3.044: Materials Processing

Adam Powell* Randolph Kirchain† Wanida Pongsaksawad‡

Spring 2005

1 Administrivia

1.1 Schedule

Lectures will be held Monday, Wednesday and Friday at 11:00 AM in room 4-270. Recitations will meet on Thursdays at noon and Fridays at 2:00 PM in 8-205. Students may attend either (or both) of the recitations.

1.2 Textbook

There is *no required text for 3.044.* The topics and order of coverage are such that we will use excerpts from the following textbooks, which will be on reserve (and at the Coop if you really want to buy them):

[A] Michael Ashby, *Materials Selection in Mechanical Design.*
[BSL] Bird, Stewart and Lightfoot, *Transport Phenomena.*
[F] Merton Flemings, *Solidification Processing.*
[ID] Incropera and DeWitt, *Introduction to Heat and Mass Transfer.*
[PG] D.R. Poirier and G.H. Geiger, *Transport Phenomena in Materials Processing.*

1.3 Grading

There will be two tests on Wednesday–Friday March 9–11 and Wednesday–Friday April 20–22, and a final during finals week. Grades will be determined from exams and eight homework assignments as follows:

Problem sets	16%
Test 1	22%
Test 2	22%
Final exam	40%

1.4 Electronic Resources

The home page for 3.044 is at `http://stellar.mit.edu/S/course/3/sp05/3.044/`. The email list `3.044-students` is for special announcements, problem set corrections, etc. And there is a zephyr instance for 3.044:

To subscribe, type:	`zctl sub message 3.044 \*`
To subscribe permanently:	`zctl add message 3.044 \*`
To write to the instance:	`zwrite -i 3.044`
To unsubscribe:	`zctl unsub message 3.044 \*`
To undo a '`zctl add`':	`zctl delete message 3.044 \*`

*Assistant Professor in DMSE; Office: 4-117, x2-2086; Email: `hazelsct@mit.edu`; Office hours: TBA.
†Assistant Professor in DMSE and ESD; Office: E40-421, 8-202A, x3-4258; email: `kirchain@mit.edu`; Office hours: TBA
‡Graduate Student in DMSE; Office: 4-043, x3-5706; Email: `wanida@mit.edu`; Office hours: TBA.

The lecturer is permanently subscribed to this instance, so whenever he is running zephyr he will receive these messages and (usually) answer questions. If you want to talk behind his back, you can create another instance. But if you have questions or comments which are not of a private nature (*i.e. not* grades, planned absence, etc.), please use the zephyr instance, so that others can try to help you, and the answer will be available in the zephyr log for everyone's benefit.

2 Subject Overview

The goal of 3.044 is to teach cost-effective and sustainable production of solid material with a desired geometry, structure or distribution of structures, and production volume. Toward this end, it is organized around different types of phase transformations which determine the structure in various processes for making materials, in roughly increasing order of entropy change during those transformations.

2.1 Solid Heat Treatment

This section will take advantage of the mathematical similarity between diffusion and heat conduction to introduce you to the phenomenon of heat transfer by conduction, convection and radiation. These tools will provide understanding on how to induce or avoid the various chemical reactions, precipitation, annealing and other solid-state phase transformations learned in 3.022.

2.2 Liquid-Solid Processing

Most large-scale processes for making solids involve the liquid state at some point, and the initial microstructure formed during the liquid-solid transition often persists into the final part. This section will deal with solidification and precipitation/coating reactions from solution, with a focus on the mechanisms which determine structure in this processing step.

2.3 Fluid Behavior

Fluid behavior and fluid-solid interactions are crucial to understanding many processes. This section will focus on concepts of drag force on solids and fluids in relative motion, from particles to flat surfaces to porous media. It will close with a discussion of overall mass and momentum balances on large control volumes.

2.4 Deformation Processing

This section will introduce mechanical deformation processes from sheet forming to sintering, which provide opportunities for inexpensively forming very advantageous structures on a large scale. It will build on concepts from the previous section to treat deforming solids as moving fluids, and also deformation mechanisms discussed in 3.032.

2.5 Vapor-Solid Processing

As the transformation with the largest entropy change, vapor-solid processes present unique opportunities for precise control of structure.

2.6 Special Topics

3.044 will close with a set of lectures summarizing and contextualizing course material and placing it in the context of society at large.

3 Lecture Schedule

Dates	Topic	Motivating Process	Reading(s)
2/2	**Introduction**		
Solid Heat Treatment			
2/4	Energy conservation, 1-D conduction	TBA	ID 1.3
2/7	Heat equation solution review	Various	PG 9.4
2/9	Phase transformations	Glass-ceramics	
2/11	Radiation		ID 12
2/14	Dimensional analysis	Furnace wall	
2/16	Transient graphs	Thermal spray	PG 9.3
2/18	Finite differences and heat conduction	Polymer extrusion	ID 5.9
2/22	Intro to engineering economics		
2/23	Cost modeling I: unit operations	Pizza oven	
2/25	Cost modeling: cost factors & scale	More pizza	
Liquid-Solid Processing			
2/28	Moving boundary and planar melting	Vacuum arc remelting	
3/2	Continuous solidification	Continuous casting	PG 10.1-10.3
3/4	Conduction-limited solidification	Injection molding	F
3/7	Liquid-limited solidification	Casting, precipitation	F
3/9	**Test 1**	Through 2/25	
3/11	Complex structure formation		
Fluid Behavior			
3/14	Introduction, shear stress		BSL 1.1-1.2, 2.1-2.2
3/16	Drag force on a sphere	Precipitation, bubbles	BSL 6.3
3/18	Engineering and society	Lessons of 9/11	
3/28	Friction factor: tubes, plates		BSL 6.1-6.2
3/30	Turbulent fluid flow		BSL 5.1-5.2, video*
4/1	Turbulent transport, batch reactors	Fermentation	
4/4	Continuous flow reactors	Fermentation	BSL 23.1
Deformation Processing			
4/6	Intro: deformation mechanisms	Polymers, metals	A 7.5,7.6
4/8	Non-Newtonian fluids	Various	BSL 8.3
4/11	Viscoelasticity		BSL 8.4
4/13	Stress-strain and sheet forming	Polymers, metals	
4/15	Consolidation processes	Sintering, HIP, CM	
4/20	**Test 2**	Through 4/6	
4/22	Consolidation mechanisms	Sintering, HIP, CM	
Vapor-Solid Processing			
4/25	Evaporation kinetics, transport	Zirconia PVD	
4/27	Rate/temperature/structure maps	Various thin films	
4/29	Growth: epitaxial/strained, incoherent		
5/2	Masking and patterning		
5/4	Advanced structure formation	Polymer sputter, VLS	
Special Topics			
5/6	Life Cycle Analysis		
5/9	Systematic process selection		
5/11			

*Video: "Turbulence", QC151.T8 in the Barker video collection