

Claims

1. A device (1) for the crucible-free melting of a material and for atomising the melted material for manufacturing powder, comprising
 - an atomisation nozzle (5) configured as a Laval nozzle and defining a nozzle axis;
 - an induction coil (4) with windings (4a-d), which at least in sections become narrower in the direction towards the atomisation nozzle (5); and
 - a material rod (3) which is introduced at least partly into the induction coil (4);
 wherein the induction coil (4) is configured to melt the material of the material rod (3) for producing a melt flow (16); and
 - wherein the induction coil (4) and the atomisation nozzle (5) are arranged in a manner such that the melt flow (16) can be introduced or is introduced into the atomisation nozzle (5) through a first opening (20) of the atomisation nozzle (5), for the atomisation of the melt flow (16) by way of an atomisation gas (19) which can be introduced into the atomisation nozzle (5),
 characterised in that
 - the atomisation nozzle (5) is designed in a manner such that the atomisation gas (19) can only be introduced or is only introduced into the atomisation nozzle (5) through the mentioned first opening (20) of the atomisation nozzle (5); that the atomisation nozzle (5) is configured to accelerate the atomisation gas (19) in a laminar manner in a direction parallel to the melt flow (16), at least up to the speed of sound of the atomisation gas (19); wherein the induction coil is disposed at a distance from the atomisation nozzle along the nozzle axis; wherein the induction coil is disposed such and the atomisation nozzle is configured such that $a_{\min} < 3 \cdot d_{\min}$, wherein $a_{\min}$ is a minimum distance between the induction coil and a plane perpendicular to the nozzle axis and defined by a minimal cross-sectional area of the atomisation nozzle, and wherein $d_{\min}$ is a smallest inner diameter of the atomisation nozzle determined within said plane; and that the material rod (3), the induction coil (4) and the atomisation nozzle are arranged in a manner such that along the nozzle axis at least a winding of the induction coil facing the atomisation nozzle is disposed between the atomisation nozzle and an end of the material rod facing the atomisation nozzle, so that the melt flow (16) is inductively heatable or heated by the induction coil (4), before entry of the melt flow (16) into the atomisation nozzle (5).
2. The device (1) according to claim 1, characterised in that the material, from which the material rod (3) is formed, comprises metal or ceramic.
3. The device (1) according to claim 2, characterized in that the metal contains aluminium, iron or titanium.

4. The device (1) according to one of the preceding claims, characterised in that a smallest inner diameter $d_{\min}$ (23) of the atomisation nozzle (5) is smaller than 7 mm.
5. The device (1) according to one of the preceding claims, characterised in that the material rod (3) and the atomisation nozzle (5) are arranged in a manner such that for a smallest distance L (25) between the material rod (3) and the mentioned plane (24), the following applies: $L \leq 5 \cdot d_{\min}$.
6. The device (1) according to one of the preceding claims, characterised in that the atomisation nozzle (5) and the induction coil (4) are designed as separate components.
7. The device (1) according to one of the preceding claims, characterised in that $a_{\min} \leq 2 \cdot d_{\min}$.
8. The device (1) according to one of the preceding claims, characterised in that the atomisation nozzle (5), for the minimisation of a heat quantity dissipated by the activity of the induction coil (4) in the atomisation nozzle (5), is formed from a nozzle material, for whose specific electrical resistance ρ , the following applies: $\rho \leq 0.02 \cdot 10^{-6} \Omega\text{m}$ or $\rho \geq 10^{-2} \Omega\text{m}$.
9. The device (1) according to one of the preceding claims, characterised by a high-pressure chamber (7), an atomisation chamber (8) which is in fluid connection with the high-pressure chamber (7) via the atomisation nozzle (5), first pressure control means (17) for introducing the atomisation gas (19) into the high-pressure chamber (7) and for the control of a first gas pressure p_1 in the high-pressure chamber (7), as well as second pressure control means (18) for the control of a second gas pressure p_2 in the atomisation chamber (8), wherein the first and the second pressure control means are configured to set the pressures p_1 and p_2 for accelerating the atomisation gas (19) in a direction parallel to the flow direction of the melt flow (16), in a manner such that: $p_1/p_2 > 1.8$ and $p_1 > 10 \text{ bar}$.
10. The device (1) according to one of the preceding claims, characterised in that at least one of the windings (4a-d) of the induction coil (4) which is arranged in the region of the end (15) of the material rod (3) which faces the atomisation nozzle (5) at least in sections runs perpendicularly to the rod axis, for producing an electromagnetic field which with respect to the rod axis of the material rod (3) is as symmetrical as possible in this region.
11. The device (1) according to claim 10, characterized in that at least the last winding (4d) of the induction coil (4) which faces the atomization nozzle (5) at least in sections runs perpendicularly to the rod axis, for producing an electromagnetic field which with respect to the rod axis of the material rod (3) is as symmetrical as possible in this region.

