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Article

Exotic Alloys Obtained by Condensation of Metallic Vapors

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Abstract: New methods of producing small quantities of exotic alloys from immiscible metals (and elements in general) are described with two examples: An alloy of aluminium with silver and one of aluminium with tungsten. There is no limit to the number of components that can form special alloys by this method and their applications can be foreseen to be quite useful in the future.

Keywords: alloys; metallic vapors; condensation

1. Introduction

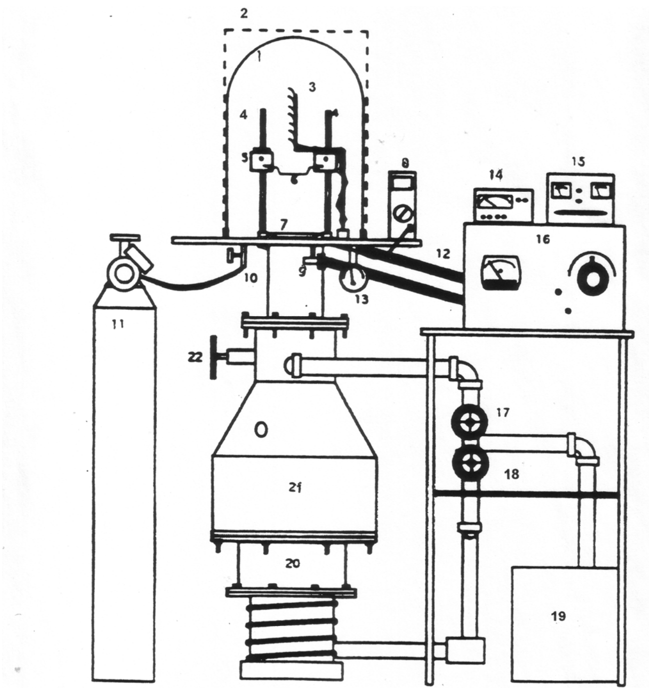
Alloys of metals pervade many areas of present day technologies, providing special characteristics not available by metals in their pure state. Traditional methods for the production of alloys consist in the mixture of liquid metals or sintering of metallic particles. Here we describe procedures based in the condensation of metallic vapors that may allow the production of alloys with any number of components, independently of their individual liquid state threshold temperatures. In essence they consist in the interaction of vapors produced by ohm heating or of atomic beams produced by laser abrasion. Non metals can be added to these alloys without limitations. Here the production of small quantities of alloys are described: aluminium (Al) with silver (Ag) and (Al) with tungsten (W). However it is possible to envisage techniques for the production of macroscopic quantities of alloys by methods based on the interactions of metals in the vapor phase.

2. Ohmic Heating Evaporation

Ground Based System

The experimental apparatus is shown in Figure 1 [1–4]. It is stationary and used in a ground based laboratory. For experiments in a gravity reduced environment, on board of aircraft in parabolic flight a portable version was developed. Basically it consists of a large glass enclosed volume and evaporation crucibles made of elements with high melting temperatures, Ta and/or W. The evaporation takes place within an atmosphere of inert gases. Helium, argon and krypton were used to slow down the vaporized atoms and allow their condensation, with pressures below one atmosphere. A vacuum system allowed to get residual pressures of 10^{-6} tor before proceeding to inject the inert gas. It was essential to remove any residual oxygen and this was accomplished by repeated flushing of the volume with an inert gas (up to four times). The crucibles and elements to be evaporated were out gassed heating them to high temperatures before introducing the inert gas for each experiment.

Figure 1. Ohmic evaporation, condensation apparatus. 1, Bell jar; 2, Protective grid; 3, Thermocouple support; 4, Electrodes; 5, Crucible support; 6, Crucible; 7, Recovery Plate; 8, Temperature gauge; 9, Vent valve; 10, Filling gas valve; 11, Gas container; 12, Conducting rod; 13–15, Pressure gauge; 16, Power supply; 17–18, Vacuum valve; 19, Mechanical pump; 20, Diffusion pump; 21, Liquid nitrogen trap; 22, By-pass valve.



The salient aspects of the evaporation are shown in Figure 2. A high density particle region is formed above the crucible due to a circular spiraling of the atoms within the gas. The resultant condensations fall to the plate at the bottom of the glass jar. They are recovered once the evaporation is finished and analyzed with scanning electron microscopes (SEM's) and mass analyzers. A SEM image of the results is shown in Figure 3. A mass spectrum of a monomer is shown in Figure 4.

