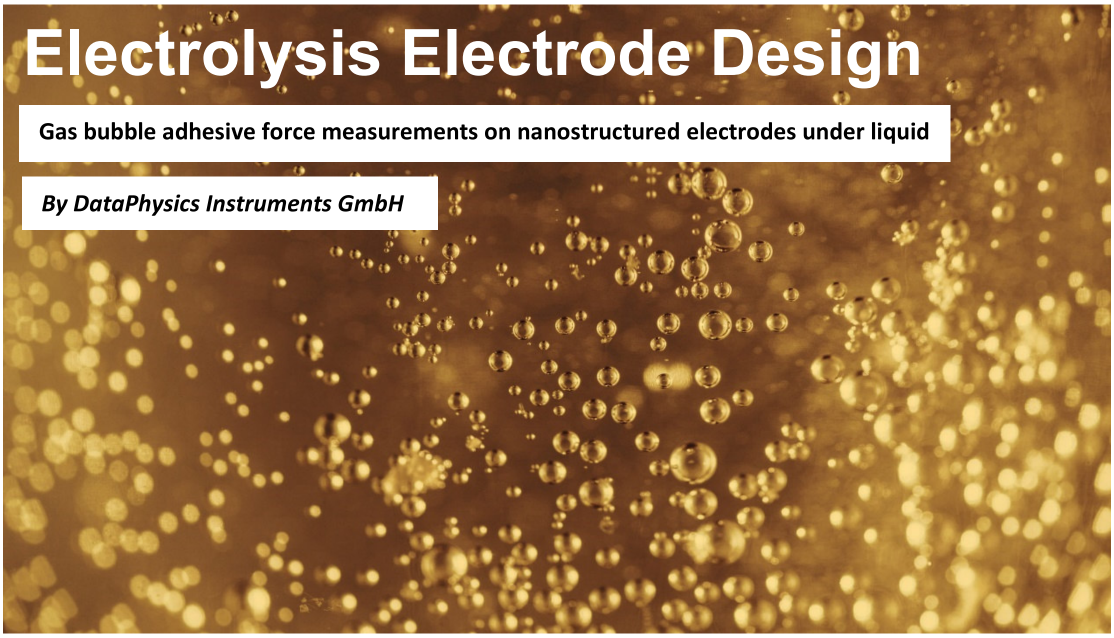
How adhesive force measurements of gas bubbles can help to improve electrolysis efficiency.



The design and application of high performance, low-cost electrocatalysts for water electrolysis has attracted more and more attention. This is due to high impotency of making water splitting a more accessible and efficient energy conversion technology. There are several electrode characteristics that lead to a decreased overpotential and thus improve the efficiency of water splitting such as:

1. Improving the catalytic sites intrinsic activity
2. Increasing the electrocatalytic active sites density
3. Enhancing the electrode materials conductivity
4. Optimizing the mass transfer properties on the electrode surface

To improve the mass transfer, nanoarray architectures on the electrode have been found to accelerate the reactions dramatically on cathode and anode by facilitating the gas bubble release from the electrode surface. At the same time nanostructures o the electrode surface increase the surface area and maximize the density of catalytic active site. Trimetallic iron, cobalt, nickel-based (Fe, Co, Ni-based) sulfides have been known for their adjustable and inherent hydrogen and oxygen evolution reaction (HER and OER) reactivity and are thus a good candidate for electrolysis electrode materials. Recently, Wang *et al*. have developed a facile solvothermal method to synthesize Fe, Co, Ni-based hybrid nanotube arrays (FeCoNi-HNTAs) from layered double hydroxide nanowire arrays (FeCoNi-LDH-NWAs) supported on a Ni foam substrate (**Figure 1**). This bifunctional electrocatalyst, showed an outstanding activity and very good stability when applied for water splitting.