12. The device (1) according to claim 11, characterised in that the at least one winding (4d) is designed as a ring conductor which is electrically interrupted at a location.
13. The device (1) according to claim 12, characterised by at least two of these ring conductors, wherein the at least two ring conductors are connected electrically in parallel.
14. The device (1) according to claim 13, characterised in that ring conductors with a different periphery have differently designed cross sections and/or have different distances to one another along the coil axis, so that they each have an approximately equal electrical resistance and produce an as homogeneous as possible field distribution along the rod axis.
15. The device (1) according to one of the preceding claims, characterised in that the induction coil (4) at least in sections is wound in a spiral manner with a pitch which is different to zero with respect to a direction parallel to the rod axis, wherein the windings (4a-d) in this section run on the envelope of a cone symmetrical to the rod axis.
16. The device (1) according to one of the preceding claims, characterised in that a conductor forming the induction coil (4) is designed as a hollow tube for leading a cooling fluid.
17. The device (1) according to one of the preceding claims, characterised by at least one further nozzle (33) which is arranged aligned to the atomisation nozzle (5) and which is arranged between the material rod (3) and the atomisation nozzle (5), so that the melt flow (16) can also be led or is led through the further nozzle (33), wherein the further nozzle (33) is configured to accelerate a gas introduced with the melt flow (16) into the further nozzle (33), in a direction parallel to the melt flow (16), at least up to 0.5-fold the speed of sound of the gas introduced into the further nozzle (33).
18. A method for manufacturing powder by way of crucible-free melting of a material and by way of atomisation of the melted material using the device according to claim 1, comprising the steps:
 - at least partly introducing a material rod (5) into an induction coil (4) which tapers conically at least in sections;
 - subjecting the induction coil (4) to an alternating voltage for melting the material rod (3) and for producing a melt flow (16);
 - introducing the melt flow (16) into an atomisation nozzle (5) through a first opening (20) of the atomisation nozzle (5); and
 - introducing an atomisation gas (19) into the atomisation nozzle (5) and atomising the melt flow (16) by way of the atomisation gas (19);
 - wherein the atomisation gas (19) is only introduced into the atomisation nozzle (5) through the first opening (20) of the atomisation nozzle (5);

wherein the atomisation gas (19) which is to be introduced and/or is introduced into the atomisation nozzle (5) through the first opening (20) is accelerated in a laminar manner in a direction parallel to a flow direction of the melt flow (16), at least up to the speed of the sound of the atomisation gas (19), so that the melt flow (16) divides up or even bursts and powder with a grain size in the micrometer range and/or sub-micrometer range is produced; and

wherein the melt flow (16) is inductively heated by the induction coil (4) before the entry of the melt flow (16) into the atomisation nozzle (5).

19. The method according to claim 18, wherein the atomisation gas (19) is accelerated parallel to the flow direction of the melt flow (16) along an acceleration path with a length L_B , at least to the speed of sound of the atomisation gas (19), wherein for L_B the following applies: $L_B \leq 5 \cdot d_{\min}$, wherein $d_{\min}$ (23) is the smallest diameter of the atomisation nozzle (5) perpendicular to the nozzle axis.

20. The method according to claim 18 or 19, wherein the melt flow (16) is led through a further nozzle (33) which is arranged aligned to the atomisation nozzle (5), and wherein a gas introduced with the melt flow (16) into the further nozzle is accelerated in a direction parallel to the melt flow (16), at least up to 0.5-fold the speed of sound of the gas introduced into the further nozzle (33).

21. A powder, in particular a metal powder or ceramic powder, manufactured by the method according to claims 18 to 20.

22. The powder according to claim 21, characterised by a mass-related mean grain diameter which is smaller than 50 μm .

23. The powder according to one of the claims 21 and 22, characterised in that the powder is manufactured from one of the following metals or of an alloy of one or more of the following metals: titanium, aluminium, iron, zirconium, hafnium, vanadium, niobium, tantalum, chromium, molybdenum, wolfram, rhenium, nickel, cobalt.