the current CMOS does, but can benefit from the existing technologies.

It is envisioned that this position will mostly focus on fundamental science, experimenting with devices with learning capabilities that combine memory and adaptability to be used as key elements in cognitive computers. The integration of this devices on CMOS circuits and architecture is instrumental for developing novel technologies which can benefit from the existing one.

The new staff member will strongly collaborate with other disciplines and expertise. Most important will be the collaborations with on the one hand with materials scientists, and on the other hand with the group *Bio-inspired Circuits and Systems*, with knowledge on circuit integration of cognitive and bio-inspired devices. This provides the necessary knowledge to integrate materials in working circuits that can be tested for cognitive applications and low-power/low-latency smart computing at the edge.

Additional collaborations within FSE in mathematics, computer science and artificial intelligence (in particular image analysis, dynamical networks, systems and control theory and stochastic methods) can strengthen this research. These collaborations will allow for the processing of large data sets and complex images acquired from new materials and devices. Additionally, they will support the development, simulation

and analysis of neural networks based on the cognitive devices. To achieve optimal performance and learn how to modify the cognitive devices in working integrated circuits, feedback is required from experts in cognitive systems, neuromorphic computing and algorithm development.

### **5. Embedding: institute (and base unit)**

This position on Cognitive Devices will be established within the Zernike Institute for Advanced Materials and play a crucial role within the Centre “CogniGron - Groningen Cognitive Systems and Materials”. We anticipate that the position will fit best in the base unit *Bio-inspired Circuits and Systems*, and together they will be instrumental in bridging the materials expertise with the artificial intelligence and computer science expertise, already existing in the Faculty of Sciences and Engineering (FSE).

The CogniGron (Groningen Cognitive Systems and Materials) Centre is a joint venture between FSE-institutes Bernoulli Institute for Mathematics, Computer Science and Artificial Intelligence, and the Zernike Institute for Advanced Materials. It comprises researchers from materials science, physics, chemistry, mathematics, computer science and artificial intelligence. The centre provides structure, coherence, and visibility for a joint research program in the direction of cognitive systems and materials. The main goal of the Groningen Cognitive Systems and Materials Centre is to create self-learning materials that will perform the tasks that are now assigned to thousands of transistors and complex algorithms in a more efficient and straightforward manner, hence, forming the basis for a new generation of computer platforms for cognitive applications, such as pattern recognition and analysis of complex data.

The Zernike Institute for Advanced Materials is one of the leading institutes in the field of materials science. It focusses on the design and scientific study of nanostructured and (bio)functional materials to achieve unprecedented functionality.

### **6. Local and (inter)national position**

The Cognitive Devices research line will occupy a unique position both at the national and international level, being part of the research centre “CogniGron - Groningen Cognitive Systems and Materials”.

In the Netherlands few efforts in this direction are currently being set up. A relevant research initiative is the Centre for Brain Inspired NanoSystems (BRAINS) at the Technical University Twente. At the Technical University Eindhoven there is the Eindhoven Artificial Intelligence Systems Institute (EAISI) where amongst others dr. Y. van der Burgt works on the implementation of organic transistors for neuromorphic applications. At the Radboud University there is the Donders Institute for Brain, Cognition and Behaviour, which is embedded in the Faculty of Science. At the Delft University of Technology, groups explore the relevance of these developments for biomedical implants (prof. W. Serdijn) and small drones (prof. G. de Croon). Together with Groningen the before mentioned universities are frequently in the lead for the formation of various consortia.

Internationally, industrial research organizations, such as IBM, HP and IMEC, are moving strongly into this direction, by investing in so-called neuromorphic computers in parallel to their efforts on quantum computers. There are also several comparable academic research groups, though with a different focus on the topic. The group of Julie Grollier at CNRS/Thales (Paris) is focussing on spintronic-based bio-inspired devices. The groups of Rainer Waser and Regina Dittmann (FZ-Jülich and U. Aachen), Hermann Kohlstedt (U. of Kiel), Martin Ziegler (U. Ilmenau), Siegfried Karg, Bert Offrein and Heike Riel (IBM-Zurich), Jean-Pierre Locquet (KU Leuven) and various others are studying two-terminal memristive devices. Sabina Spiga (CNR Italy) is developing oxide-based resistive switching non-volatile memories and memristive devices for neuromorphic systems. Martin Salinga (U. of Münster) investigates the dynamics of amorphous materials and their application in novel electronics. Agnes Barthelemy (CNRS-Thales), Manuel Bibes and (CNRS-Thales) and Jean Fompeyrine (Lumiphase Corporation) are focussing rather on ferroelectric memristors. Additionally, important efforts are taking place in the UK, China and Japan (AIST being a strong contender) as well as in the USA, with Q-MEEN-C being a large initiative on Quantum Materials for Energy Efficient Neuromorphic Computing.

## **7. Expected contributions to research**

The candidate is expected to initiate and develop an internationally leading research programme in the field of cognitive devices. The research should have a visibility at the international level and lead to publications in journals with solid reputation. Further, it is expected that the new professor will take a leading role in the field of cognitive devices within the Netherlands. The research programme is also expected to initialize collaborations and cross-fertilize with the existing research both within CogniGron (Groningen Cognitive Systems and Materials) centre and the Zernike Institute and should thus strengthen the international reputation of the research centre and institute. Obtaining substantial external funding for PhD projects is crucial, and in addition the supervision of PhD students is considered to be an important part of the research activities.

## **8. Expected contributions to teaching**

The candidate is expected to contribute to the teaching programmes in the bachelor and master degree programs within the Schools of Science and Engineering, especially courses with Physics and Applied Physics content. This concerns in part specialized courses in relation to cognitive devices, adaptable electronics and other related topics. These topics are currently little represented in the faculty and can be linked to teaching in electronics, nanoelectronics, spintronics, 2D materials, memristive materials, *etc.* Furthermore, the candidate will be involved in supervising bachelor, master and PhD students.

Upon appointment, depending on experience and formal qualifications to date, the candidate may be required to enter a nationally standardized tertiary teaching skills certification trajectory (BKO or Basis Kwalificatie Onderwijs), successful completion of which is a condition for extensions and tenure.

## **9. Expected contributions to the organization**

The candidate is expected to have an active interest and to provide a positive contribution to the management and organizational tasks of the institute. At the level of the FSE, the candidate will contribute to the organization of the faculty, for example by participating in working groups and committees in the area of teaching, research, and management. The candidate will participate in relevant national and international organizations.