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In-vacuum magnet technology inspired from semiconductor equipment

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Outside of the application field of (scientific) particle accelerators, in the applications area of semiconductor manufacturing equipment, demanding modules similar to accelerator magnets are developed and used: high field accuracy, high power levels (for high productivity), ultra-high vacuum regimes (EUV lithography), very limited outgassing and particle contamination (contamination of substrates impairs yield) and excellent reliability (equipment up-time is important). We believe that these modules are worth being considered by the magnet community, potentially inspiring novel engineering practices. Typical topologies: An application area is the e-beam technology: critical magnetic design in vacuum environment with strict thermal requirements for stability. Another application area are electrodynamic actuators, for magnetic levitation and active position control with μm or sub-nm level accuracy. They generate highly accurate forces of several kN peak. A typical short stroke electrodynamic actuator consists of a yoke with permanent magnets, and a coil unit in between, enabling contactless actuation in a UHV environment. Force levels and linearity are constantly improved, leading to high-density designs of coils and permanent magnets topologies and the use of high grade materials. Water cooling is applied on both sides of the coil, achieving a high thermal efficiency (temperature gradient in the order of 10 K) at only a small expense in air gap. Both coil and permanent magnet structures are encapsulated for use in UHV. For this, high-reliability designs and manufacturing processes have been developed. Why consider these modules for accelerator magnets? By building magnets closer to particle beam, smaller (aperture) size can be realized, leading to smaller (chromatic) aberrations, higher achievable field strength and a lower volume claim for total magnet system. Challenges for (scientific) particle accelerators: Special materials are required for use in the 1E-10 to 1E-11 mbar regime and complex shape magnetic lenses will require special (e.g. 3D-printed) thermal cooling channels.

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