Figure 2. Operation of a crucible.

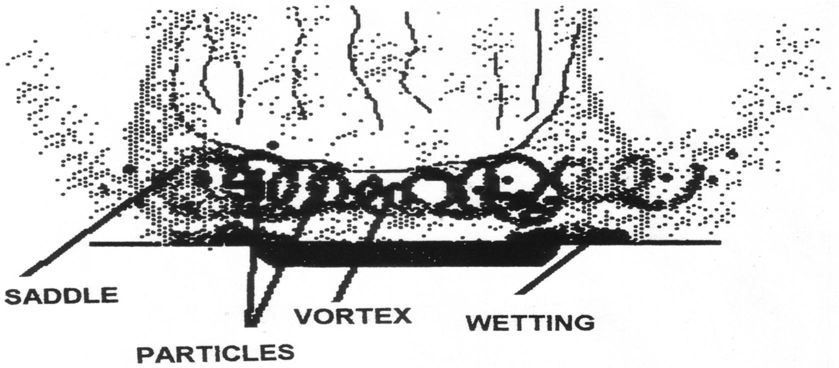


Figure 3. Al–Ag condensation SEM image.

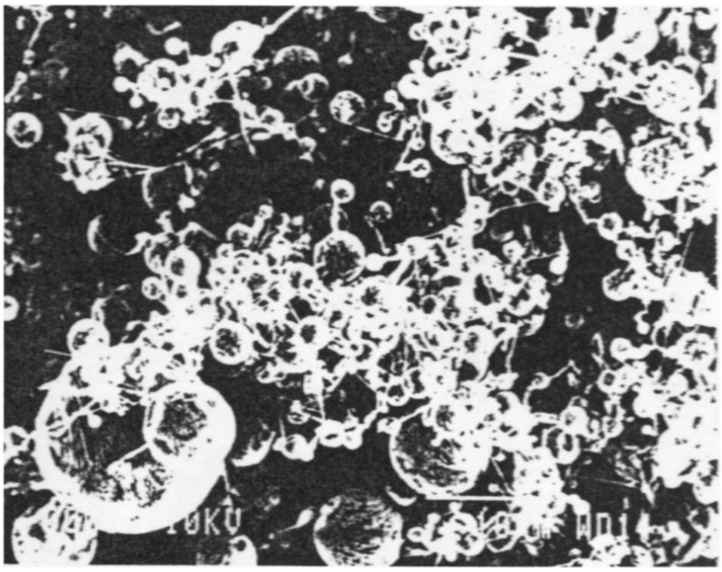


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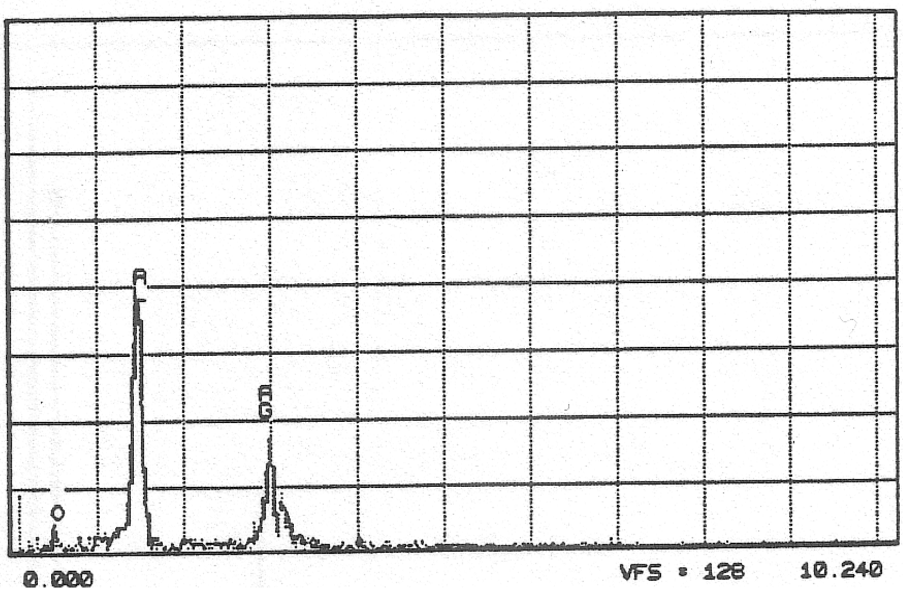
Figure 4. Mass spectrum of the monomer over the arrow in Figure 3.



