PRESS RELEASE

‘Green’, Coin-Sized Sensors from the MetaVEH Project for 6G and Seismic Monitoring

Research by a consortium consisting of ZHAW Zürich, Imperial College London and the Politecnico di Milano, together with Multiwave Technologies and STMicroelectronics, has led to a microscale prototype free of lead and rare earths, without the need for batteries

23rd October 2025 – ‘Green’, **energy-independent** sensors as small as a coin have been developed for wireless networks and real-time monitoring. These are the results of the **MetaVEH** (Metamaterial Enabled Vibration Energy Harvesting) project, which has just ended, following funding of **€4 million** under the **Horizon 2020 ‘**Pillar 1 – Excellent Science’ call to reduce CO_2 emissions. The research was conducted by a consortium consisting of three universities — **Imperial College London**, the **Politecnico di Milano** and **ZHAW Zürich** as lead institute — together with **Multiwave Technologies** and **STMicroelectronics**.

The initial idea was simple: **to exploit the movement of vehicles** on structures such as **bridges and motorways, feeding the harvested energy into sensors used to monitor those same structures**. The sensors are now widely used but often difficult (or impossible) to reach for battery replacement, as they are situated in inconvenient places, perhaps at the top of an antenna or on the girders of a viaduct. **The real challenge** lays in creating a small device and solving the issue of the power needed by the sensors for both operation and data transmission, thus limiting battery waste and the environmental impacts of dead battery disposal.

The prototype developed by **MetaVEH** after nearly five years of studies is based on the concept of ‘**energy harvesting**’, that is, using the vibrational energy available in the environment and relying on piezoelectric materials to convert mechanical energy into electrical energy. The most effective piezoelectric materials currently used in existing sensors, however, contain lead, an environmentally toxic element. Instead, the project focused on **developing and testing ‘green’ piezoelectric materials free of rare earths,** using a standard, readily available element: **aluminium nitride**.

At the same time, **technology was developed to produce mechanical metamaterials** — materials specially ‘engineered’ for certain properties and reactions — **that can manipulate the propagation of elastic waves**, greatly amplifying the performance of energy harvesters. The resulting metamaterials, manufactured using innovative 3D printing techniques, have particular mechanical properties due to which they can ‘catch’ the wave passing through them, forcing it to concentrate on the piezoelectric material, a phenomenon known as ‘rainbow trapping’. **The technology developed for engineering the metamaterials was patented by Imperial College London and the Politecnico di Milano**. This allowed the energy harvesters to be prototyped on various scales, down to the **MEMS** (Micro-Electro-Mechanical Systems) **scale**. The device has a total length of 300 microns, i.e. less than half a millimetre, and **it all fits within a 1-cent coin.**

‘In MetaVEH we have shown that vibration harvesters can move from concept to a complete autonomous sensing platform – says **Andrea Colombi**, professor at **ZHAW Zürich** and **MetaVEH coordinator** – By coupling advanced metamaterial structures with nonlinear energy management and wireless transmission, **we demonstrated that sensors can operate without batteries and still deliver reliable data**, even in environments where replacing batteries is difficult or impossible. This opens the door to sustainable monitoring solutions for infrastructures and the Internet of Things’.

‘MetaVEH has also been a rich mathematical challenge, where we tackled the complexity of nonlinearity, metamaterial modelling and multiphysics coupling – says professor **Richard Craster**, Dean of the Faculty of Natural Sciences at **Imperial College London** – These advances in theory and simulation have been essential to guide the prototypes and demonstrate their potential in real applications’.

‘We are dealing with a wide range of structural mechanics, especially for this type of sensor,’ says **Raffaele Ardito**, professor at **DICA – Department of Civil and Environmental Engineering** of the Politecnico di Milano. ‘With colleagues in the university’s Department of Mechanical Engineering, we have worked hard to find a ‘green’ alternative. At the end of the project, we now have **a prototype for a microscale energy harvester based on a piezoelectric material without lead or rare earths,** and therefore neutral with respect to ethical and environmental sustainability’.

This device **holds a strong potential for practical applications,** namely in two domains: as **high-quality resonators for 6G telecommunications** and as **autonomous sensors for structural health and environmental hazard monitoring**. By harvesting energy from ambient vibrations, such devices can be deployed in inaccessible locations, becoming active only when needed and transmitting real-time data to safeguard infrastructures. For example, they could provide early warnings of earthquake-induced motions, terrain instabilities, or fatigue damage in critical structures such as bridges and tunnels.

For the project, **STMicroelectronics** has created micrometer-scale prototypes by integrating lead-free piezoelectric materials directly into the MEMS manufacturing process. This innovation has improved conversion efficiency of mechanical energy into electrical energy and has paved the way for new applications, potentially useful in the fields of 6G communications and Internet of Things (IoT). Furthermore, the MetaVEH project was selected within the EU Innovation Radar Platform initiatives for its high innovative content.

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LINK TO MetaVEH WEBSITE HERE

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