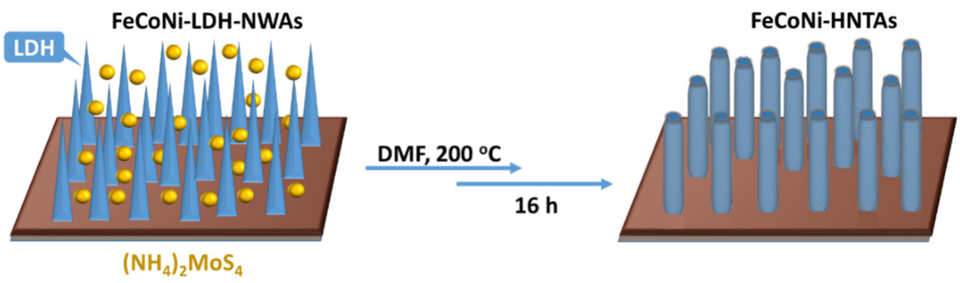


Figure 1. *Synthetic process of the hybrid nanotube array FeCoNi-HNTAs.*

To get a deeper understanding why nanoarrays have a structural advantages for efficient bubble release and superaerophobicity, adhesive force and contact angle measurements of gas bubbles on the electrode surface were conducted. As shown in **Figure 2**, there is only a negligible adhesive force of bubbles on the surfaces of FeCoNi-HNTAs and FeCoNi-LDH-NWAs, especially, the contact angle of bubble on FeCoNi-HNTAs surface under electrolyte reached about 171.0°, demonstrating that FeCoNi-HNTAs possesses a remarkable superaerophobicity. It is caused by the discontinuous state of the three-phase contact line (TPCL) between bubbles and the electrode surface that results in extremely low contact area. In addition, the excellent superhydrophilicity could facilitate the wetting film formation on the electrode surface, which may also decrease the contact area between the bubbles and surface. As comparison, MoS_2/Ni Foam and bare Ni foam were studied, which further confirmed that nanoarray electrodes have a stronger superhydrophilicity and superaerophobicity explaining their effective bubble release.

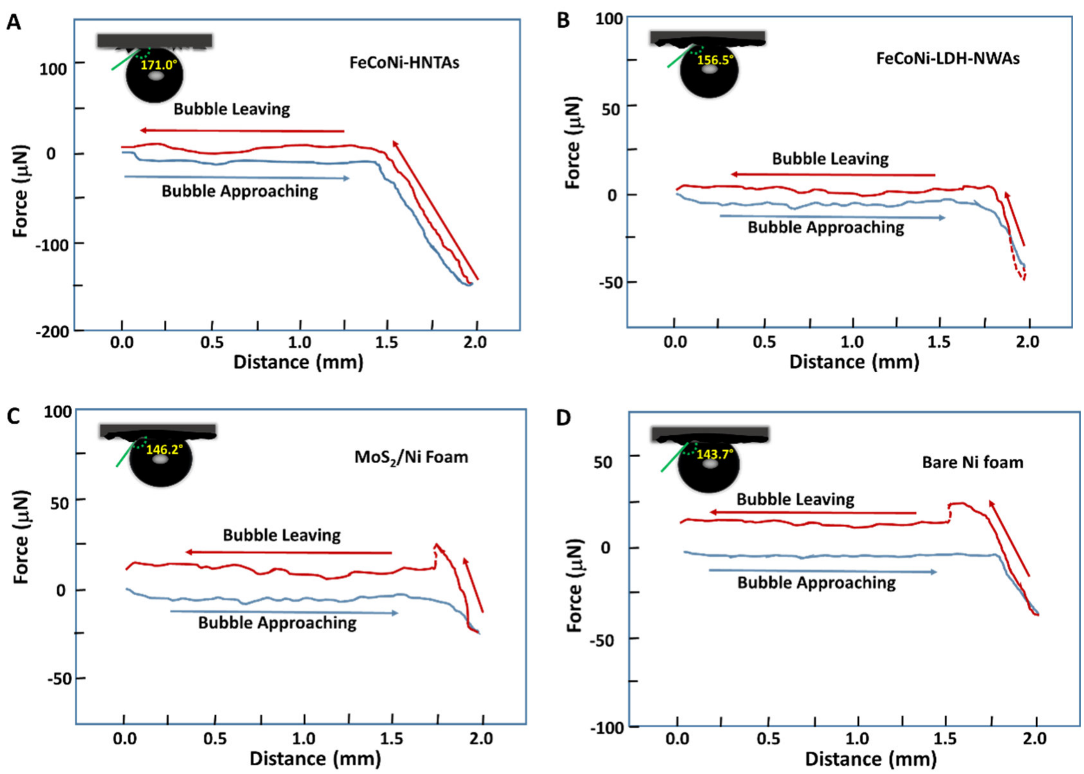
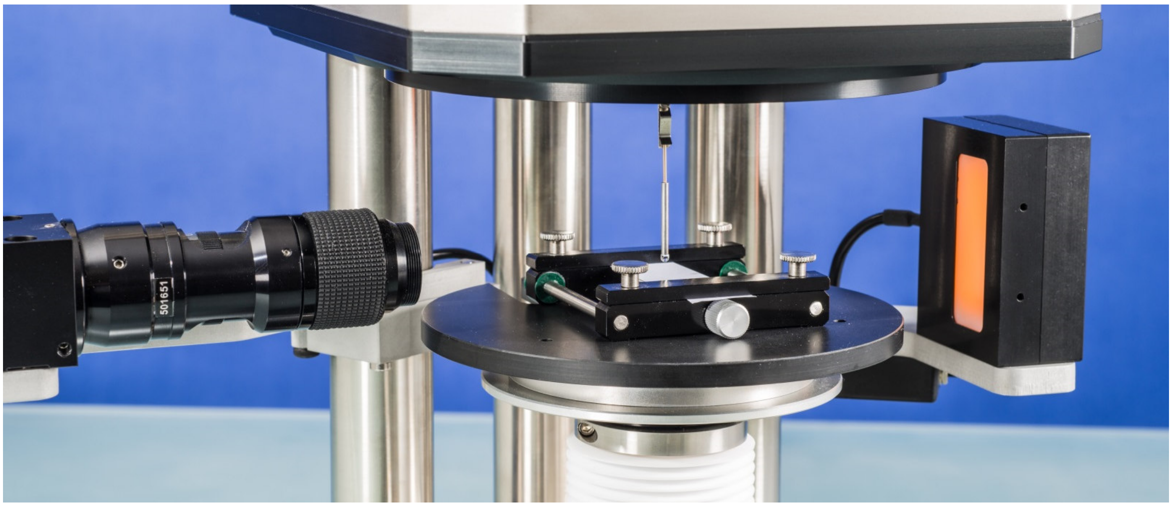