3. Evaporation by Laser Beam Abrasion

This method has several advantages over ohmic heating: Self supporting samples can be used avoiding contacts with crucibles which may introduce impurities into the vapors. The support gas is not significantly heated by the laser beam and thus convection is reduced, allowing the vaporized particles to remain in a defined volume as will be seen later.

3.1. Laser Characteristics

The laser used for evaporations was an Excimer Pulse Master PM-848 KrF. Optimum parameters are given in Table 1.

Table 1. Laser characteristics.

Parameters	Nominal values	Values used
Wavelength (nm)	248	248
Maximum energy per pulse (mJ)	450	120 to 240
Mean energy maximum (W)	80	1 to 2.5
Repetition rate (pps)	200	10
Length of pulse (ns)	12 to 20	12 to 20
Size of the beam (mm)	8 − 12 × 25	8 − 12 × 25
Divergence of the beam (mrad)	1 × 3	1 × 3

The evaporation cube is shown in Figure 5. It was machined from a single block of duraluminium and is provided with four windows and a valve for vacuum and gas filling.

Figure 5. Image of the evaporation cube.

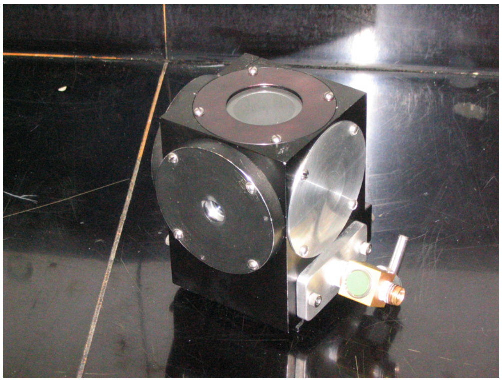
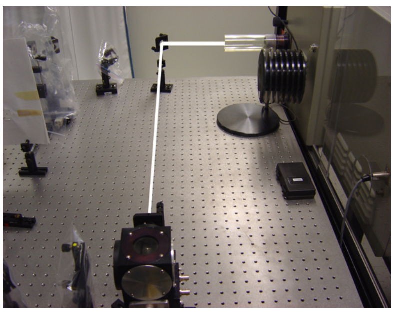
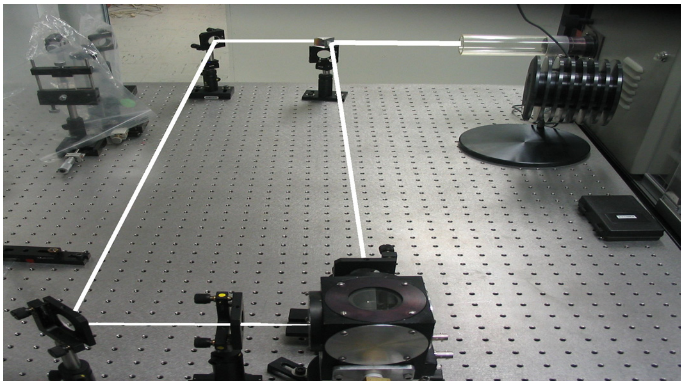


Figure 6. Single element evaporation, the EC is at the bottom.



A single element evaporation is shown in Figure 6.The simultaneous evaporation of two elements was effected splitting the beam in two, as shown in Figure 7. A mirror beam splitter was used.

Figure 7. The beam is split and impinges the EC at right angles upon the targets.



