debates, from "Although secondary nucleation appears to be major source of nuclei in industrial crystallization, little is known about the mechanism by which such nuclei are produced",[57] and some 35 years later...."Despite years of studies, the mechanism of contact secondary nucleation has not been resolved".[55] Although various complex models for secondary nucleation can be proposed, it is experimentally challenging to determine which mechanism occurs in reality, and this might also differ from compound to compound. However, the main secondary nucleation scenarios can be categorized as:

- Parent crystal present in "stagnant" solution
- Parent crystal subjected to fluid shear
- Parent crystal subjected to collision with impellers or vessel walls
- Parent crystal subjected to collision with others crystals

1.2.2.2 Attrition, Fragmentation, Breakage

These can be seen as mechanical separation of preformed crystals (or their pieces) from larger crystals or aggregates/agglomerates, typically due to collisions with impellers, vessel walls or with other crystals or due to fluid action on crystal (*e.g.*, fluid shear or turbulent eddies). This can be also seen as crystal breakage or de-aggregation/de-agglomeration. The collision-based processes can be studied separately from crystal growth, *i.e.*, in saturated solutions or non-solvents.

Small pieces of larger crystals are broken off due to mechanical collisions (*e.g.*, with impeller) and these small crystalline pieces appear to be new particles. This effect can be influenced by suitably designing the crystallizer vessel, agitation and suspension density.[58–63] Attrition rate is a function of the number of collisions and the energy impact of those collisions as well as system-specific properties such as the material's hardness, solution viscosity and density difference between solution and crystalline material. The collision rate with the stirrer can be increased by, for instance, increasing the stirrer speed or changing the stirrer design. Another way to increase the collision rate is by increasing the suspension density so that there are more crystals. Also the crystal size plays a role: above a certain size the impulse of the particle originating from the density difference between solution and solid becomes too large for the fluid to drag the particle with it and the probability of collisions drastically increases.[11] However, the effect of attrition can be influenced by suitably designing the crystallizer vessel, agitation and suspension density.[64,65]

At high stirring speeds, macroabrasion of crystals results in fragments that serve as nucleation sites. As opposed to contact nucleation, which involves microabrasion of the crystals, this phenomenon results in the rounding of edges and corners of crystals. This process is referred to as collision or attrition breeding. Attrition causes small particles of acetaminophen crystals that have already been formed on the surface of the excipient