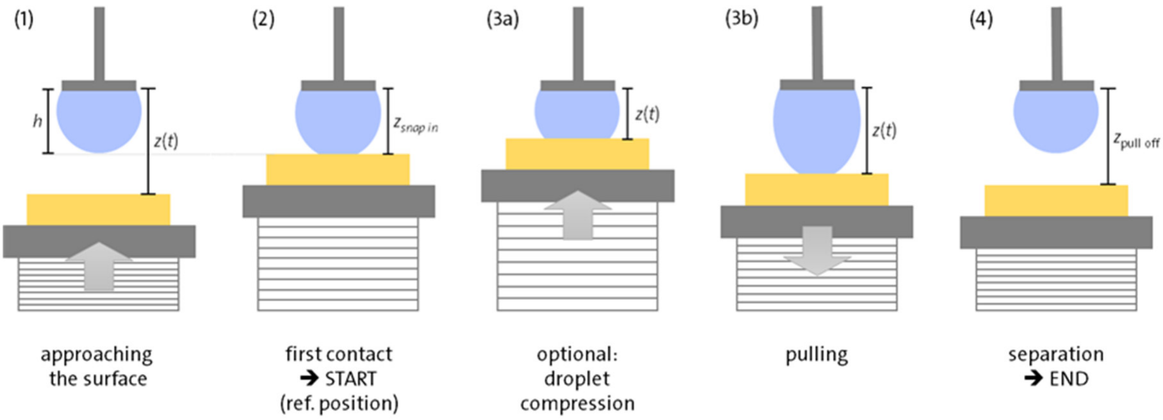
Figure 2. *Adhesive force and contact angle measurements of gas bubbles on FeCoNi-HNTAs, FeCoNi-LDH-NWAs, MoS_2/Ni Foam, and bare Ni foam.*

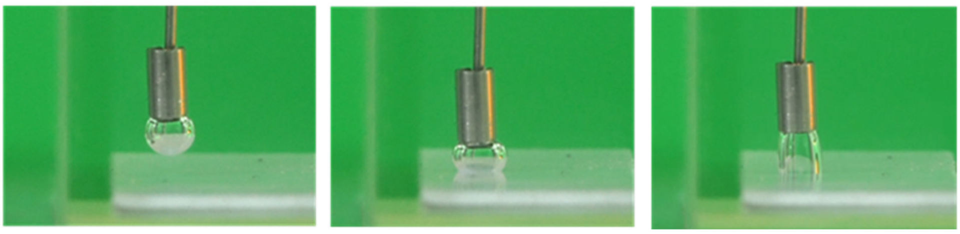
Adhesive Force Measurements of gas bubbles under water with DCAT 25

Adhesive forces of liquids in air phase or of gas bubbles under liquid phase can be analysed with the Dynamic Contact Angle measuring devices and Tensiometer DCAT 25 with video upgrade.



This system combines a force measurement to determine the force of adhesion and an optical system to determine the area of contact between the liquid/gas and solid phase for each force that is measured. Like this a force per area can be determined. The measurement procedure involves a liquid or gas bubble being pushed onto a solid substrate under air or liquid and being pulled of from it again.





Overall, this work reported an efficient and stable bifunctional nanotube-array electrode for water splitting, which has a big potential in energy conversion applications. Moreover, a clear understanding of the nanoarray structural advantages for efficient bubbles release from electrode surface by adhesive force and contact angle measurements of gas bubble on the electrode surfaces could be generated which is very inspiring to develop highly-efficient electrodes.

For more information, please refer to the following article:

Systematic design of superaerophobic nanotube-array electrode comprised of transition-metal sulfides for overall water splitting; H. Li, S. Chen, Y. Zhang, Q. Zhang, X. Jia, Q. Zhang, L. Gu, X. Sun, Li Song, X. Wang; **2018,** *Nat Commun* 9, 2452. https://doi.org/10.1038/s41467-018-04888-0