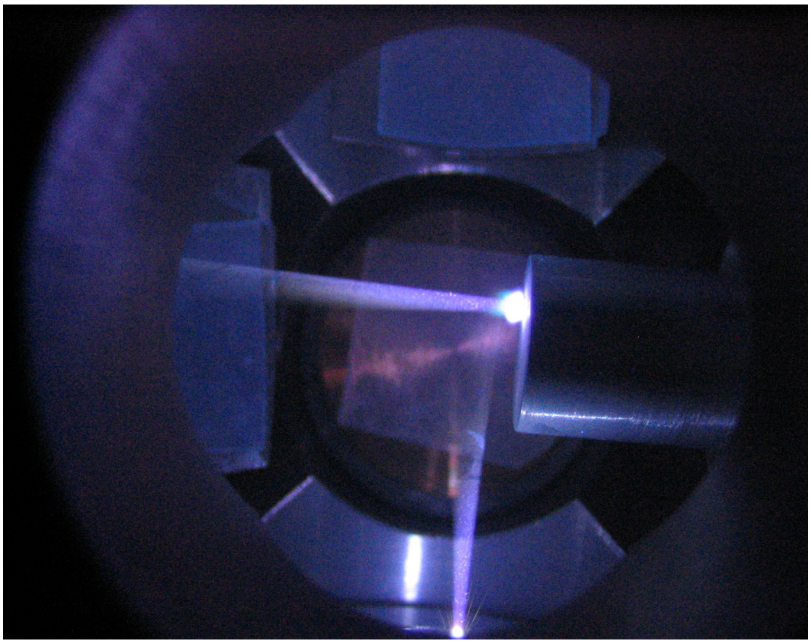
3.2. Alloy of Al and Tungsten

The basic idea consists to obtain the interaction of vapors of Al and W obtained through laser abrasion in order to produce alloys.

Figure 8 is a photograph of the perpendicularly colliding beams in the EC.

Figure 8. Particle beams ejected from the targets.

Horizontal beam: Al



W beam, vertical

The configuration shown in Figure 8 proved to produce small alloys of aluminium and tungsten (Figures 9 and 10). A collinear beam configuration was inadequate for use with the EC. Similar results were obtained consistently during these experiments.

Figure 9. Electron microscope image of condensed particles.

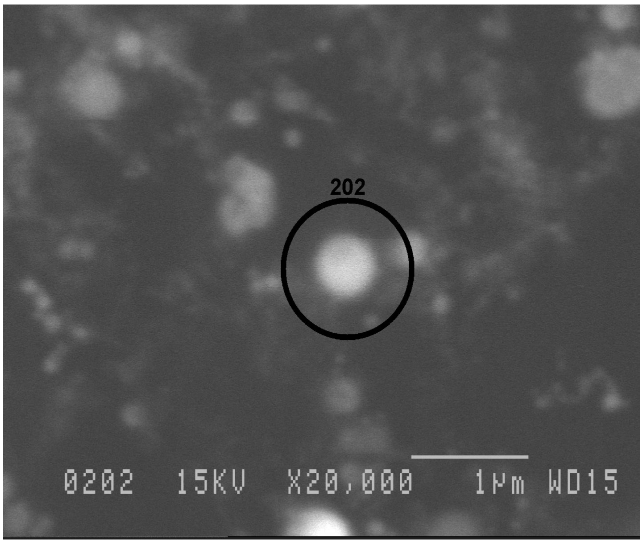
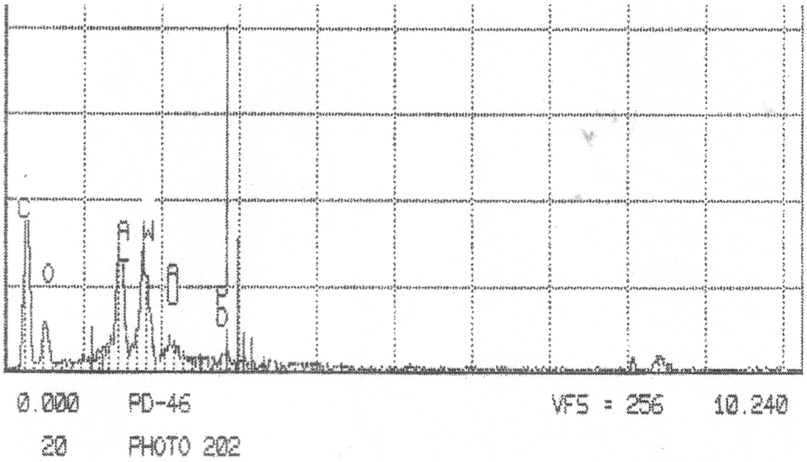


Figure 10. Mass spectrum of the circled drop of Figure 9. A, Aluminium; W, Tungsten.



4. Concluding Remarks

According to the evidence provided here there is no limit in the possibilities provided by the evaporation condensation of elements in order to produce alloys or combinations of atoms. It should be possible to produce alloys of multiple elements by the intersection of several atomic beams. The properties of some exotic alloys thus obtained may allow a variety of novel applications.

Acknowledgments

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